Teck Coal
Environment Office
Bag Service 2000, 421 Pine Avenue
Sparwood, B.C. Canada V0B 2G0

+1 250 425 3352 Tel
www.teck.com

Technical Report Overview

Report: 2019 Calcite Effects to Spawning Habitat Suitability of Westslope Cutthroat Trout

Overview: This report provides results from further investigations into the relationship between calcite and incubation conditions for Westslope Cutthroat Trout. The 2019 study was expanded to include 17 tributary streams across the Elk River valley.

This report was prepared for Teck by Ecofish Research Ltd.

For More Information

If you have questions regarding this report, please:

• Phone toll-free to 1.855.806.6854

• Email **feedbackteckcoal@teck.com**

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Teck Coal Ltd

2019 Calcite Effects to Spawning Habitat Suitability of Westslope Cutthroat Trout

Prepared for:

Teck Coal Limited
Suite 1000 – 205 9th Street
Calgary, AB, T2G 0R3

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Prepared by:

Ecofish Research Ltd.

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Senior Reviewer:

Todd Hatfield, Ph.D., R.P.Bio. No. 927

Senior Environmental Scientist/Project Manager

Technical Leads:

Morgan Hocking, Ph.D., R.P. Bio. No. 2752

Senior Environmental Scientist

Alejandro Buren, Ph.D.

Senior Fisheries Biologist

Disclaimer:

EXECUTIVE SUMMARY

Teck Coal Limited (Teck) operates five steelmaking coal mines in the Elk River watershed in south-eastern British Columbia. Calcite formation has been observed in the tributaries both upstream and downstream of Teck mining activities, at some locations in the Fording River and, to a lesser extent, in the Elk River and in reference streams unaffected by mining. There are concerns that high levels of calcite may have an effect on Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*) and other biota.

In the Elk Valley Water Quality Plan (EVWQP), Teck committed to continuing a program of monitoring and management for calcite with the objective of understanding potential effects and managing mine-related calcite formation. In November of 2014, the BC Ministry of Environment and Climate Change Strategy (ENV) approved the EVWQP and issued Permit 107517, which included requirements related to calcite management and monitoring, monitoring of potential effects to aquatic ecosystems and implementation of a Water Quality Adaptive Management Plan (AMP). The AMP supports continuous improvement in understanding water quality and ecological conditions including an evaluation of the effect of calcite on aquatic ecosystem condition, focusing on periphyton, benthic invertebrates, and fish. Within the AMP, Teck is addressing two key management questions related to calcite effects, including Management Question 4 - *Is calcite being managed effectively to meet site performance objectives and to protect the aquatic ecosystem?*; and Management Question 5 - *Does monitoring indicate that mine-related changes in aquatic ecosystem conditions are consistent with expectations?*

The purpose of this study is to assess potential effects of calcite on Westslope Cutthroat Trout (WCT) spawning and incubation success. The study design in 2019 built on the outcomes of previous studies in the upper Fording River watershed, including a preliminary study on the effects of calcite to spawning habitat suitability carried out in 2018 (Hocking *et al.* 2019), as well as studies implemented in 2016 and 2017 that measured hyporheic flow and dissolved oxygen over a range of sites with varying levels of calcite (Wright *et al.* 2017; 2018). Studies in 2016 and 2017 did not find a strong effect of calcite on incubation conditions, and rather suggested that the more important effect of calcite to fish is likely to be related to spawning substrate suitability. The preliminary study carried out in 2018 did not find a strong relationship between mean presence or density of redds and calcite index (CI), but found a negative relationship between the 90th quantile of redd density and CI. This result suggested that a WCT spawning suitability response curve with calcite could potentially be developed. Two main limitations of the 2018 study were the limited sample size (only five streams) and the limited range of CI sampled (CI range sampled 0 to 1.66; where a maximum CI possible = 3).

The sampling design was expanded in 2019 to include 17 tributary streams across the Elk River valley, and more intensive sampling of all mesohabitat units within ~ 1 km reaches in each stream that were accessible to WCT spawners (e.g., each riffle, pool, glide mesohabitat). This increased the range of CI previously observed and enabled greater inference on the relationship between calcite and spawning habitat suitability. The objective of the current study was to develop a suitability curve between stream bed calcite and spawning habitat suitability for WCT including a statistical model to test the following research hypothesis:

$H_0$2 (null): Observed calcite conditions on stream substrates have no effect on suitability of fish spawning habitat.

H_A2 (alternate): Observed calcite conditions on stream substrates have an effect on suitability of fish spawning habitat.

This study measured the presence and abundance of WCT redds, calcite, and other fish habitat data (e.g., substrate composition, water quality, mesohabitat type and structure) all at the mesohabitat scale. Results were used to model relationships between calcite and spawning use to ultimately develop a spawning habitat suitability curve with calcite, taking into consideration other components of fish habitat (i.e., covariates). Accounting for fish habitat variables in addition to calcite provided greater confidence in the assessment of calcite effects than a simpler model and provided a broader understanding of spawning habitat suitability across a range of fish habitat conditions in the Elk Valley.

Fieldwork was conducted between May and October 2019 at all five streams sampled in 2018 (Lower Greenhills, LCO Dry, Clode, Fish Pond and Henretta Creeks) from the upper Fording River watershed as well as an additional twelve streams from throughout the Elk Valley. Additional streams were selected for having moderate to high levels of calcite (Upper Greenhills, Corbin, Thompson, Michel, EVO Dry, Harmer, Erickson and Grave Creeks) or as reference sites (Alexander, Grace, McCool and Lizard Creeks). These watercourses were selected as they have habitats used by WCT for spawning and have a range of calcite cover.

Redd surveys

Two spawning surveys were conducted for each tributary, one in late May or June and the second in July. Redds were observed in twelve of the seventeen streams surveyed. Two response variables were calculated from the redd survey data: the number of redds per mesohabitat unit, and, the presence (1) or absence (0) of redds within a mesohabitat unit.

The number of redds observed varied spatially; the largest number of redds in 2019 were observed in Lizard Creek (n = 28, 31% of all redds), McCool Creek (n = 14, 16% of all redds), Michel Creek (n = 12, 13% of all redds), and LCO Dry Creek and Harmer Creek (n = 10 in each stream, 11% of all redds in each stream). High redd counts occurred in LCO Dry Creek during 2018 as well. No redds were observed in Corbin Creek, EVO Dry Creek, Erickson Creek, Grace Creek, Clode Creek (in 2019), or Henretta Creek (in 2018). The total number of redds observed in 2019 was 311.

Calcite Index

Calcite levels on the streambed were quantified using the CI. Calcite surveys were conducted using Teck's CI measurement protocol to provide a CI (CI = CI_{Total}), calcite presence (CI_{Pres}) and calcite concretion (CI_{Conc}) score for each mesohabitat unit within sampled reaches. The design and sample size of the calcite data collection for this project was modified from Teck's current CI protocol.

All mesohabitat units within ~1 km reaches in 17 streams were sampled, yielding a total of 796 mesohabitat units sampled, which greatly increased the statistical inference that could be drawn compared to the work in 2018. Due to the increased number of mesohabitat units sampled, the number of pebbles sampled per mesohabitat unit was reduced from 100 pebbles per mesohabitat to 30 pebbles per mesohabitat. Despite this reduction in effort per mesohabitat unit, the total number of pebbles sampled per stream averaged 1,366 ± 495 (±SD) for a total of 23,222 pebbles sampled in 2019, compared to 8,548 pebbles sampled in 2018.

CI varied spatially within and among streams of the study area, as expected from previous studies (Minnow Environmental 2016, Robinson *et al.* 2016, Wright *et al.* 2017; 2018, Hocking *et al.* 2019). Given the expanded survey design implemented in 2019, the range of CI observed (0 – 2.87) was wider than the range of CI observed in 2018 (0 – 1.66).

The highest calcite presence, calcite concretion and CI were observed in Corbin Creek, EVO Dry Creek and Erickson Creek in 2019. Concretion was also observed in Upper Greenhills Creek, Lower Greenhills Creek (both years), and Clode Creek (both years). Low calcite presence and zero concretion were observed in Grave Creek, Fish Pond Creek (both years), Henretta Creek (both years), Alexander Creek, Grace Creek and LCO Dry Creek (2018 only). Moderate to high calcite presence (mean presence > 0.5) was observed in six streams where zero calcite concretion was recorded. These streams included Harmer Creek, Michel Creek, Thompson Creek, LCO Dry Creek (in 2019), Lizard Creek, and McCool Creek.

Fish Habitat

A Level 1 Fish Habitat Assessment Procedure (FHAP) was used to quantify fish habitat in all study streams. Fish habitat data included streamflow, velocity, depth, bankfull and wetted width, substrate, cover, functional large woody debris tally, spawning gravel quantity and water quality. Mesohabitat unit types were classified as pools, glides, runs, riffles, cascades, chutes and falls according to definitions in Johnston and Slaney (1996).

Calcite is one of many influences on fish and fish habitat, and these other influences (e.g., substrate type, cover, gradient, water quality, etc.) need to be considered as potential covariates. Initial data exploration of explanatory variables used to predict redd presence and density was carried out following the protocol of Zuur *et al.* (2010). Data exploration revealed collinearity among fish habitat variables. The final set of fish habitat variables used to model redd presence and density included CI, calcite concretion, mean water velocity, spawning gravel, bankfull depth, functional large woody debris tally, and water temperature. All of these fish habitat variables are hypothesized to affect spawning suitability.

Modelling of Redd Presence and Redd Abundance

The relationship between spawning habitat suitability and calcite conditions was assessed at two levels: calcite effects on the likelihood of redd presence, and calcite effects on the number of redds in a stream. To provide a characterization of the effects of calcite on the number of redds in a stream, effects on redd counts were assessed using two main approaches, including the effect on the mean number of redds and the effect on the 90th quantile of redd counts (i.e., how does calcite affect the probability of having high counts of redds).

Relationships of redd presence and redd counts versus explanatory variables were investigated a using a model selection approach where alternate models with different combinations of explanatory variables were competed against one another and ranked using Akaike Information Criterion (AICc) scores (McCullagh and Nelder 1989; Burnham and Anderson 2002; Zuur *et al.* 2009; Grueber *et al.* 2011). All analyses were conducted using the R Statistical Language (R Core Team 2018).

Results

Based on analyses of collected data, calcite concretion was the most important variable to describe variance in redd presence, mean redd count, and the 90th quantile of redd counts. Overall, redds were observed only in habitats with low concretion (CI_{Conc} < 0.5); no redds were observed at moderate to high calcite concretion (CI_{Conc} > 0.5). The influence of calcite concretion on response variables was negative, and the three modelled spawning habitat suitability curves for WCT decreased with increasing levels of calcite concretion. Redd counts in a stream decreased with increasing calcite concretion, although at a slightly slower rate than redd presence.

Other habitat variables were also found to predict WCT spawning. Water temperature positively influenced the likelihood of redd presence and the 90th quantile of redd counts, which suggests that cold water temperatures may limit distribution of spawning and rearing WCT in the highest elevation tributaries. Mean number of redds in a stream was positively influenced by tally of functional large woody debris and spawning gravel area. Increased cover of woody debris is hypothesized to increase structural complexity of stream habitats and provide cover for spawning WCT during the day. Increases in spawning gravel area also intuitively reflects that as the area available for spawning increases so does the number of redds.

Overall, the results suggest that the null hypothesis $H_0 2$ should be rejected in favour of the alternate hypothesis $H_A 2$. However, it is important to note that the confidence interval surrounding the predicted effect size is high, which leads to uncertainty in the mean predicted slope of the spawning suitability curves. So, while we are confident that the slope between redd presence and redd abundance and calcite concretion is negative, the confidence intervals of the slopes of the spawning suitability curves overlap based on the uncertainty estimated from the models. Given the naturally high variability in the data, the strength of the relationships is not yet clearly defined.

Conclusion

A redd presence-absence model and two different redd count models were developed to test if calcite conditions influence spawning habitat suitability for Westslope Cutthroat Trout in tributaries streams of the Elk River, B.C. The study in 2019 builds upon similar data collected in 2018 from five streams in the upper Fording River watershed and captured a broader range of calcite conditions (CI range = 0 to 2.87) compared to the 2018 study (CI range = 0 to 1.66). Overall, based on streams sampled in both years, redd presence and counts were found to be negatively influenced by calcite concretion; few redds were observed in Erickson Creek, EVO Dry Creek, Corbin Creek, Upper Greenhills Creek, Lower Greenhills Creek and Clode Creek where concretion was observed. In contrast, moderate to high redd counts were observed in both mine-affected and reference streams with moderate to high calcite presence (CI_{Pres} > 0.5) but no concretion. In all models, calcite concretion outcompeted CI in explaining redd presence or counts, which led to the conclusion that concretion may be a better measure of spawning suitability than CI.

While the results presented here are more clear than those presented in 2018 (Hocking *et al.* 2019), there remains uncertainty in the spawning suitability curves based on the broad confidence intervals. Additional field work and analysis are required to reduce remaining uncertainties and to improve the predictive ability of the spawning suitability response curves, particularly at low to moderate levels of concretion.

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1. INTRODUCTION

Teck Coal Limited (Teck) operates five steelmaking coal mines in the Elk River watershed in south-eastern British Columbia. Calcite formation has been observed in the tributaries downstream of Teck mining activities, at some locations in the Fording River and, to a lesser extent, in the Elk River and in reference streams unaffected by mining. Calcite is created by the reaction between dissolved calcium (Ca^{2+}) and carbonate (CO_3^{2-}) ions under conditions that occur naturally but can be enhanced when water passes through waste rock from mining. A number of seasonal factors can contribute to the precipitation or dissolution of calcite, including physical forces (e.g., scouring of the substrate during high flow periods) and water chemistry (water temperature, pH, composition of dissolved ions and minerals); therefore, timing and location of calcite formation can be challenging to predict (Minnow Environmental 2016).

In the Elk River watershed, there are wide ranges in the spatial extent and degree of calcite cover. Calcite cover ranges from areas with minimal calcite formation to areas in certain streams where calcite precipitation can completely cover portions of the stream bed, making the gravels largely immovable (Smithson *et al.* 2019). There are concerns that high levels of calcite may have effects on Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*) and other biota.

In the Elk Valley Water Quality Plan (EVWQP), Teck committed to continuing a program of monitoring and management for calcite. The objective of the program is to understand and manage mine-related calcite formation so that streambed substrates in the Elk and Fording rivers and their tributaries can support abundant and diverse communities of aquatic plants, benthic invertebrates and fish comparable to those in reference areas (Teck 2014). Teck's requirements for monitoring biological effects as part of its Regional Aquatic Effects Monitoring Program (RAEMP) include:

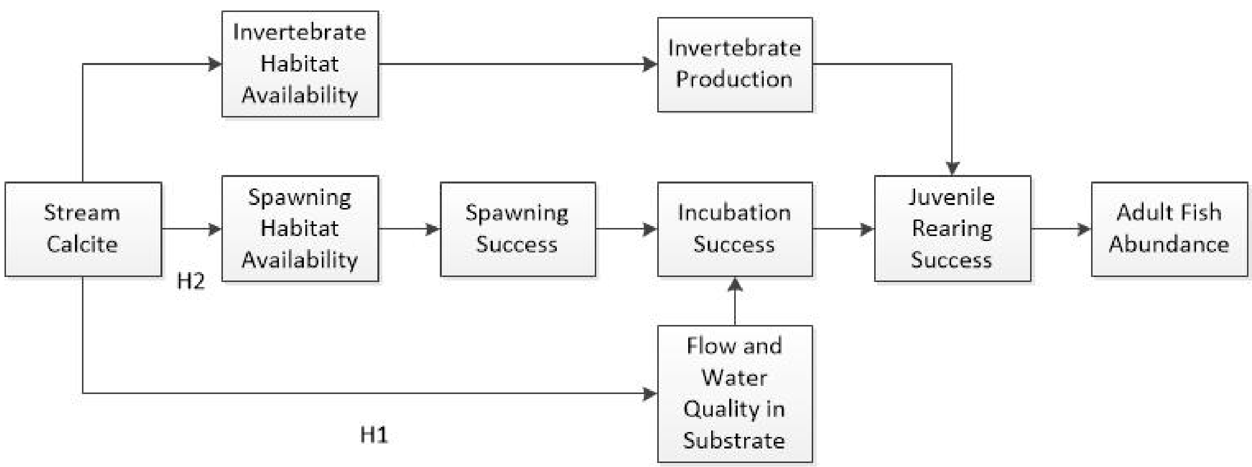
> "*Teck shall complete the assessment to determine the potential relationships between calcite and benthic invertebrate community structure, periphyton productivity and fish spawning and incubation success. Teck shall work in collaboration with the Ministry and Ktunaxa Nation representatives ideally in a monitoring committee forum to prepare study designs for work proposed in 2015 and 2016.*"

This study addresses the "fish spawning and incubation success" aspects of the RAEMP requirements described above by furthering assessment of potential calcite effects on spawning and incubation habitat. The study design builds on the outcomes of the calcite effects study in 2018 (Hocking *et al.* 2019), and of previous studies in the Elk Valley, including studies implemented in 2016 and 2017 that measured hyporheic flow and dissolved oxygen over a range of sites in the upper Fording watershed with varying levels of calcite (Wright *et al.* 2017; 2018) and ongoing biological programs being undertaken by Teck. The basic premise of the study is that calcite accumulation on a streambed may influence the suitability of spawning habitat and incubation habitat, and thereby the carrying capacity of fish habitat. The effects of calcite on spawning and incubation habitat are hypothesized links in effect pathways linking calcite to fish production (Figure 1).

The objective of this study is to further test the link between streambed calcite and spawning habitat availability for Westslope Cutthroat Trout (i.e., impact hypothesis H2 in Figure 1). Note that studies in 2016 and 2017 focused on impact hypothesis H1 related to the effects of calcite on incubation conditions including flow and water quality in the substrate (Wright *et al.* 2017; 2018).

This study also helps address Management Question 4 from the Water Quality Adaptive Management Plan (Teck 2018), which states: "*Is calcite being managed effectively to meet site performance objectives and to protect the aquatic ecosystem*?". The study specifically supports the reduction in Key Uncertainty 4.1 "*Are the calcite site performance objectives (SPOs) protective of fish and aquatic life?*" The current SPO for calcite under the AMP includes two calcite index (CI) thresholds related to the extent of calcite concretion (CI_{conc}) and total calcite (CI_{total}). Both SPOs (CI_{conc} and CI_{total}) identify CI ≤ 0.50 as protective of fish and aquatic life.

Figure 1. Effect pathway diagram linking calcite on the streambed to fish production.



1.1. Study Questions and Hypotheses

The calcite effects on fish habitat study aims to address the following three study questions:

1. To what extent does calcite influence incubation conditions within the shallow hyporheic zone?
2. What is the response relationship between calcite and spawning habitat suitability in Elk Valley tributaries affected by Teck operations?
3. What is the status of spawning habitat as affected by calcite in Elk Valley tributaries?

In addressing the questions, the calcite effects on fish habitat study is designed to test the following two research hypotheses, which include null and alternate hypotheses:

$H_0$1 (null): Observed calcite conditions on stream substrates have no effect on hyporheic flow and dissolved oxygen.

H_A1 (alternate): Observed calcite conditions on stream substrates have a negative effect on hyporheic flow and dissolved oxygen.

$H_0$2 (null): Observed calcite conditions on stream substrates have no effect on suitability of fish spawning habitat.

H_A2 (alternate): Observed calcite conditions on stream substrates have a negative effect on suitability of fish spawning habitat.

Habitat use by fish is well known in the Elk River and the upper Fording River, and their respective tributaries, which aided development of the study design and selection of study sites (Russell and Oliver 1996; Windward Environmental *et al.* 2014; Cope *et al.* 2016; Minnow Environmental 2016b; Lamson 2018; Hocking *et al.* 2019; Robinson, pers. comm. 2019). Research hypotheses were tested by empirically assessing incubation conditions and spawner use in tributaries to Elk and Fording Rivers. As discussed at the EMC#12 meeting[1], some aspects of the study questions may have to be addressed over multiple years, as conditions allow for adequate sampling. Study question #1 and hypothesis H1 were addressed in earlier research reports (Wright *et al.* 2017; 2018). The present study focuses on study question #2 and hypothesis H2; and builds upon findings and recommendations from the Year 1 spawning suitability report (Hocking *et al.* 2019).

Several key recommendations from the Year 1 spawning suitability report (Hocking *et al.* 2019) have been implemented in the 2019 study. First, sampling effort is expanded to include twelve more streams, specifically targeting streams with moderate to high levels of calcite. In 2018, the study streams all had moderate to low CI, so testing the relationship between CI and redd presence and density across the full range of possible calcite conditions could not be completed. Including additional streams for 2019 with higher calcite was also confirmed as a priority during the January 9, 2019 EMC meeting[2]. Second, the addition of reference streams was identified as a key priority to understand the natural range of spawning in the absence of mining and to better interpret spawning suitability relationships with other measured fish habitat variables. The overall increase in number of study streams in 2019 is intended to improve the predictive power of the data analysis.

[1] EMC#12 meeting, 26 April 2017, Cranbrook, BC.

[2] EMC meeting, 9 January 2019, Cranbrook, BC.

2. METHODS

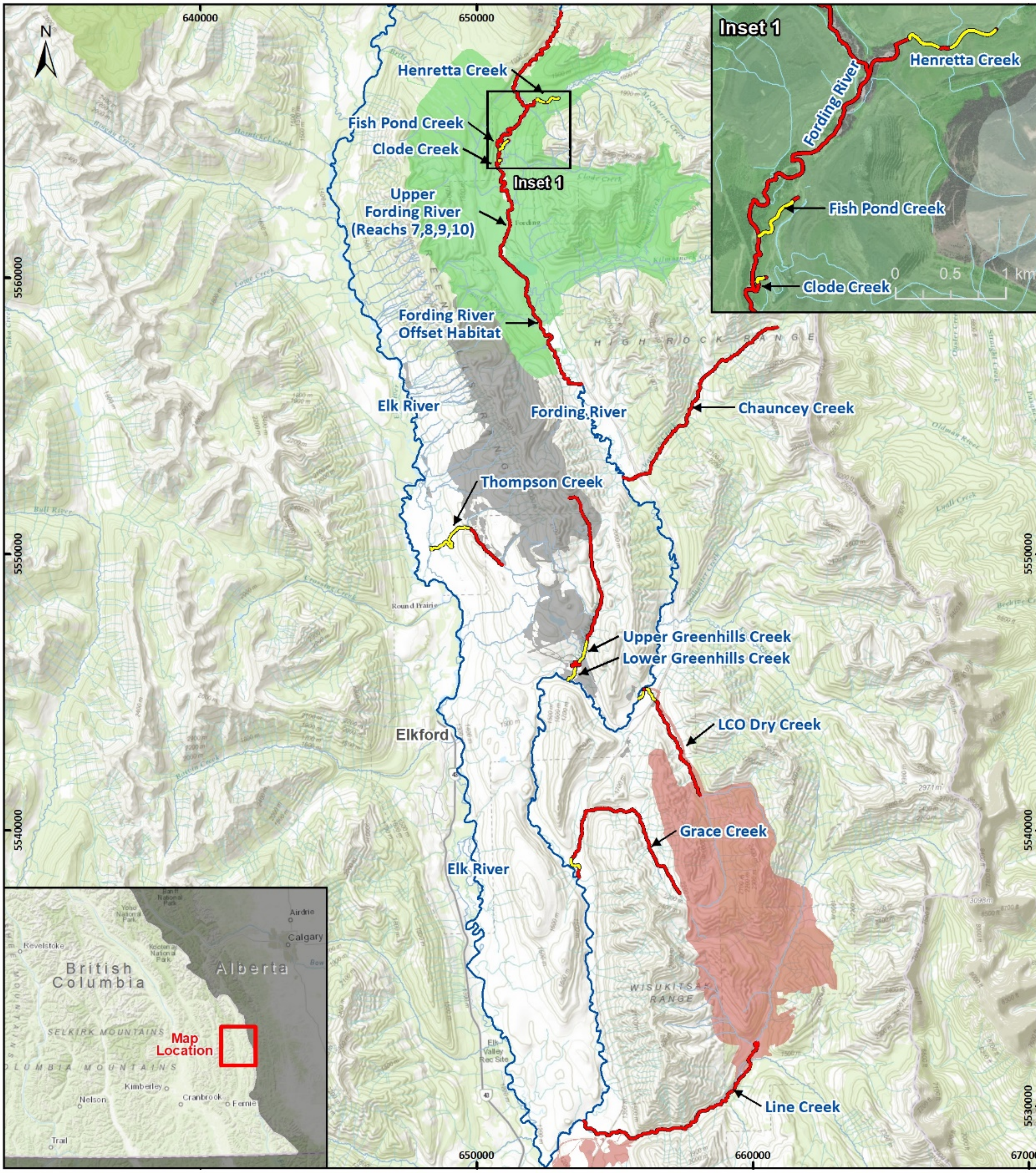
2.1. Study Area

The study was conducted in tributaries of the Elk and Fording rivers, located in the East Kootenay region of south-eastern British Columbia. The Fording River is itself a tributary to the Elk River. Study sites were selected to represent tributary spawning habitats used by Westslope Cutthroat Trout (WCT). The focus continues to be on tributary habitats rather than the Elk and Fording mainstems.

Data collection in 2019 was carried out in all five streams sampled in 2018 (Lower Greenhills, LCO Dry, Clode, Fish Pond and Henretta Creeks) from the upper Fording River watershed as well as an additional twelve streams from throughout the Elk Valley. Additional streams were selected for having moderate to high levels of calcite (Upper Greenhills, Corbin, Thompson, Michel, EVO Dry, Harmer, Erickson and Grave creeks) or as reference sites (Alexander, Grace, McCool and Lizard creeks) (Map 1, Map 2). Calcite prevention activities have begun on Lower Greenhills Creek in reach GREE1 (Smithson *et al.* 2019; Teck 2019) Habitat improvements are also being completed on Fish Pond and Henretta creeks to improve conditions for WCT (Teck 2016). Waypoints and study reach lengths for each stream are shown in Appendix A.

The specific watercourses selected have habitats used by WCT for spawning, have a range of calcite scores (i.e., 0 to 3 CI, see definition of CI in Section 2.3.2), and are expected to be representative of streams and WCT spawning conditions throughout the Elk Valley. WCT spawning has been confirmed in various tributaries of the upper Fording watershed (Beswick 2007; Cope *et al.* 2016; Minnow Environmental 2016a; Buchanan *et al.* 2016; Faulkner *et al.* 2018; Hocking *et al.* 2019). Spawning habitat and redd information for streams in the larger region was acquired from technical reports (Russell and Oliver 1996; Windward Environmental *et al.* 2014; Cope *et al.* 2016; Minnow Environmental 2016b; Lamson 2018) and was also provided by Lotic Environmental (Robinson, pers. comm. 2019). Table 1 summarizes existing fish habitat, calcite, and fish presence/spawning data available for each of these streams prior to 2019 sampling. Spawning was previously confirmed (i.e., redds and/or fry present) in all study streams, except for Corbin and Thompson Creeks.

Study Area and Sampling Locations



Legend

- Study Streams
- FHAP Section
- Streams
- Paved Road
- Provincial Border
- Parks and Protected Areas

Permit Boundaries

- FRO
- GHO
- LCO

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 2 4 6 km

Scale: 1:200,000

NO.	DATE	REVISION	BY
1	6/26/2020	1229_StudyAreaSamplingLocationsNorth_3402_20190918	CGA
2			
3			
4			
5			

Date Saved: 6/26/2020
Coordinate System: NAD 1983 UTM Zone 11N

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Map 1

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Study Area and Sampling Locations

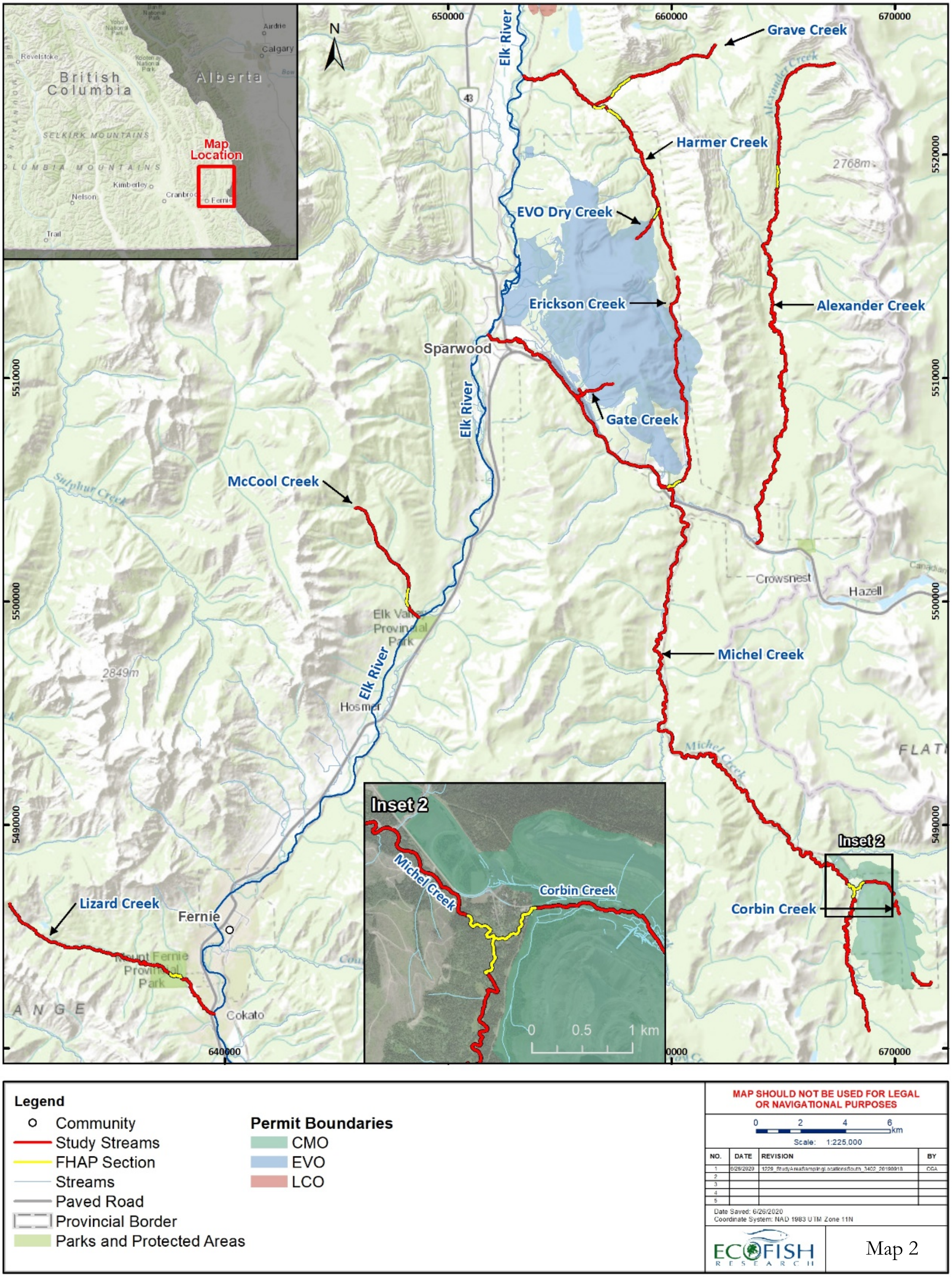


Table 1. Summary of fish, calcite and habitat information available for study streams prior to 2019 sampling.

Project[1]	Stream Name	Stream Type (Mine Influenced or Reference)	Existing FHAP[2]	Mean CI Score[3]			Existing Redd Surveys[4]	Fish or Redds Observed[5]
				CI_p	CI_c	CI (Cp+Cc)		
CMO	Corbin Creek	Mine Influenced	Confluence to Pond (2019)	0.04	0.00	0.04	No	No
	Michel Creek	Mine Influenced	No	0.99	1.82	2.81	No	Yes[6]
EVO	Dry (EVO) Creek	Mine Influenced	No	0.35	0.04	0.39	Yes, date unknown	Yes
	Erickson Creek	Mine Influenced	No	0.25	0.01	0.26	Yes, date unknown	Yes
	Grave Creek	Mine Influenced	No	0.89	1.43	2.32	Yes, date unknown	Yes
	Harmer Creek	Mine Influenced	No	0.94	1.58	2.52	2013	Yes
FRO	Clode Creek	Mine Influenced	Confluence to Pond (2018)	n/a	n/a	n/a	2018	Yes
	Fish Pond Creek	Mine Influenced	Complete (2018)	0.17	0.01	0.17	2015, 2018	Yes
	Henretta Creek	Mine Influenced	Confluence to Pit Lake (2018)	0.16	0.00	0.16	2018	Yes
GHO	Lower Greenhills Creek	Mine Influenced	Confluence to Pond (2018)	0.44	0.20	0.64	2015, 2018	Yes
	Upper Greenhills Creek	Mine Influenced	No	0.99	1.63	2.62	No	Yes[6]
	Thompson Creek	Mine Influenced	No	0.73	0.20	0.93	No	No
LCO	Dry (LCO) Creek	Mine Influenced	Confluence to East Tributary (2016)	0.21	0.00	0.21	2016, 2017, 2018	Yes
SRO	Alexander Creek	Reference	No	0.00	0.00	0.05	Yes, date unknown	Yes
	Grace Creek	Reference	No	0.00	0.02	0.36	Yes, date unknown	Yes
	Lizard Creek	Reference	No	n/a	n/a	n/a	Yes, date unknown	Yes
	McCool Creek	Reference	No	n/a	n/a	n/a	Yes, date unknown	Yes

[1] CMO (Coal Mountain Operations), EVO (Elkview Operations), FRO (Fording River Operations), GHO (Greenhills Operations), LCO (Line Creek Operations), SRO (Sparwood Regional Operations).

[2] FHAP = Fish Habitat Assessment Procedure

[3] Historical Calcite Index scores calculated from Appendix 2 of Smithson *et al*. 2019. Values of reference and mine influenced streams calculated using "Reference" and "Mine Influenced" type values, respectively. CI_p denotes calcite presence score; CI_c denotes calcite concretion score. CI denotes calcite index

[4] Includes surveys completed by Ecofish and/or Lotic (Robinson, pers. comm. 2019).

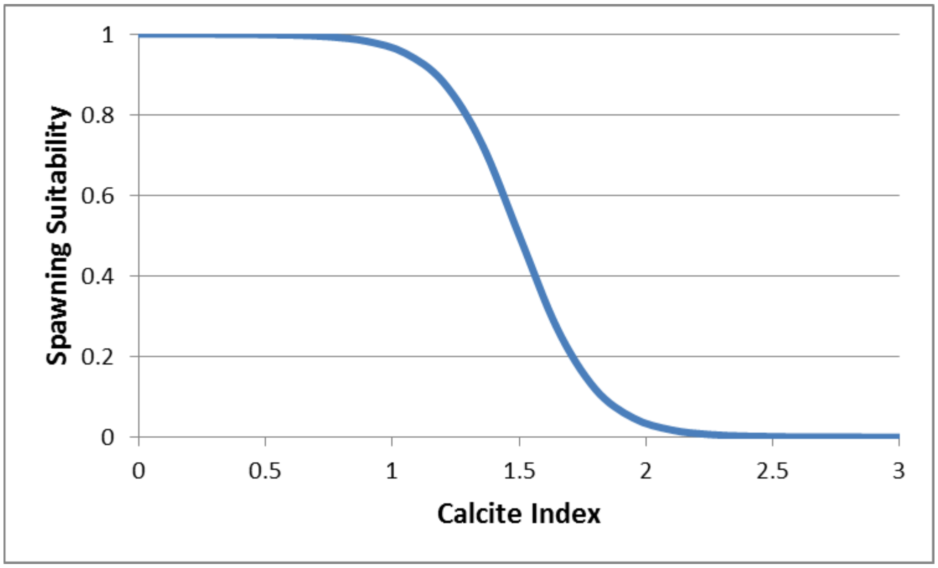
[5] Includes Ecofish, Lotic and Westlope Fisheries surveys and other sources

[6] Incidental observation of redds and mature spawning WCT in by E. Vogt, July 2019.

2.2. Experimental Design

The relationship between calcite and spawning habitat will be referred to here as a response curve (conceptual curve shown in Figure 2), in an attempt to quantitatively describe the influence of calcite (i.e., one aspect of habitat) on WCT habitat suitability. A response curve can be used in combination with habitat surveys to describe the status of spawning habitat in an area. The two main response variables used to develop the spawning suitability curve were redd presence and redd abundance, measured as counts (# of redds) or density (redds/m^2) in the study tributaries.

Figure 2. Conceptual response curve for calcite as it relates to spawning habitat suitability for Westslope Cutthroat Trout.



There are two fundamental challenges to developing a response curve for calcite, which need to be considered when implementing the WCT spawning suitability study. First, calcite is one of many influences on fish and fish habitat, and these other influences (e.g., substrate type, cover, gradient, water quality) need to be considered as potential covariates. Likewise, it is necessary to assess where fish are spawning as well as where they are not spawning. The approach to this study component can therefore be described as a mensurative experiment because the intent is to undertake measurements across a range of conditions occurring in the watershed, rather than directly manipulating conditions (variables) of interest (Hurlbert 1984). The approach thus attempts to develop a habitat suitability model for WCT that includes the key variable of interest, calcite, but also other potential fish habitat drivers.

Second, to build a spawning suitability response curve, the overall experimental design requires that redd data, calcite data and fish habitat data be collected at the same spatial scale. The most appropriate scale for measuring spawning habitat selection by WCT is at the mesohabitat scale (i.e., individual pools, riffles or runs in a given stream reach). In the 2018 study, redd sites and a roughly equivalent number of null sites, which are defined as sites without redds, were sampled on each stream, with redd, calcite and fish habitat data collected at the mesohabitat scale in all tributaries (Hocking *et al.* 2019). In 2019, sampling for redds, calcite and fish habitat information was again carried out at the mesohabitat scale. However, rather than selecting a comparable number of null sites to spawning sites, all mesohabitat units were sampled in a roughly 1 km reach per stream (mean = 948 m, range = 172 to 1,516 m). This removed potential bias in null site selection. For each stream, sample reaches were identified using historical redd and/or fry presence data and input from local experts (e.g., Robinson, pers. comm. 2019).

The two main response variables used were redd presence/absence (0, 1) and redd abundance, measured as counts (# redds) or density (redds/m^2) in each mesohabitat unit. Data collected in 2019 was integrated with data collected in 2018 (Hocking *et al.* 2019). It is possible that there may be two different relationships between calcite and spawning habitat; one response curve that describes a relationship for the presence of redds, and a second relationship for the abundance of redds. In Year 1 (2018), models were developed to test relationships between redd presence and redd abundance with calcite and found different results for each curve. However, data collected in 2018 was considered preliminary as sampling only occurred on five streams and did not span the full range of calcite conditions possible, particularly sites with moderate to high concretion. These findings were used to inform 2019 study design improvements, namely, increasing the number of study streams and sampling effort.

2.3. Field Data Collection

Sampling in 2019 included a combination of redd surveys, calcite data collection, and spawning gravel and fish habitat assessments in seventeen tributary streams in the Elk Valley, and was carried out based on the sampling schedule in Table 2.

For several streams in the study, the fish habitat assessment (FHAP) and/or redd survey data was already available from prior years or different Teck projects in the Elk Valley (Table 1). 2019 redd survey data for EVO Dry, Harmer, and Grave creeks were provided by Scott Cope (Cope, pers. comm. 2019) to Ecofish for inclusion in this study.

All 2019 field sampling was performed between May 11 and October 18, which generally included two redd surveys per stream in May to July, initial stream habitat (FHAP), water quality and water velocity data collection in May, June and July, and completion of the FHAP, the spawning habitat surveys and calcite data collection in August. The specific dates of field sampling for the various sampling types by stream are shown in Appendix A.

Westslope Cutthroat Trout redd data, calcite data and the majority of the stream habitat data were collected at the mesohabitat scale at each stream (i.e., in individual pool, riffle, run habitats). The average reach length sampled per stream was 948 ± 310 m, while the average mesohabitat unit length was 20.2 ± 21.0 m. A total of 796 mesohabitat units were sampled across the 17 streams in 2019.

The data collection in 2019 resulted in a high quantity of information. Maps highlighting mesohabitat units and redd locations within each stream are presented in Appendix B. Summaries of habitat, water quality, water velocity, calcite, and WCT redd data are shown in Appendix C for each stream, and broken down by habitat type within streams. The data and relationships between the habitat variables and redds can be explored in an HTML data viewer provided in Appendix D.

Table 2. Summary of field data collection required for calcite study with proposed sampling windows, 2019.

Field Trip	Survey	Clode	LCO Dry[1]	Fish Pond	Greenhills (lower)	Henretta	Greenhills (upper)	Corbin[2]	Michel	EVO Dry[3]	Harmer[3]	Grave[3]	Erickson	Thompson	Alexander	Grace	McCool	Lizard
Trip 1: late May/June	Delineate mesohabitats (start FHAP)						✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Redd Survey #1	✓		✓	✓	✓	✓		✓				✓	✓	✓	✓	✓	✓
	Water Quality and Velocity	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Trip 2: July	Redd Survey #2	✓		✓	✓	✓	✓		✓				✓	✓	✓	✓	✓	✓
	Complete FHAP						✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Trip 3: August	Spawning Gravel	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Calcite Index	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

[1] Redd surveys on LCO Dry Creek completed as part of LCO Dry Creek Baseline Monitoring

[2] FHAP and redd surveys completed as a part of the Corbin EFN study

[3] Redd surveys for EVO Dry, Harmer and Grave creeks completed by Scott Cope in 2019

2.3.1. Redd Surveys

Two or more WCT redd surveys were conducted for each tributary between May 27 and July 16 (Appendix A). WCT are known for variable spawning behaviours, which can make predicting peak spawning times difficult. Therefore, prior to undertaking the redd surveys, available information on weather, flows, turbidity, and fish behaviour were reviewed to maximize the likelihood of observing redds. Field reconnaissance trips were also undertaken on occasion and more detailed redd survey dates were adjusted based on observed fish and conditions, particularly high flows, which can inhibit observations of redds.

The redd surveys were conducted as bank walk counts during which two surveyors walked slowly and methodically along opposite banks in an upstream direction to maintain water visibility and minimize flushing fish prior to observation. Efforts were made to flush holding fish out from under cover such as undercut banks, large woody debris, and heavily aerated riffles/chutes. Observed fish were counted and assigned to one of four size bins: 0-70 mm (fry), 71-150 mm (1+ and 2+ parr), 151-200 mm (sub-adults or small adults), and ≥201 mm (adults). All fish counted during these surveys ≥150 mm in fork length were conservatively considered to be potential spawners based on observations of fish on or near redds during the surveys. During each survey, the presence of redds, habitat unit type, and water quality data (i.e., water temperature and visibility) were recorded. Additional water quality data were collected during redd surveys as described in Section 2.3.4. Redds were identified as recent, clean excavations in gravel substrates. All redds were recorded by fish biologists with extensive redd survey experience. Test redds, identified as partial or incomplete excavations, were recorded on datasheets but excluded from analyses. Water clarity was assessed using a measuring stick in each mesohabitat unit. GPS coordinates were recorded for each redd, and the site was flagged for subsequent habitat surveys (see sections below on methods for calcite (2.3.2) and habitat (2.3.3) surveys). Two response variables were calculated from the redd survey data: the number of redds per mesohabitat unit, and, the presence (1) or absence (0) of redds within a mesohabitat unit. The number of redds per mesohabitat unit was further standardized by the area of the mesohabitat unit to derive a measure of redd density (redds per m^2).

Maps of each stream showing the mesohabitat units and redd observations are presented in Appendix B. Photographs of observed redds are included in Appendix G.

2.3.2. Calcite Index

Calcite surveys were conducted using Teck's calcite index measurement protocol (Robinson and MacDonald 2014, Minnow Environmental 2016, Robinson *et al.* 2016) to provide a CI score for each mesohabitat unit within sampling reaches. The surveys were carried out from August 13 to 22 in all study streams, with additional survey effort in Grave and Harmer Creeks from October 16 to 18 (Appendix A).

While the methods of calcite data collection were the same, the design and sample size of the calcite data collection for this project differed from Teck's current CI measurement protocol. The current Regional Calcite Monitoring Program measures CI in reaches of 100 m in length, which includes observations of CI on 100 pebbles per stream reach. In comparison, the ~1 km reaches per stream sampled in this study had up to 73 mesohabitat units to be sampled. Representative calcite data were desired for each mesohabitat unit, which also provides an indication of the within-stream variability in calcite conditions. Because the number of units sampled is equal to the sample size of the study, the level of inference that can be drawn increases directly with number of mesohabitats sampled. Therefore, due to trade-offs between effort and time for sampling, the number of pebbles sampled per mesohabitat unit was reduced from 100 to 30. Previous work by Robinson *et al.* (2016) showed that a reduction in pebble count to as low as 25 pebbles had a minimal effect on the mean result observed. Despite this reduction in effort per mesohabitat unit, the total number of pebbles sampled per stream averaged 1,366 ± 495 (±SD) for a total of 23,222 pebbles sampled in 2019, 271% more than the 8,548 pebbles sampled in 2018. Increased sampling effort in 2019 also resulted in 796 mesohabitat units sampled versus 62 mesohabitat units sampled in 2018.

At each mesohabitat unit, the observer moved systematically over the unit, stopping every one, two or three steps to randomly select a pebble ≥ 2 mm in diameter (i.e., gravel or larger) along a stream section of variable length (20 to 100 m). If the substrate selected was < 2 mm in diameter, this was noted and another pebble was chosen to ensure a total count of 30 pebbles per mesohabitat unit.

Thirty pebbles were sampled for each CI measurement and the following information was recorded for each pebble:

- The concretion score (CI_{Conc}): if the pebble was removed with negligible resistance (not concreted to an adjacent pebble, score = 0), notable resistance but removable (partially concreted, score = 1), or immovable (fully concreted, score = 2);
- Absence or presence of calcite (score = 0 or 1 respectively) (CI_{Pres}); and
- The b-axis length of the pebble, to the nearest mm. Pebbles less than 2 mm (b-axis) were recorded as fines for the purpose of CI calculations.

Substrate was classified using the Wentworth Scale (Table 3). Additional substrate classification was recorded for fines and sand (<2 mm). The mesohabitat unit type (riffle, run, cascade, pool, glide) was also recorded and mapped (Appendix B).

The results for each mesohabitat unit were expressed as a CI_{Total} score using the following equation:

$$CI_{Total} = CI_{Pres} + CI_{Conc}$$

where,

$CI_{Total} = Calcite\ Index$

$CI_{Pres} = Calcite\ Presence\ Score = \frac{\text{Number of pebbles with calcite}}{\text{Number of pebbles counted}}$

$CI_{Conc} = Calcite\ Concretion\ Score = \frac{\text{Sum of pebble concretion scores}}{\text{Number of pebbles counted}}$

Note, for the remainder of the document, CI_{Total} is generally referred to as CI.

Table 3. Substrate classification scheme.

Substrate Type	Substrate Category	Size Range (mm)
Fines and Sand	Clay	<0.0039
	Silt	0.0039-0.0625
	Sand	0.0625-2
Gravel	Small Gravels	2-16
	Large Gravels	16-64
Cobble	Small Cobble	64-128
	Large Cobble	128-256
Boulders	-	256-4,000
Bedrock	-	>4,000

2.3.3. Fish Habitat

A Level 1 Fish Habitat Assessment Procedure (FHAP), as described by Johnston and Slaney (1996), was used to quantify fish habitat in all study streams to be used as predictors of WCT redd presence and redd abundance. FHAP was collected for LCO Dry Creek in 2016 (Buchanan *et al.* 2016), Lower Greenhills Creek and Henretta Creek in 2017 (Wright *et al.* 2018) and Fish Pond Creek and Clode Creek in 2018 (Hocking *et al.* 2019) (Table 2). On Corbin Creek, FHAP was collected in May 2019 as part of the ongoing Corbin Creek EFN study (Teck 2018). FHAP data collection was required in 2019 at Upper Greenhills, Thompson, Michel, Grave, Harmer, Erickson, EVO Dry, Alexander, Grace, Lizard and McCool creeks, and was carried out between May 11 and July 15, with additional survey effort in Grave and Harmer Creeks from October 16 to 18 (Appendix A).

Mesohabitat unit types were classified as pools, glides, runs, riffles, cascades, chutes and falls according to definitions in Johnston and Slaney (1996). Glide and run mesohabitat units typically share similar physical parameters (i.e., gradient, substrate, bankslope, depth profile) but are differentiated by flow profile. For example, run mesohabitat units have a defined thalweg, whereas glide mesohabitat units have uniform flow and lack a defined thalweg.

Table 4 lists the physical parameters surveyed at each mesohabitat unit along with the units of measurement and the equipment used. Parameters were measured rather than estimated wherever possible. Estimates were made for dominant and subdominant bed materials, and percent cover. Substrate was classified according to a modified Wentworth scale as shown in Table 3. The dominant and subdominant substrate type within each habitat unit was estimated based on coverage area. Photographs of each mesohabitat unit were taken.

Mesohabitat units were additionally classified by location within the stream as primary, secondary, and tertiary. Primary mesohabitat units occupy more than 50% of the wetted width of the main channel. Secondary units occupy secondary channels, and tertiary units are embedded within primary units but meet the minimum size criteria (Table 5).

A key habitat variable hypothesized to affect WCT spawning is spawning substrate availability. A spawning gravel assessment was completed to provide more specific spawning substrate information following methods described by Johnston and Slaney (1996). Within each mesohabitat unit, functional (below water surface) and non-functional (above water surface) gravel patch area was measured for spawning fish using a gravel size range of 10 to 75 mm thought to represent the preferred substrate size range for spawning WCT. Available spawning habitat was further determined by summing the functional gravel area for all patches in each mesohabitat unit. These spawning gravel assessments were carried out in conjunction with calcite assessment, August 13-22, 2019, with additional survey effort in Grave and Harmer Creeks from October 16 to 18 (Appendix A). Spawning substrate area per mesohabitat unit was used as an additional fish habitat explanatory variable in data analyses described in Section 2.5.

Mesohabitat units identified within each stream are mapped in Appendix B, and a summary of habitat data collected at mesohabitat units during the calcite assessment is presented for each stream, and broken down by mesohabitat type, in Appendix C.

Table 4. Physical parameters, units of measure and equipment used during the FHAP.

Parameter	Unit	Measured or Estimated	Equipment Used
Bankfull Width	m	Measured	Metre Tape or Rangefinder
Bed Material Type	n/a	Visual Estimate	Visual
Cover Proportion	n/a	Visual Estimate	Visual
Cover Type	n/a	Visual Estimate	Visual
Gradient	%	Measured	Clinometer
Habitat Unit Length	m	Measured	Metre Tape or Rangefinder
Maximum Pool Depth	m	Measured	Metre Stick
Wetted Depth	m	Measured	Metre Stick
Wetted Width	m	Measured	Metre Tape or Rangefinder

Table 5. Minimum size criteria for tertiary mesohabitat unit types.

Bankfull Channel Width (m)	Minimum Area (m^2)	Minimum Residual Depth (m)
0 - 2.5	1.0	0.20
2.5 - 5	2.0	0.40
5 - 10	4.0	0.50
10 - 15	6.0	0.60
15 - 20	8.0	0.70
> 20	10.0	0.80

2.3.4. Water Quality and Velocity

In addition to calcite and measures of geomorphic habitat from the FHAP, other physical habitat parameters such as water quality and water velocity were also collected at mesohabitat scale. Because flows and temperature vary on shorter time scales than habitat or calcite, extra efforts were made to collect water quality and velocity data as close in time as possible to redd surveys. Water quality and velocity surveys were performed between May 30 and July 16 to reflect conditions during the period of WCT spawning. Supplemental water quality surveys were completed during the August collection of calcite and spawning substrate data, with additional efforts in Grave and Harmer Creeks on October 16 to 18, 2019 (see Section 2.3.5 below). A summary of stream level physical habitat data collected during the water quality and velocity surveys is presented in Appendix C. Mesohabitat level data can be explored with an HTML viewer linked in Appendix D.

At each mesohabitat unit, water temperature, pH, and electrical conductivity were measured with a handheld Hanna HI98129 Combo pH/Conductivity/TDS Tester. In addition, reach scale measures of water quality were taken at approximately 250 m intervals along assessed reaches. Reach scale water quality data was collected in triplicate using a calibrated YSI Pro Plus, and parameters included in analysis were dissolved oxygen (DO), water temperature, pH, and electrical conductivity. Water quality meters were maintained and calibrated and water quality sampling procedures followed the guidelines of the British Columbia Field Sampling Manual, Part E Water and Wastewater Sampling (Clark 2013). Water quality summary statistics (stream average and standard deviation) were calculated for DO (mg/L), water temperature (°C), pH, and specific conductivity (µS/cm), and broken down by habitat type within each study stream, (Appendix C).

Velocity was measured in all mesohabitats at three stations (approximately one quarter, half, and three quarters of stream width) along a transect perpendicular to the primary flow using a calibrated Swoffer velocity meter (Model 2100) and a 140 cm top-set rod with an 8.5 cm diameter propeller. For each sampling site, an estimate of mean velocity was calculated from the measures recorded along the transect.

Water quality and velocity data were collected in the immediate vicinity of redds when present, and in a representative location in mesohabitats where no redds were observed.

2.3.5. Additional Sampling at Grave and Harmer Creeks

In Grave and Harmer Creeks, redd surveys performed by Scott Cope from May 27 – July 12 covered large reaches of each stream that extended beyond our original ~1 km study reaches. Because spawning was confirmed in areas within a few hundred meters of our original study reach boundary, our study reaches were expanded to more accurately represent spawning activity. The study reach at Grave Creek was expanded by 467 m downstream (original = 1022 m) and the study reach at Harmer Creek was expanded by 268 m downstream and 272 m upstream (original = 976 m) during additional fish habitat and calcite surveys completed in October 2019. Water quality and velocity, calcite, and FHAP data collection were again carried out at mesohabitat scale in the expanded reaches. Since water quality and velocity data from October did not coincide with the spawning window, water quality and velocity sampling were repeated in the original study reach and the change in parameters from the spawning window to October were used to adjust the data collected in the expanded reaches. This calibration procedure is detailed in Appendix E. Since habitat and calcite are not as seasonally variable as water quality and velocity, no such calibration was necessary for these parameters.

2.3.6. Estimation of Hydrology Data at Thompson Creek

The data collected in May 2019 in Thompson Creek did not include flow and velocity measurements. Hydrology data were collected in August 2019, outside of the spawning period. As a result, these data required similar adjustments to what was outlined above for Grave and Harmer Creeks. For these adjustments, instream flow data (IFS) collected during the spawning period was used. The IFS transects were consolidated depending on habitat type, and the average velocity, depth, and wetted width were calculated. These average values were then compared to the August 2019 data (averaged by habitat type) to compute an adjustment factor. This resulted in estimated hydrology conditions at the mesohabitat scale during the spawning period, which were used during data analysis. A detailed summary of this procedure can be found in Appendix E.

2.4. Data QA/QC

All field data were entered into Ecofish's proprietary data management platform, EcoDAT. This data management platform has built-in rigorous QA/QC protocols. Hardcopy data from field forms were transcribed into EcoDAT and entries were visually compared by a second person to check for data entry errors. All data analysis was completed by a qualified data analyst and raw data, coding and exports were reviewed by a senior data analyst prior to reporting.

2.5. Data Analysis

2.5.1. Data Exploration and Variable Selection

The effects of calcite on fish spawning suitability was assessed using two primary response variables, including the presence/absence of redds and the count (#) or density of redds (redds/m^2) present per mesohabitat unit within streams. Calcite data was tested as the primary explanatory variable of interest. Additional fish habitat variables were also included as explanatory variables to account for the range of conditions present in WTC spawning habitat. Data from 2018 (Hocking *et al.* 2019) and from 2019 (this study) were included in the analysis for redd count and density. However, only data from 2019 was included in the redd presence models. This was because of the difference in data collection methods between years with an equal number of redd sites and null sites with no redds sampled in 2018.

Prior to modelling, data exploration was conducted including generation of summary statistics for the redd survey, calcite, FHAP and water quality and velocity data. Redd density (redds/m^2) and proportion of spawning gravel were respectively calculated by dividing the total number of redds and the total area of WCT spawning gravel by the mesohabitat unit area (calculated as unit length × bankfull width).

Initial data exploration included generation of plots showing the distribution of redd density and redd counts by tributary and mesohabitat type. CI scores were also plotted by tributary and mesohabitat type. To support data exploration, a HTML viewer was created, which enables manual comparison of calcite and fish habitat variables for each stream surveyed (Appendix D).

As a first step of data exploration of explanatory variables, collinearity was analyzed between the values of CI, and its components (i.e., calcite presence score and calcite concretion score). High correlation was found between CI and calcite presence ($r = 0.865$) and between CI and calcite concretion ($r = 0.873$), and modest correlation was found between calcite presence and calcite concretion ($r = 0.511$) (Figure 3). Calcite concretion was observed to begin to occur above a calcite presence score of ~0.70, although high calcite presence (> 0.90) with zero concretion was also observed.

The remaining data exploration of explanatory variables was carried out following Zuur *et al.* (2010) protocol. The explanatory variables initially hypothesized to affect WCT spawning included CI, mesohabitat type, streamflow, mean water velocity, bankfull depth, bankfull width, mean substrate size, grain size distribution, spawning gravel, water temperature, DO, specific conductivity and pH. Explanatory variables were standardized to have a mean of zero and a standard deviation of one prior to being included in the analyses. Data exploration revealed substantial collinearity among explanatory variables (Figure 4). For example, specific conductivity was highly correlated to calcite concretion. Therefore, a number of variables were excluded from consideration due to collinearity and challenges with model fitting. The final set of explanatory variables included CI, calcite concretion, mean velocity, spawning gravel, bankfull depth, functional Large Woody Debris (LWD) tally, and water temperature (Table 6).

Figure 3. Correlations between CI, calcite presence and calcite concretion across 17 streams in the Elk Valley in 2018 and 2019

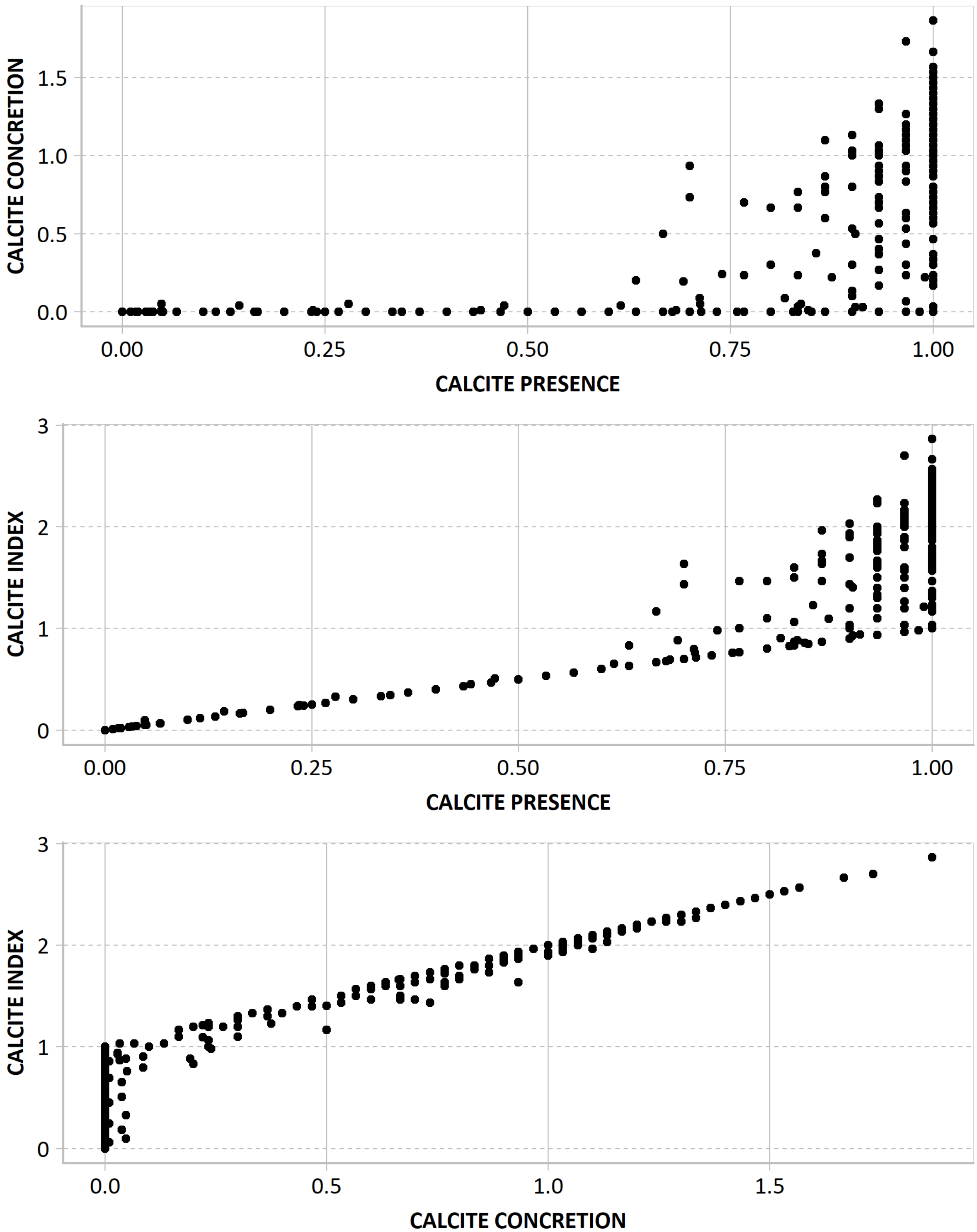


Figure 4. Correlation matrix of explanatory variables. Main diagonal: density plots. Lower triangle: scatterplots. Upper triangle: correlation coefficients.

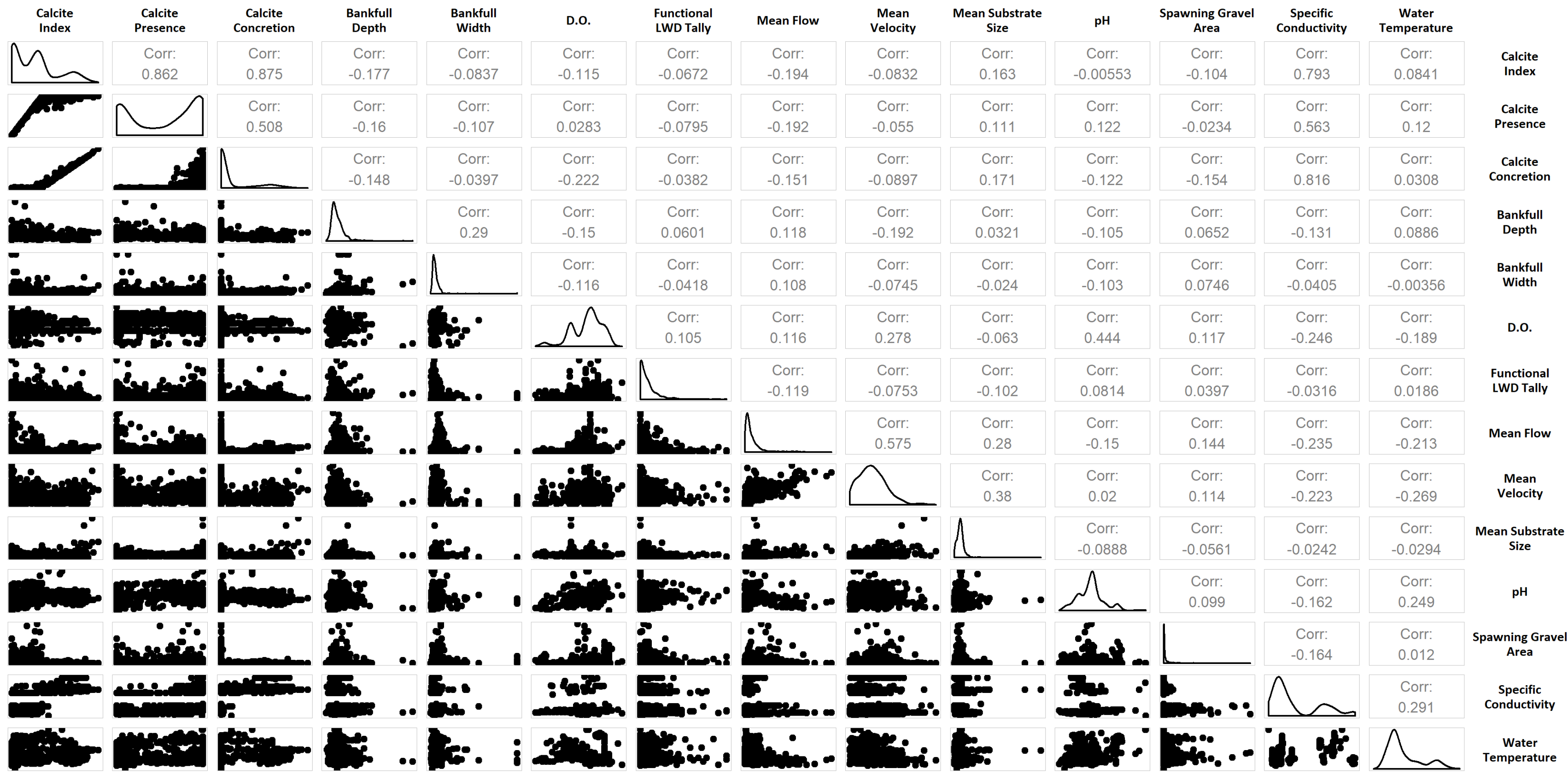


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Table 6. Summary and description of variables selected for modelling and included in the final model set.

Variable Type	Variable	Description
Response	Redd Counts	Sum of the observed number of new redds observed during surveys within each mesohabitat unit.
	Redd Presence/Absence	Binary variable indicating presence (1) or absence (0) of redds within a mesohabitat unit.
Random Effects	Year	Categorical variable indicating year of sampling.
	Tributary Stream	Categorical variable indicating waterbody where sampling occurred.
Fixed Effects	Calcite Index (CI)	Sum of calcite presence and calcite concretion scores.
	Calcite Concretion (CI_{Conc})	Score assigned to individual pebbles indicating degree of concretion.
	Bankfull Depth	Water depth (m) within mesohabitat unit at bankfull flow conditions.
	Mean Velocity	Mean stream velocity (m/s) of mesohabitat unit.
	Proportion of Spawning Gravel	Proportion of mesohabitat unit area with gravel suitable for spawning. Calculated as the total area of functioning spawning gravel divided by the mesohabitat unit area.
	Water Temperature	Water temperature (°C) within mesohabitat unit, collected during calcite measurements.
	Mesohabitat Area	Total area (m^2) of mesohabitat unit, calculated as mean bankfull width × mean bankfull width.
	Mesohabitat Type[1]	Categorical variable indicating mesohabitat unit type (Pool, Glide, Run, Riffle, Cascade).
	Streamflow[1]	Volume of water (m^3/s) moving through the mesohabitat unit.
	Bankfull Width[1]	Width (m) of wetted channel at bankfull flow conditions.
	Mean Substrate Size[1]	Mean size of pebbles (mm) within each mesohabitat unit, collected during calcite index measurements.
	Dissolved Oxygen[1]	Mean *in situ* measure of dissolved oxygen (mg/L and % saturation), collected within each mesohabitat unit.
	Specific Conductivity[1]	Mean *in situ* measure of specific conductivity (µS/cm) collected within each mesohabitat unit.
	pH[1]	Mean *in situ* measure of pH, collected within each mesohabitat unit.

[1]These predictor variables were excluded from modelling due to collinearity.

2.5.2. Redd Presence

Relationships between redd presence and explanatory variables were investigated a using a model selection procedure on a series of logistic regression models, where the response variable followed a binomial distribution with a logit link function (Hosmer and Lemeshow 2000). This step was implemented using the "stats" package in the R Statistical Language (R Core Team 2018). Only 2019 data were included in the redd presence model.

Model selection techniques were used to assess the relative importance of each predictor variable, including CI and CC, in explaining redd presence (e.g., Zuur *et al.* 2009, Grueber *et al.* 2011). Once the initial 'global model' was determined, which included all explanatory variables, the second step of the model selection procedure involved an all-model-combinations model selection approach where candidate models containing all possible combinations of each predictor variable (without including interactions) were competed against one another to find the top models that best describe redd presence. One restriction that was imposed was that no candidate model could have both CI and calcite concretion included as predictors, due to collinearity. This set up a direct competition between CI and calcite concretion in what best predicted redd presence.

Each candidate model was compared using Akaike Information Criterion corrected for small sample sizes (AICc), which balances model simplicity with variance explained. A subset of the candidate models was then retained based on the difference between each model's AICc value and the AICc of the best model (the ΔAICc). Models with a Δ value smaller than 2 have substantial empirical support (Burnham and Anderson 2002), and models with Δ values in the 2–7 range have some support (Burnham *et al.* 2011). Only models with a ΔAICc of less than 4 were retained, a cut-off threshold used to prevent the inclusion of overly complex models (Grueber *et al.* 2011). The retained models within ΔAICc <4 were then model-averaged to obtain a final, weighted model. Model-averaged products for each response variable include the set of top models that explain redd presence, and the parameter estimates, confidence and relative variable importance associated with each predictor variable. Model selection and model averaging was implemented using the "MuMIn" package (Barton 2018) in the R Statistical language.

2.5.3. Redd Counts

To derive the spawning suitability curve with redd abundance, two response variables were considered, either redd counts (#/mesohabitat unit) or redd density (#/m^2). Modeling was conducted as described below using both response variables and results were similar. However, model performance was improved, including a reduction in model convergence errors, when redd counts were used as opposed to redd density. As such, results are presented for redd counts as the primary response variable for models testing the abundance of redds per mesohabitat unit within streams. Mesohabitat unit area was therefore included as an additional predictor to account for sampling effort in the redd count models. Redd count models included data from 2018 (Hocking *et al.* 2019) and 2019 (this study).

To characterize the effects of calcite on the number of redds in a stream, effects on redd counts were assessed using two main approaches, including the effect on the mean number of redds and the effect on the 90th quantile of redd counts (i.e., how does calcite affect the probability of having high counts of redds). The effect of calcite on the mean number of redds was evaluated within the framework of generalized linear mixed models (McCullagh and Nelder 1989, Bolker *et al.* 2008), whereas the effect on the 90th quantile of redd counts was assessed in the framework of quantile regressions (Huang *et al.* 2017).

The relationship between mean number of redds and relevant explanatory variables described in Section 2.5.1 was modelled as a generalized linear mixed model suited to describing counts. Redd counts were modelled by applying a ln(x + 0.01) transformation to prevent the model from predicting negative redd counts. Initially, redd counts were modelled using a Poisson error distribution with a logit link function. However, due to the large number of zero redd counts, this model was found to have significant overdispersion. To account for the increased variability, the Poisson distribution was replaced with a Negative-Binomial which allows for a quadratic relationship between the mean and the variance term in the model. In all cases, year and stream were included as random effects in the models to account for repeated observations (Zuur *et al.* 2009). Generalized linear mixed models were fit using packages "lme4" and "glmmTMB" in the R Statistical Language (Bates *et al.* 2015, Brooks *et al.* 2017). Model selection techniques were used to assess the relative importance of each predictor variable, including CI and calcite concretion, in explaining the mean number of redds as described in Section 2.5.2.

Linear modelling describes differences in the mean of response variables, but is not able to detect heterogeneous effects of covariates at different quantiles of the response variable. Quantile regression is an analytical method well-suited to examining limiting factors for species abundance and distribution (Cade and Noon 2003). A species' abundance may be limited by many ecological factors, and will be constrained to lower abundance than expected in a potentially suitable habitat if other factors are more limiting (Cade *et al.* 1999, Cade and Noon 2003, Cade *et al.* 2005). This means that species abundance data often appear wedge-shaped when plotted against any single habitat variable. Quantile regression is used to understand potential relationships at the outer bounds of the data and can be useful when there are many habitat factors that limit fish populations. For example, the 90th quantile is a robust model to describe the upper bounds of wedge-shaped relationships (Scharf *et al.* 1998, Koenker and Machado 1999; Armstrong *et al.* 2010, Hocking *et al.* 2013). The relationship between the 90th quantile of the number of redds and relevant explanatory variables described in Section 2.5.1 was modelled as a quantile regression model using the "quantreg" package (Koenker 2018) in the R Statistical Language (R Core Team 2018). Year was initially included as a random effect in the model. However, given the limited number of observations at the 90th quantile, a few data points had disproportionate leverage on the behavior of the model. Thus, to increase the number of observations at the 90th quantile and reduce the leverage of these observations, year was removed from the model. Redd counts were exclusively zero (i.e., no redds were observed) in several streams, and thus variance terms could not be estimated. Hence, stream was also not included as a random effect in the 90th quantile model. Redd counts were modelled by applying a ln(x + 0.01) transformation to prevent the model from predicting negative redd counts. All possible candidate models (no interactions) were built, and ranked and selected the best model based on the Akaike Information Criterion corrected for small sample sizes (AICc; Burnham and Anderson 2002) and the derived measure evidence ratio (Anderson 2008).

3. RESULTS

Increased sampling effort in 2019 resulted in 796 mesohabitat units sampled versus 62 mesohabitat units in 2018. Over 30 mesohabitat units were sampled in 15 of the 17 streams, with 8 of these having sample sizes of over 50 mesohabitat units. Harmer Creek (n = 73) and LCO Dry Creek (n = 70) were the most intensively sampled streams. The most intensively sampled mesohabitat types surveyed in 2019 were riffles (n = 238), followed by cascades (n = 180), runs (n = 153), glides (n = 112), and pools (n = 93). Falls (n = 94) and chutes (n = 6) were less intensively sampled in 2019 (Figure 5).

3.1. Redd Surveys

Westslope Cutthroat Trout redds were observed in twelve of the seventeen streams surveyed in 2019; no redds were observed in Corbin Creek, EVO Dry Creek, Erickson Creek, Clode Creek, or Grace Creek (Figure 5). Most mesohabitats surveyed in 2019 did not have redd presence (n = 707, 89% of observations). The total number of redds observed in 2019 was 311, compared to 77 in 2018. The highest number of redds observed per mesohabitat unit was 17 redds, which was observed in Lizard Creek. Representative photos of redd sites in study streams are shown in Figure 6 to Figure 9.

The number of redds varied spatially; the largest number of redds in 2019 were observed in Lizard Creek (n = 28, 31% of all redds), McCool Creek (n = 14, 16% of all redds), Michel Creek (n = 12, 13% of all redds), and LCO Dry Creek and Harmer Creek (n = 10 in each stream, 11% of all redds in each stream). High redd counts occurred in LCO Dry Creek during 2018 as well. Low numbers of redds were consistently recorded in Henretta Creek (Figure 5).

Average WCT redd counts by mesohabitat unit in streams in the upper Fording River watershed were lower in 2019 than in 2018 (Figure 10). More redds were observed in 2018 versus 2019 in Fish Pond Creek (38 vs. 9), Clode Creek (6 vs. 0) and Lower Greenhills Creek (10 vs. 1). Spawn timing and total WCT abundance throughout the Elk Valley in 2019 was inconsistent with previous years, possibly attributable to seasonally uncharacteristic flows in the region. Figure 11 shows extended periods of low flows in the Elk River near the Fording River confluence, in May and June, 2019. Flows were recorded near and below the tenth percentile of twenty-year median flows during parts of the expected spawning window (WSC 2019a, 2019b). Periods of higher precipitation also resulted in high flows during this period.

Redd counts were higher in mesohabitats with moderate velocity, including in runs, riffles and glides, and were less abundant in pools and cascades (Figure 12). During the 2019 surveys, redds were more frequently observed in runs (45% of redds, n: 40), and riffles (33% of redds, n: 29), whereas during 2018 redds were more frequently observed in glides (52% of redds, n: 15), and riffles (31% of redds, n: 9). Redds were not observed in chutes or falls.

Maps of the individual redd locations by stream are shown in Appendix B.

Figure 5. Distribution of Westslope Cutthroat Trout redd presence (orange) and absence (green) by stream and mesohabitat type in tributaries of the Elk River, B.C., in 2019.

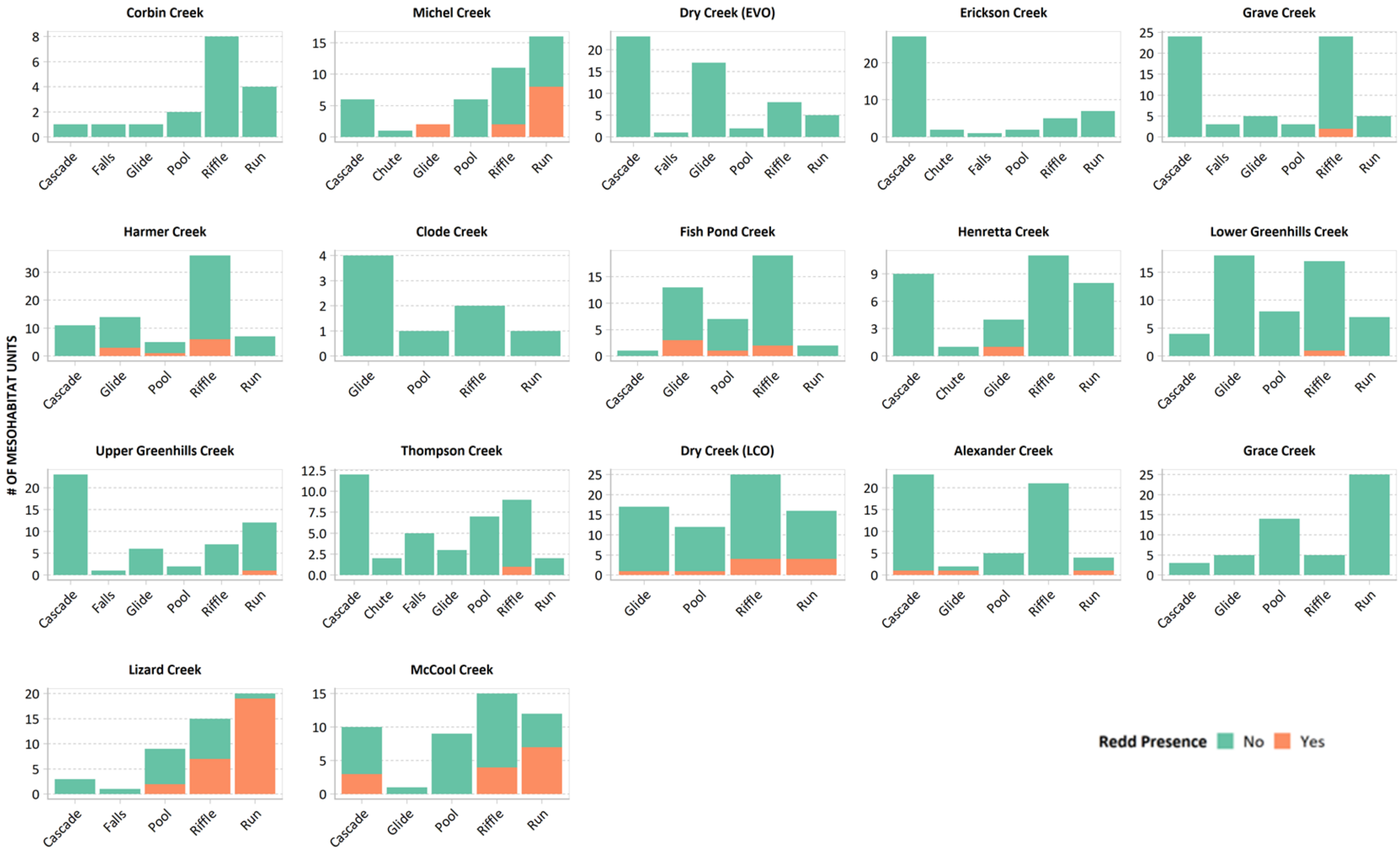


Figure 6. Westslope Cutthroat Trout (upper right circle) observed on redd (lower left circle) in Fish Pond Creek, FHAP unit 6 (Appendix B), on July 8, 2019.

Figure 7. Westslope Cutthroat Trout redds observed (circles) in LCO Dry Creek, FHAP unit 10 (Appendix B), on July 17, 2019.

Figure 8. Westslope Cutthroat Trout redd observed (circle) at Alexander Creek, FHAP unit 19 (Appendix B), on July 13, 2019.

Figure 9. Westslope Cutthroat Trout redd observed (circle) at Lower Greenhills Creek, FHAP unit 31 (Appendix B), on July 16, 2019.

Figure 10. Average Westslope Cutthroat Trout redd counts (± 1 SD) for each mesohabitat unit by stream in tributaries of the Elk River, B.C. from 2018 and 2019. CMO: Coal Mountain Operations, EVO: Elkview Operations, FRO: Fording River Operations, GHO: Greenhills Operations, LCO: Line Creek Operations.

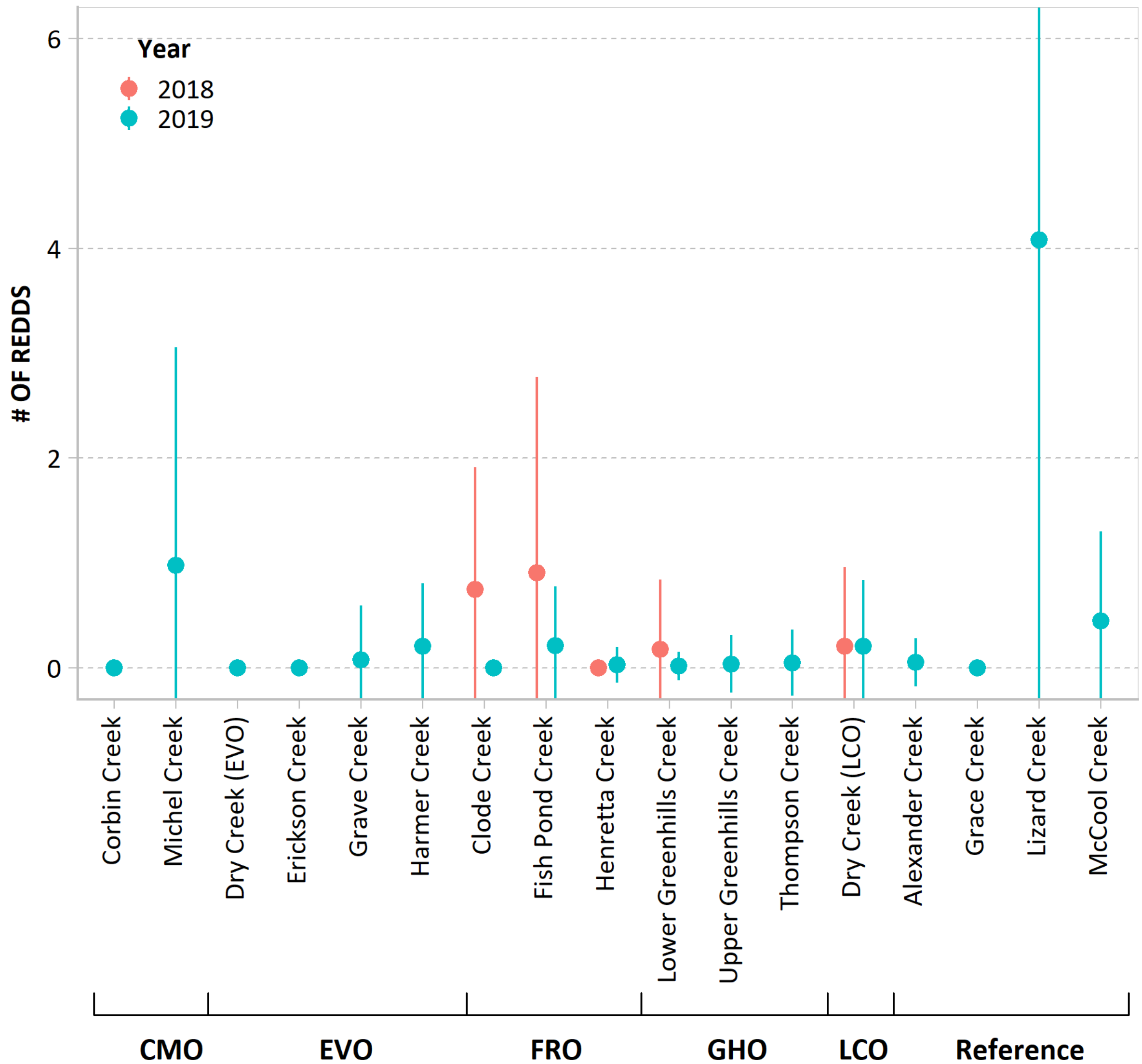


Figure 11. Daily average flows in Fording River at confluence with Elk River, May-September, 2019 (red line) and 2000-2019 median (black line). Shaded area represents the 10^{th}-90^{th} percentiles of 2000-2019.

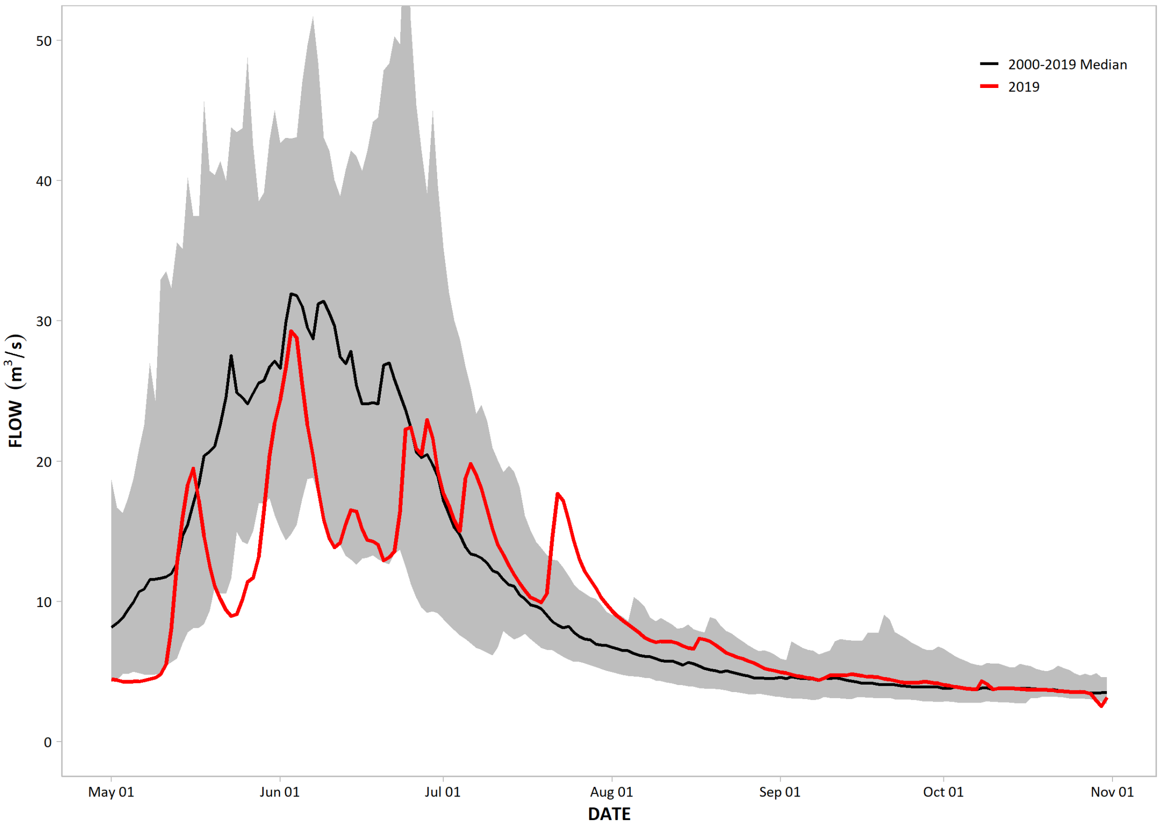
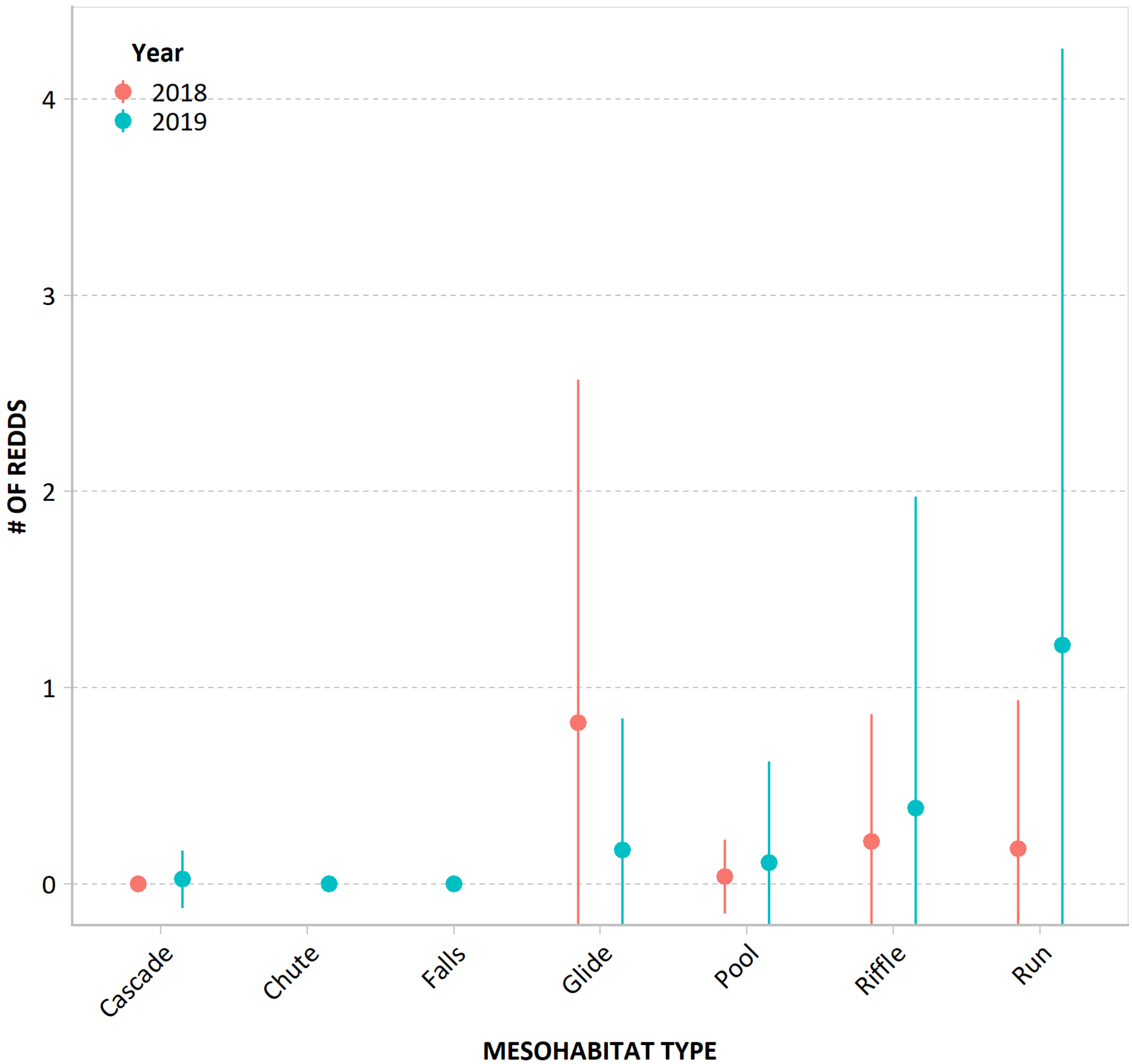


Figure 12. **Average Westslope Cutthroat Trout redd counts (± 1 SD) for each mesohabitat unit by mesohabitat type in tributaries of the Elk River, B.C. from 2018 and 2019.**



3.2. Calcite Index and Fish Habitat

Calcite levels varied spatially within and among streams of the study area (Figure 13), consistent with previous studies (Minnow Environmental 2016, Robinson *et al.* 2016, Wright *et al.* 2017; 2018). Given the expanded surveyed area implemented in 2019, the range of CI observed (0 – 2.87) was wider than the range of CI observed in 2018 (0 – 1.66) from Hocking *et al.* (2019).

The highest calcite presence, calcite concretion and CI were observed in Corbin Creek, EVO Dry Creek and Erickson Creek in 2019 (Figure 13). Average concretion in 2019 in Corbin Creek, EVO Dry Creek and Erickson Creek was 1.15, 0.95 and 1.08, respectively. Concretion was also observed in Upper Greenhills Creek (2019), Lower Greenhills Creek (both years), and Clode Creek (both years). Low calcite presence and zero concretion were observed in Grave Creek, Fish Pond Creek (both years), Henretta Creek (both years), Alexander Creek (2019), Grace Creek (2019) and LCO Dry Creek (2018 only).

Moderate to high calcite presence (mean presence >0.5) was observed in six streams where zero calcite concretion was recorded (Figure 13). These streams included Harmer Creek, Michel Creek, Thompson Creek, LCO Dry Creek (in 2019), Lizard Creek, and McCool Creek. Note that there are no mining developments upstream of either Lizard (mean CI_{Pres}: 0.58) or McCool Creeks (mean CI_{Pres}: 0.83). For these streams, when calcite was present on a rock, coverage was variable; occasionally, small patches (<1 cm^2) were observed but these did not completely cover the rock. Particularly in Lizard Creek, higher calcite presence was observed further upstream in the reach sampled. Representative photos of high calcite presence, high calcite concretion, and low calcite presence are included in Figure 14, Figure 15, Figure 16, respectively.

Observed values of calcite presence and concretion were similar for individual streams surveyed in 2018 versus 2019, with the exception of LCO Dry Creek, which had higher calcite presence in 2019 than in 2018 (Figure 13). Calcite presence and concretion was also modestly less at Lower Greenhills Creek in 2019 compared to 2018.

Calcite presence, and particularly concretion, tended to be higher in mesohabitats with higher water velocities (Figure 17). Mean calcite presence and concretion were highest in cascades, chutes and falls and lowest in pools.

The 17 streams sampled in 2018 and 2019 differed in aquatic habitat such as water quality, habitat structure and spawning habitat availability. Average conditions per stream habitat variable sampled are shown in Appendix C. The FHAP maps with each redd location are also shown in Appendix B and an HTML viewer, which allows exploration of the data collected is shown in Appendix D.

Figure 13. Average calcite presence, calcite concretion and CI (± 1 SD) for each mesohabitat unit by stream in 17 tributaries of the Elk River, B.C. from 2018 and 2019. CMO: Coal Mountain Operations, EVO: Elkview Operations, FRO: Fording River Operations, GHO: Greenhills Operations, LCO: Line Creek Operations.

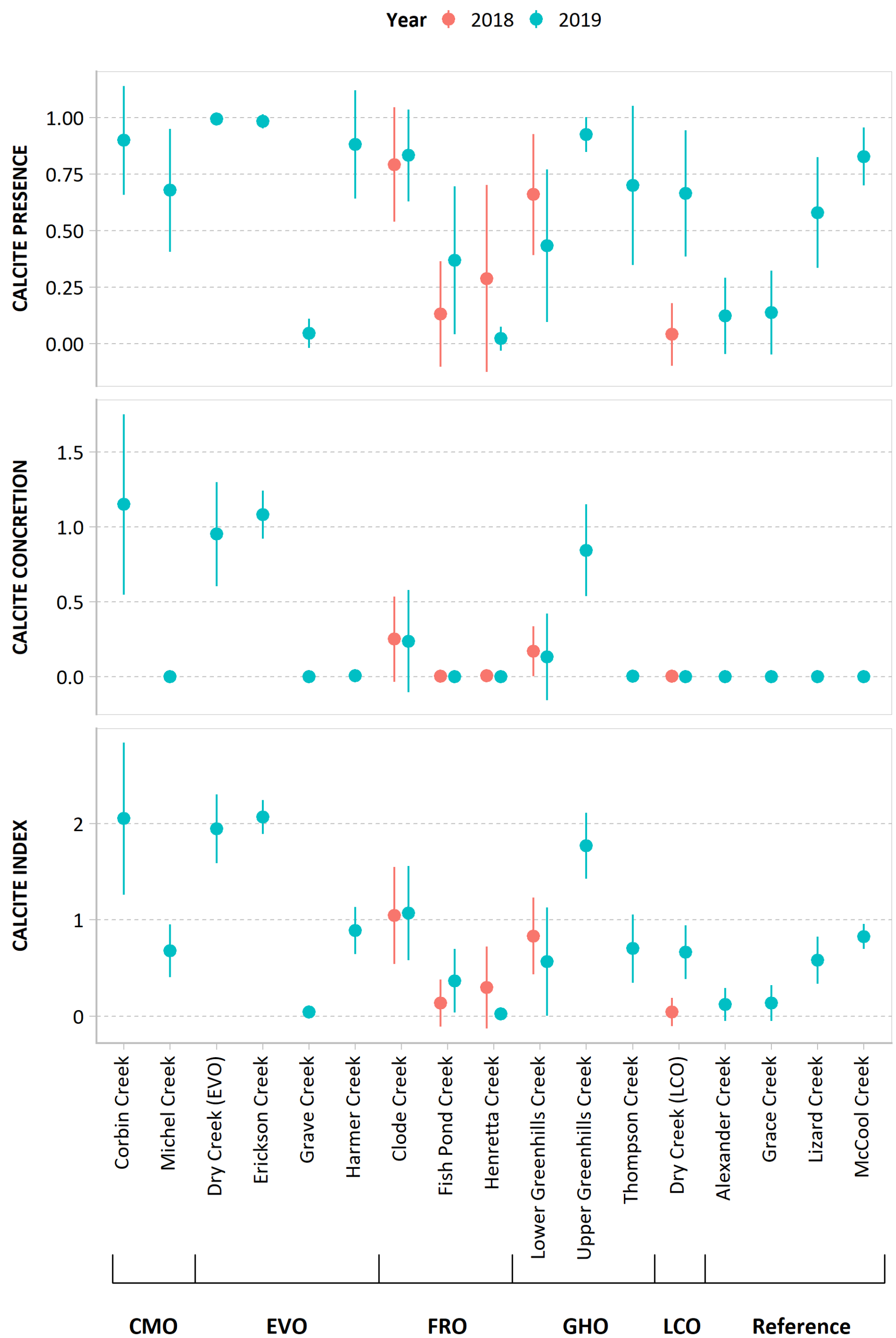
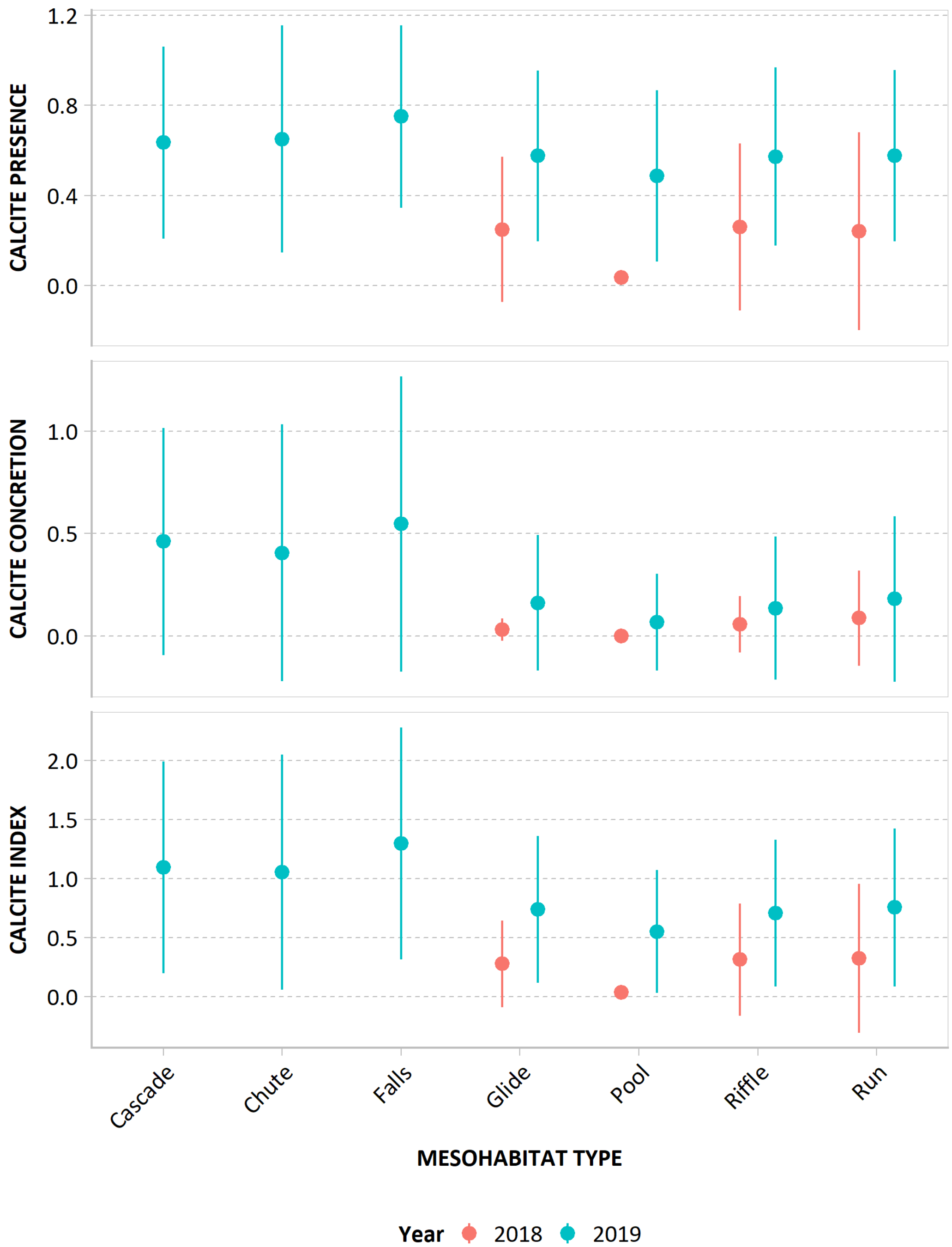


Figure 14. High calcite presence observed at a) McCool Creek and b) Lizard Creek

Figure 15. High calcite concretion observed at a) Corbin Creek and b) Erickson Creek. Note that the creek is almost completely covered by moss matts

Figure 16. Low calcite presence observed at Alexander Creek

Figure 17. Average calcite presence, calcite concretion and CI (± 1 SD) for each mesohabitat unit by mesohabitat type in 17 tributaries of the Elk River, B.C. from 2018 and 2019



3.3. Redd Presence

Based on data collected and analysis performed herein, the most important variables to explain variance in redd presence were calcite concretion and stream temperature, and to a lesser extent functional LWD tally (Figure 18). The relative strength for individual explanatory variables can be evaluated by summing the weights of models that contain the same explanatory variable to derive a score called relative variable importance (RVI); all models within the restricted model set of those models whose $\Delta AICc < 4$ contain terms for calcite concretion and temperature (Table 7) and thus these variables have an RVI of 1. The effect of calcite concretion on the likelihood of redd presence was negative (i.e., calcite decreases the likelihood of presence), whereas the rest of the variables had a positive effect on the likelihood of redd presence.

Calcite concretion was better than CI in explaining variance of redd presence in the study streams. Calcite concretion outcompeted CI in explaining redd presence, which resulted in CI not being present in any of the top models (Table 7). If calcite concretion is excluded from model selection, then the relative variable importance of CI was modest (RVI = 0.57), and its effect on redd presence is consistently negative across all top models. All results for CI when calcite concretion is excluded from consideration are shown in Appendix F.

Mean calcite concretion scores were similar between sites where redds were present (mean CI_{Conc}: 0.003, minimum CI_c: 0, maximum CI_{Conc}: 0.23) and sites where redds were absent (mean CI_{Conc}: 0.25, minimum CI_{Conc}: 0, maximum CI_{Conc}: 1.87). However, redds were only present in habitats with low calcite concretion ($CI_{Conc} < 0.5$), whereas the range of concretion scores in sites where redds were absent was much larger (Figure 19a).

Calcite concretion had the largest effect on the likelihood of redd presence compared to the other habitat variables (Figure 18). Variability in the presence of redds in the streams surveyed was explained by an exponentially decreasing function with a probability of redd presence of ~0.15 at a calcite concretion score of 0 and quickly dropping to a probability close to zero by 0.5 calcite concretion (Figure 19b). It is worth noting that the confidence limits of the probability of redd presence with calcite concretion is broad (Figure 19b).

Figure 18. **Model averaged coefficients (with 95% confidence intervals) indicating the most important variables predicting redd presence. Values in the x-axis are estimates of model parameters. RVI = Relative Variable Importance scores, where a score of 1 indicates that a predictor variable occurs in all top models with ΔAICc < 4.**

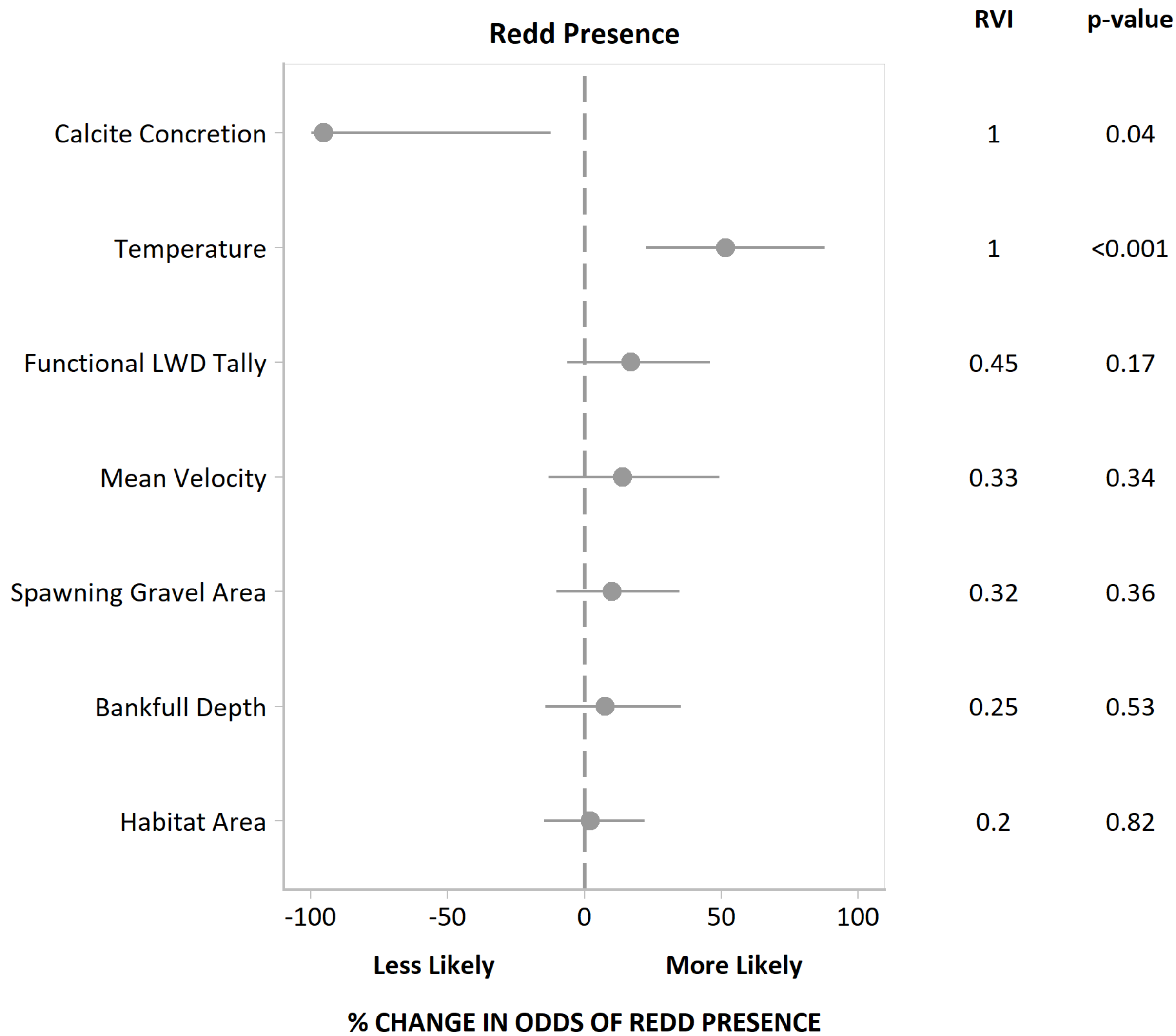


Figure 19. (a) Average calcite concretion score at mesohabitat units with redds present and with redds absent in tributaries of the Elk River, B.C. (b) Probability of redd presence versus calcite concretion. The solid line represents the predicted probability of redd presence as a function of calcite concretion, where all other predictors are held at their means (estimated from a logistic regression model: model averaged parameter estimates for calcite shown in Figure 18). The points represent the observed probability of redd presence by stream (p = # of units with redds present / total # of units in the stream). The shaded region represents the 95% confidence interval for the predicted probability of redd presence.

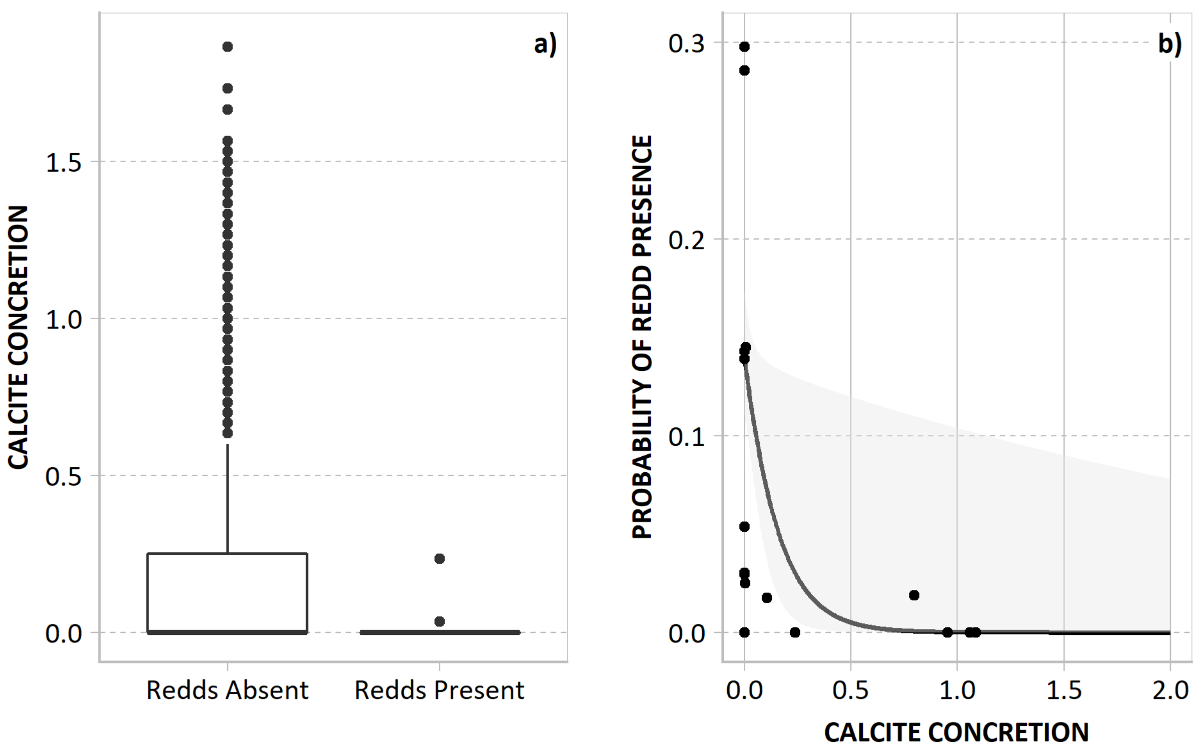


Table 7. Top models that best predict Westslope Cutthroat Trout redd presence in tributaries of the Elk River, B.C. Models are ranked by Δ Akaike Information Criterion (ΔAICc) scores. The model with the lowest ΔAICc is the best model. Model weights (range 0-1) are also shown, which provide an estimate of the likelihood that a given model is the best model compared to the other top models in the model set.

Model	ΔAICc	Weight
Redd Presence ~ Calcite Concretion + Temperature	0.00	0.13
Redd Presence ~ Calcite Concretion + Functional LWD Tally + Temperature	0.31	0.11
Redd Presence ~ Calcite Concretion + Spawning Gravel + Temperature	1.26	0.07
Redd Presence ~ Calcite Concretion + Mean Velocity + Temperature	1.30	0.07
Redd Presence ~ Calcite Concretion + Functional LWD Tally + Mean Velocity + Temperature	1.39	0.06
Redd Presence ~ Calcite Concretion + Functional LWD Tally + Spawning Gravel + Temperature	1.54	0.06
Redd Presence ~ Bankfull Depth + Calcite Concretion + Temperature	1.72	0.05
Redd Presence ~ Calcite Concretion + Mesohabitat Area + Temperature	1.98	0.05

3.4. Redd Count

3.4.1. Mean number of redds

Based on data collected and analysis performed herein, the most important variables to explain variability in the mean number of redds were calcite concretion (RVI = 1) and functional LWD tally (RVI = 0.79), and to a lesser extent spawning gravel area (RVI = 0.67) (Figure 20). Model selection statistics for models within ΔAICc <4 are detailed in Table 8. The effect of calcite concretion on the mean number of redds was negative (i.e., calcite decreases the mean number of redds), whereas the rest of the variables had a positive effect on the mean number of redds. Calcite concretion had the largest effect on the mean number of redds (Figure 20).

Variability in the mean number of redds in the streams was reasonably well explained by the averaged model as an exponentially decreasing function with mean number of redds of ~0.3 redds at a calcite concretion score of 0 and quickly dropping to close to zero by 0.5 calcite concretion (Figure 21).

Similar to redd presence, calcite concretion outcompeted CI in explaining mean number of redds, which resulted in CI not being present in any of the top models (Table 8). If calcite concretion is excluded from model selection, then the relative variable importance of CI is high (RVI = 1). However, the effect of CI on the mean number of redds was not statistically significant in any of the top models. All results for CI when calcite concretion is excluded from consideration are shown in Appendix F.

Figure 20. **Model averaged coefficients (with 95% confidence intervals) indicating the most important variables predicting Westslope Cutthroat Trout redd counts in tributaries of the Elk River, B.C. Values in the x-axis are estimates of model parameters. RVI = Relative Variable Importance scores, where a score of 1 indicates that a predictor variable occurs in all top models with ΔAICc < 4.**

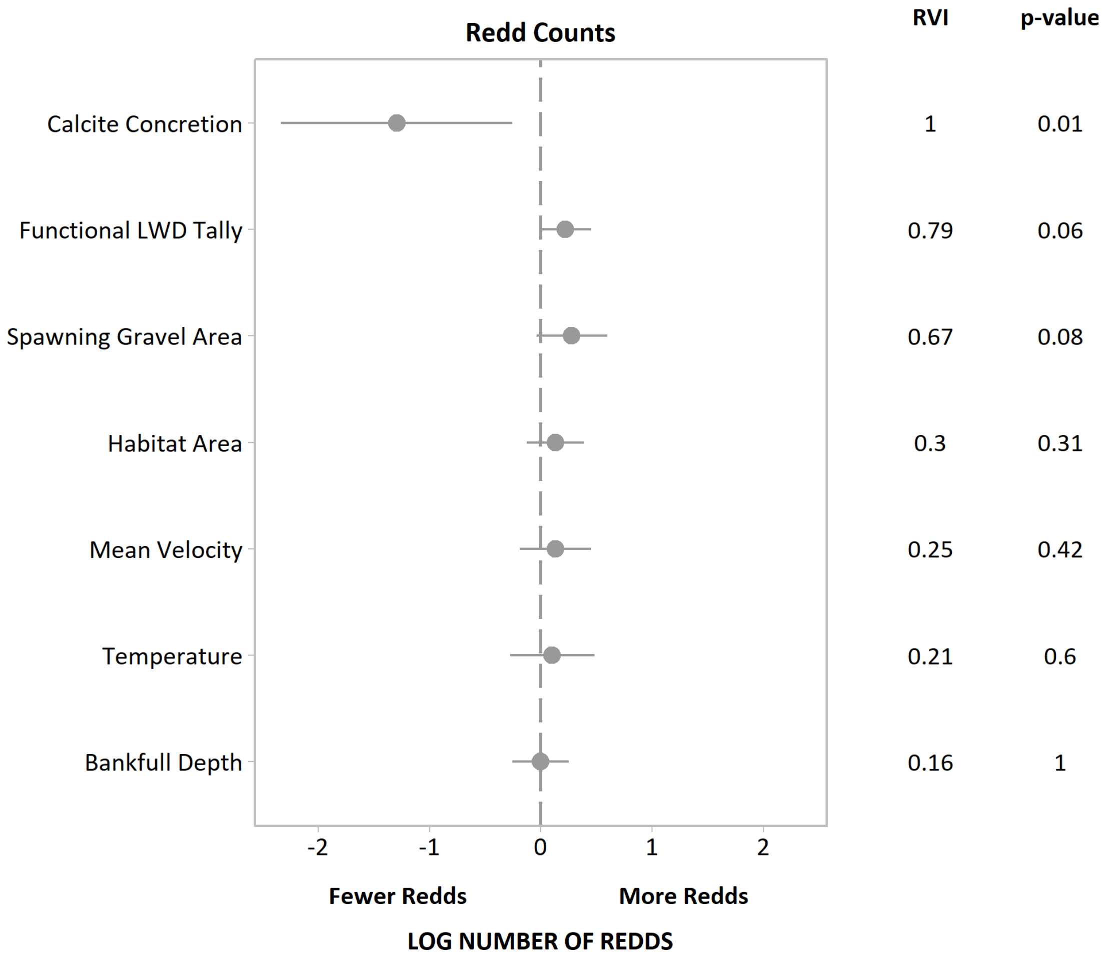


Figure 21. Westslope Cutthroat Trout redd counts as a function of calcite concretion and the mean regression fit to the data, with all other predictors held at their means. The shaded region represents the 95% confidence interval of predicted mean redd count.

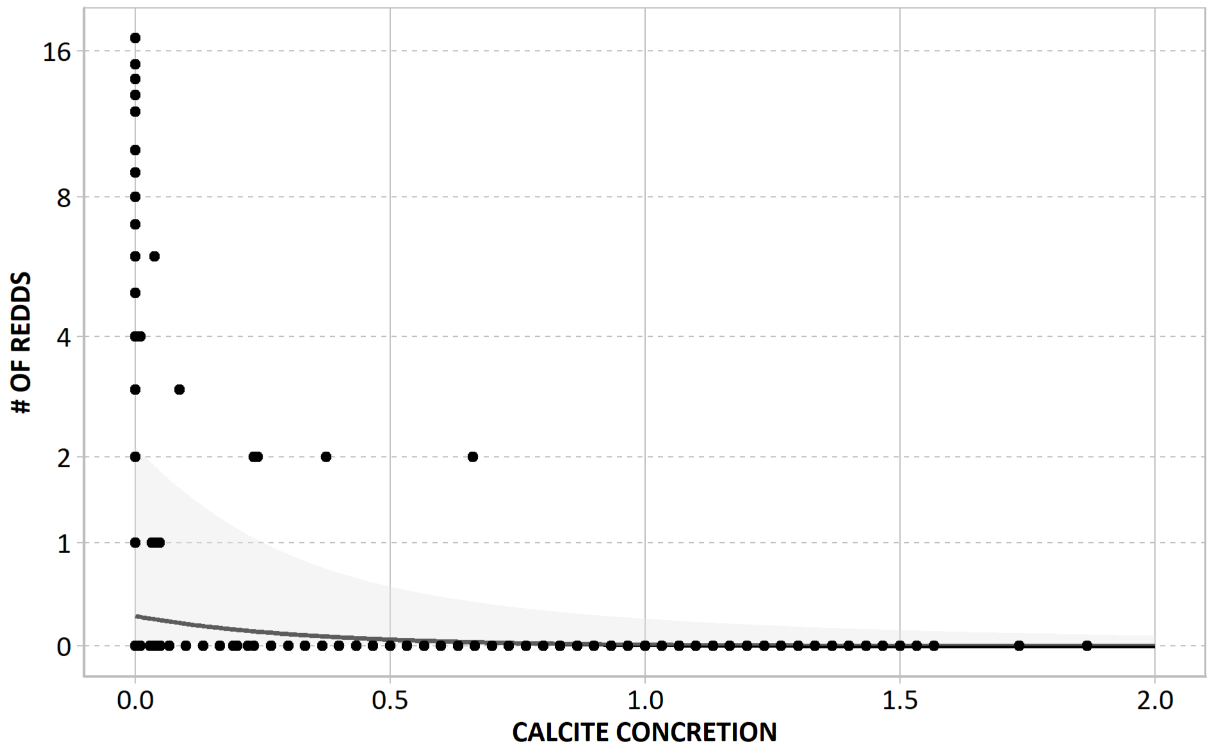


Table 8. Top models that best predict Westslope Cutthroat Trout mean redd counts in tributaries of the Elk River, B.C. Models are ranked by Δ Akaike Information Criterion (ΔAICc) scores. The model with the lowest ΔAICc is the best model. Model weights (range 0-1) are also shown, which provide an estimate of the likelihood that a given model is the best model compared to the other top models in the model set.

Model	ΔAICc	Weight
Redd Count ~ Calcite Concretion + Functional LWD Tally + Spawning Gravel	0.00	0.12
Redd Count ~ Calcite Concretion + Functional LWD Tally	0.89	0.08
Redd Count ~ Calcite Concretion + Mesohabitat Area + Functional LWD Tally + Spawning Gravel	1.01	0.07
Redd Count ~ Calcite Concretion + Functional LWD Tally + Mean Velocity + Spawning Gravel	1.34	0.06
Redd Count ~ Calcite Concretion + Spawning Gravel	1.75	0.05
Redd Count ~ Calcite Concretion + Functional LWD Tally + Spawning Gravel + Temperature	1.83	0.05

3.4.2. 90th quantile of Redd Counts

Based on data collected and analysis performed herein, the most relevant variables to explain variability in the 90th quantile of redd counts were calcite concretion and temperature (Figure 22). Additional habitat variables included in the top models of the 90th quantile of redd counts were functional LWD tally and bankfull depth (Table 9). The effect of calcite concretion on the 90th quantile of redds was negative (i.e. calcite decreases the mean number of redds), whereas the rest of the variables had a positive effect on the 90th quantile of redds. Calcite concretion had a large effect on the 90th quantile of redd counts (Figure 22).

Variability in the 90th quantile of redd counts in the streams was reasonably well explained by the averaged model as an exponentially decreasing function with 90th quantile of redds close to 1.5 redds at a calcite concretion score of 0 and quickly dropping to approximately zero by calcite concretion score of 1 (Figure 23).

Similar to redd presence, calcite concretion outcompeted CI in explaining the 90th quantile of redd counts, which resulted in CI not being present in any of the top models (Table 9). If calcite concretion is excluded from model selection, then the relative variable importance of CI is high (RVI = 1), and its effect on the 90th quantile of redd counts is consistently negative across all top models. All results for CI when calcite concretion is excluded from consideration are shown in Appendix F.

Figure 22. Model averaged coefficients (with 95% confidence intervals) indicating the most important variables describing redd count, modelled using quantile regression models. Values in the x-axis are estimates of model parameters

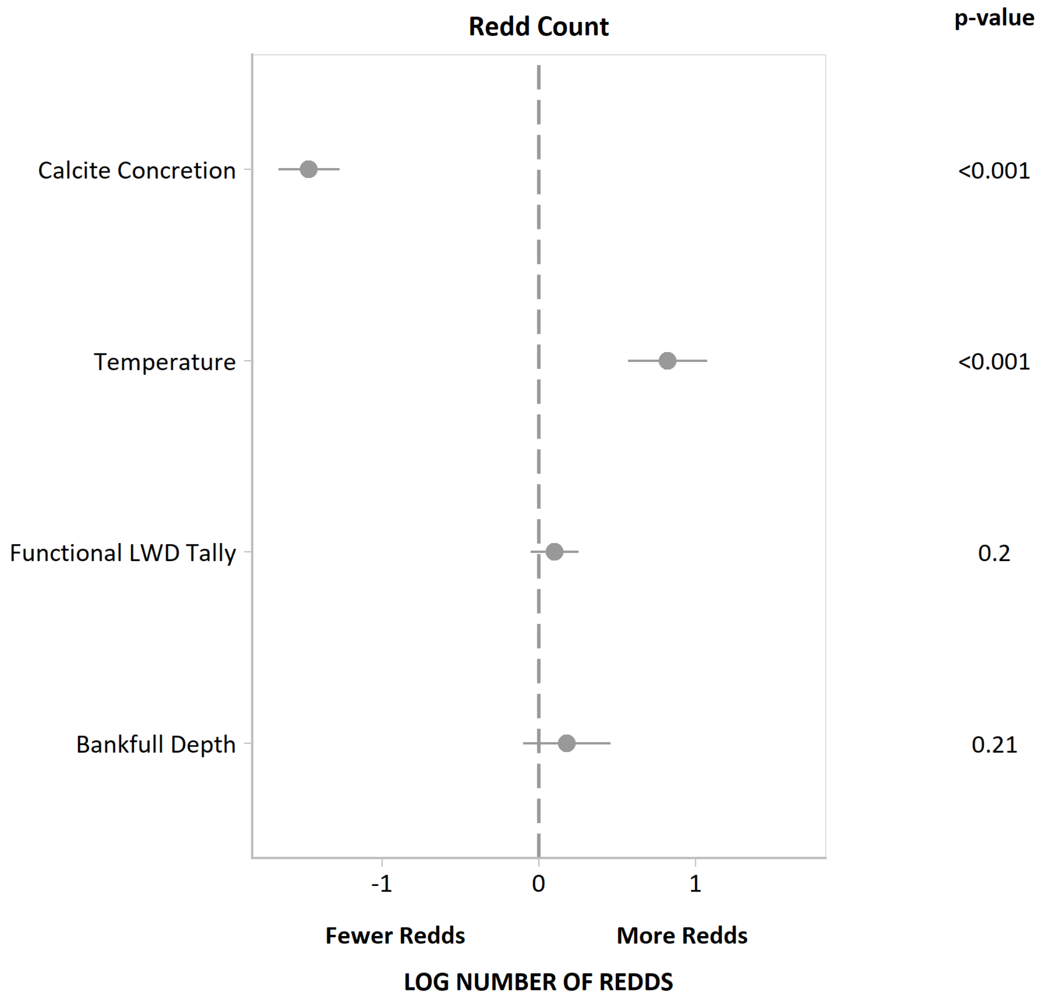


Figure 23. Westslope Cutthroat Trout redd count as a function of calcite concretion and the 90th quantile regression fit to the data, with all other predictors held at their means. The shaded region represents the 95% confidence interval of predicted 90th percentile redd count.

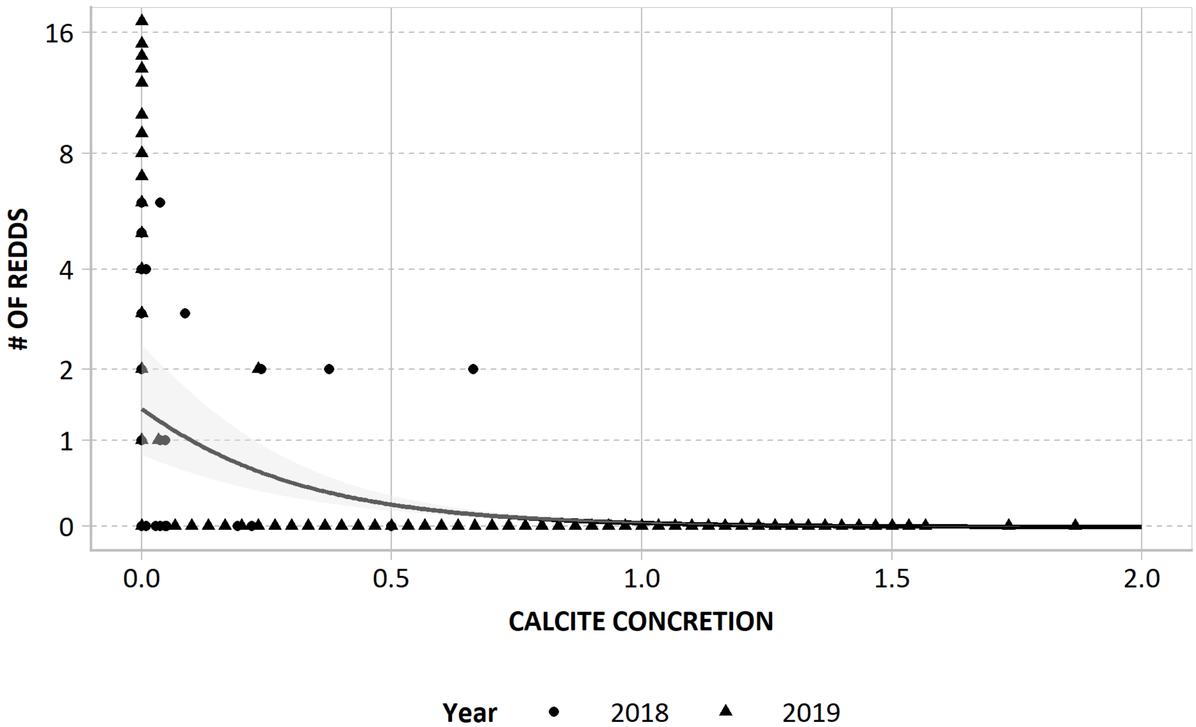


Table 9. Top model that best predicts Westslope Cutthroat Trout redd counts in tributaries of the Elk River, B.C., modelled using quantile regression. The model with the lowest ΔAICc is the best model. Model weights (range 0-1) are also shown, which provide an estimate of the likelihood that a given model is the best model compared to the other top models in the model set.

Model	ΔAICc	Weight
Redd Count (90th quantile) ~ Calcite Concretion + Bankfull Depth + Temperature + Functional LWD Tally	0.00	0.13
Redd Count (90th quantile) ~ Calcite Concretion + Bankfull Depth + Mean Velocity + Temperature + Functional LWD Tally	0.14	0.12
Redd Count (90th quantile) ~ Calcite Concretion + Bankfull Depth + Temperature + Spawning Gravel + Functional LWD Tally	0.98	0.08
Redd Count (90th quantile) ~ Calcite Concretion + Mesohabitat Area + Bankfull Depth + Temperature + Functional LWD Tally	1.21	0.07
Redd Count (90th quantile) ~ Calcite Concretion + Bankfull Depth + Mean Velocity + Temperature	1.23	0.07
Redd Count (90th quantile) ~ Calcite Concretion + Bankfull Depth + Temperature	1.29	0.07
Redd Count (90th quantile) ~ Calcite Concretion + Bankfull Depth + Mean Velocity + Temperature + Spawning Gravel + Functional LWD Tally	1.55	0.06
Redd Count (90th quantile) ~ Calcite Concretion + Mesohabitat Area + Bankfull Depth + Mean Velocity + Temperature + Functional LWD Tally	1.87	0.05

3.5. Draft Spawning Suitability Curves with Calcite Concretion

Based on data collected and analysis performed herein, calcite concretion is inferred to have a significant negative effect on the Westslope Cutthroat Trout redd presence and abundance in tributary streams of the Elk River, including three metrics analyzed in this study of likelihood of redd presence, mean count of redds, and 90th quantile of count of redds. The percentage decrease in predicted likelihood of redd presence and redd counts from a calcite concretion score of zero to calcite concretion levels of 0.25, 0.5, 0.75, 1, 1.5 and 2 is presented below (Table 10). In consideration of the uncertainty and resulting variability in the model, the below-listed projections should not be interpreted as definitive.

The predicted likelihood of redd presence decreased exponentially with increasing calcite concretion, reaching 20% (i.e., decreasing by 80%) of its predicted value when calcite concretion increases from 0 to 0.25, and reaching close to 0% by a calcite concretion of 0.5.

The predicted mean number of redds decreased exponentially with increasing calcite concretion, reaching approximately 50% (i.e., decreasing by 50%) of its predicted value when calcite concretion increases from 0 to 0.25, and reaching close to 0% by a calcite concretion of 1.5.

The predicted 90th quantile of redd counts decreased exponentially with increasing calcite concretion, reaching approximately 50% (i.e., decreasing by 50%) of its predicted value when calcite concretion increases from 0 to 0.25, and reaching close to 0% by a calcite concretion of 0.75.

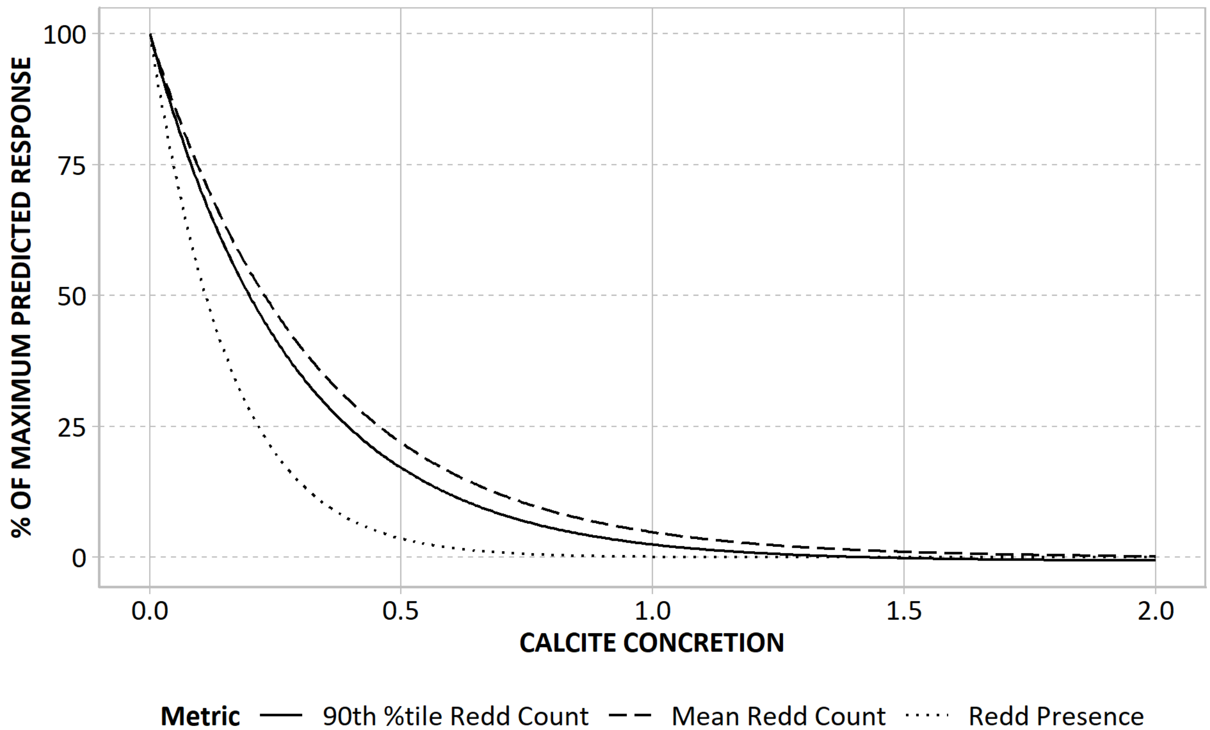
The predicted declines in redd presence and counts with calcite concretion can be visualized as draft spawning suitability curves for WCT with increases in calcite concretion (Figure 24).

Table 10. Predicted summary of effects of calcite concretion on likelihood of redd presence, and number of redds (mean and 90th quantile) per mesohabitat unit from 17 tributary streams of the Elk River, B.C. These projections should not be interpreted as definitive due to variability in the model.

Calcite Concretion (CI_{Conc})	Predicted Probability of Redd Presence	% of Probability at $CI_{Conc} = 0$	Predicted Mean Redd Count	% of Mean Redd Count at $CI_{Conc} = 0$	Predicted 90th %tile Redd Count	% of 90th %tile Redd Count at $CI_{Conc} = 0$
0	0.139	100	0.28	100.0	1.42	100.0
0.25	0.028	19.9	0.13	46.8	0.59	41.7
0.5	0.005	3.6	0.06	21.9	0.24	17.1
0.75	0.001	0.6	0.03	10.3	0.10	6.8
1	0.000	0.1	0.01	4.8	0.03	2.4
1.5	0.000	0.0	0.00	1.1	0.00	0.0
2	0.000	0.0	0.00	0.2	0.00	0.0

[1]Predicted probabilities and redd counts assume all other predictors are held at their mean values.

Figure 24. **Draft Westslope Cutthroat Trout spawning suitability curves for calcite concretion based on data collected in 2018 and 2019 from 17 tributary streams of the Elk River, B.C. Curves are model averaged predictions of the effects of calcite concretion on redd presence and redd counts (mean and 90th quantile). The y-axis should be interpreted as the percentage of predicted likelihood of redd presence and redd counts, where the responses are at their theoretical maximum (100%) at a calcite concretion score of zero**



4. DISCUSSION

4.1. Testing the Research Hypothesis H2

Data collected in 2018 and 2019 came from redd surveys, calcite surveys, fish habitat assessments and assessment of water quality and velocity from 858 mesohabitat units in 17 tributary streams of the Elk River watershed. These data were used to test research hypothesis H2:

$H_0$2 (null): Observed calcite conditions on stream substrates have no effect on suitability of fish spawning habitat.

H_A2 (alternate): Observed calcite conditions on stream substrates have an effect on suitability of fish spawning habitat.

The basic premise of the study is that calcite accumulation on a streambed may influence the suitability of spawning substrate and thereby the carrying capacity of fish habitat. Tributary streams included in the study were observed to support Westslope Cutthroat Trout spawning in previous years (Russell and Oliver 1996; Windward Environmental *et al.* 2014; Cope *et al.* 2016; Minnow Environmental 2016a,b; Faulkner *et al.* 2018; Lamson 2018; Hocking *et al.* 2019; Robinson, pers. comm. 2019).

The study design in 2019 built on the outcomes of previous studies in the Elk Valley, including a preliminary study on the effects of calcite to spawning habitat suitability carried out in 2018 (Hocking *et al.* 2019), as well as studies implemented in 2016 and 2017 that measured hyporheic flow and dissolved oxygen at a number of sites over a range of calcite (Wright *et al.* 2017; 2018). The studies in 2016 and 2017 observed that stream sites with high levels of calcite may experience some reduction in hyporheic DO, although effects are predicted to be greatest at depths greater than typical WCT spawning depths and at CI scores higher than may be useable for spawning. For example, the greatest effects on incubation conditions were predicted at sites with CI scores higher than ~1.25, high % fines, and at depths deeper than typical redd depths (Wright *et al.* 2018). Therefore, a key outcome from the studies in 2016 and 2017 was that research hypothesis H1 related to incubation conditions may be less important than research hypothesis H2 related to spawning substrate suitability for salmonids (Figure 1).

A preliminary test of H2 was carried out in 2018 (Hocking *et al.* 2019) using data from five streams in the upper Fording River watershed; data from these streams did not span the full range of calcite conditions possible (i.e., the maximum CI recorded was CI = 1.66). Hocking *et al.* (2019) did not find a strong relationship between mean presence or density of redds and CI, but found a negative relationship between the 90th quantile of redd density and CI, and suggesting that high densities of redds are found in streams with lower CI. Hocking *et al.* (2019) did not find a clear relationship between the likelihood of redd presence and CI.

The sampling design was expanded and adjusted in 2019 to include ~1 km reaches in 17 streams across a wider range of CI. All mesohabitat units were sampled within each stream reach enabling greater inference on the relationship between calcite and the likelihood of redd presence and redd abundance within and among streams. The expansion of the program in 2019 was successful in increasing the range of CI observed (maximum CI = 2.87), and eliminating bias in null site selection as all mesohabitat units without redds were sampled in the study reach of each stream.

The effects of calcite on fish spawning was assessed by testing for the likelihood of redd presence per mesohabitat unit, and on the count of redds per mesohabitat unit, by stream. Redd counts were used in 2019 as a response variable instead of redd density, which was used in 2018. Redd counts and redd density both are indices for abundance and both approaches account for the area of the mesohabitat unit sampled. To provide a characterization of the effects of calcite on the number of redds in a stream, calcite effects on redd counts was assessed at two different levels; the effect on the mean number of redds and the effect on the 90th quantile of redd count (i.e., how does calcite affect the probability of having high counts of redds). This approach is consistent with that used in 2018.

Based on data collected and analysis performed herein, calcite concretion was interpreted to be the most important variable to describe variance in redd presence, mean redd count, and the 90th quantile of redd counts (the latter two are measures of redd abundance). For all three models, calcite concretion outcompeted CI in explaining redd presence and redd abundance. One of the main explanations for this result was that redds were observed across a wider range of CI (CI_{Total} up to 1.66) than calcite concretion (CI_{Conc} up to 0.66). For example, moderate to high calcite presence (mean presence >0.5) was observed in six streams where zero calcite concretion was recorded, including the mine-influenced streams Harmer Creek, Michel Creek, Thompson Creek, and LCO Dry Creek (in 2019) and the reference streams Lizard Creek and McCool Creek. Redds for WCT were observed in all of these six streams, whereas no redds were observed in Corbin Creek, EVO Dry Creek and Erickson Creek in 2019, which had the highest levels of calcite concretion. Overall, redds were observed only in habitats with low concretion; no redds were observed at moderate to high concretion or high CI.

In all cases, the influence of calcite concretion on the response variables was negative, and the three model-predicted spawning habitat suitability curves for WCT decreased exponentially with increasing levels of calcite concretion. Redd counts in a stream also decreased exponentially with increasing calcite concretion, although at a slower rate than redd presence.

Overall, the results suggest that the null hypothesis $H_0 2$ should be rejected in favour of the alternate hypothesis $H_A 2$. The weight of evidence was high for calcite concretion as a predictor variable (RVI = 1) because it occurred in all of the top models for each response variable. The average effect size of calcite concretion was also greater than the other stream habitat variables considered. However, it is important to note that the confidence interval surrounding the predicted effect size is high, which leads to uncertainty in the mean predicted slope of the draft spawning suitability curves shown in Figure 24. Based on data collected and analysis performed the slope between redd presence and redd abundance and calcite concretion was found to be negative. However, the confidence intervals of the slopes of the three curves shown in Figure 24 overlap based on the uncertainty estimated from the models. Further discussion of uncertainties and potential next steps is developed below in Section 4.2.

Calcite is one of many influences on fish and fish habitat, and these other influences (e.g., substrate, cover, water depth, velocity, water quality, etc.) need to be considered as potential covariates when developing the spawning suitability versus calcite curve. Therefore, a number of habitat variables were included in the modelling to account for variable habitat conditions and to build a comprehensive model. After a detailed data exploration procedure (following Zuur *et al*. 2010) the final set of explanatory variables included in model selection were CI, calcite concretion, mean velocity, spawning gravel area, bankfull depth, functional LWD tally, and water temperature (Table 6). All of these habitat variables were hypothesized to affect spawning suitability.

Some habitat variables were found to positively influence WCT spawning. Water temperature positively influenced the likelihood of redd presence and the 90th quantile of redd counts. The mechanism is not clear, but cold water temperatures may limit distribution of spawning and rearing WCT in the highest elevation tributaries. For example, one of the coldest streams, Henretta Creek, had only one redd observed across both years of sampling, while one of the warmest streams, Lizard Creek, had the highest observed redd counts. Mean number of redds in a stream was positively influenced by tally of functional large woody debris and spawning gravel area. Increased cover of woody debris is hypothesized to increase structural complexity of stream habitats and provide cover for spawning WCT during the day. Increases in spawning gravel area also intuitively reflects that as the area available for spawning increases so does the number of redds (e.g., Magee *et al.* 1996).

4.2. Uncertainties and potential next steps

This study across a range of calcite conditions in 17 tributaries of the Elk and Fording River watersheds suggests that calcite concretion limits spawning habitat suitability for WCT. The predicted decreases in redd presence and counts with calcite concretion can be visualized as draft spawning habitat suitability curves (Figure 24). Calcite concretion has is inferred to have negative effects on redd presence and the number of redds in a stream. Other habitat variables measured in this study also influence spawning habitat suitability, but were less important than calcite. It is acknowledged that the there are other potentially important fish habitat variables that were not measured in this study. There remains uncertainty with respect to the slopes of the response curves as reflected by the broad confidence intervals.

An important finding in this study was that WCT spawn in mine-affected and reference streams with moderate to high calcite presence, but no calcite concretion. For example, in 2019 sampling at reference streams (Lizard and McCool Creeks) was conducted that support WCT spawning, to allow comparison of the natural range in redd presence and redd densities to streams influenced by mining. We found high calcite presence (up to 1), with zero calcite concretion in all cases. For these streams, when calcite was present on a rock, coverage was variable; occasionally, small patches (<1 cm^2) were observed that did not completely cover the rock. Particularly in Lizard Creek, higher calcite presence was observed further upstream in the reach sampled. This observation helps explain why models that incorporated calcite concretion performed better than models that included CI as explanatory variable.

Another important finding and resulting uncertainty was that overall redd counts were lower in 2019 compared to 2018 on streams in the upper Fording River watershed. For example, more redds were observed in 2018 versus 2019 in Fish Pond Creek (38 versus 9), Clode Creek (6 versus 0) and Lower Greenhills Creek (10 versus 1). This observed reduction in redds is consistent with reflects observed declines in the total numbers of WCT fry, juveniles and spawners from surveys in the Upper Fording River watershed in 2019 (Cope 2019). It is unclear if a lower spawner abundance influences the predicted spawning suitability relationships; it is possible that the suitability curves would be less steep when fish abundance is greater since fish may be less choosy if habitats are saturated. Additional sampling during a year of higher WCT spawning productivity would aid in understanding this uncertainty.

Another uncertainty is the extent to which spawning habitat suitability with calcite elicits a WCT population response. This study has not assessed how decreased likelihood of presence and abundance of redds may translate into total fish production in the system. If spawning is not the limiting life stage for WCT then the relationship between stream calcite and population abundance is likely to be less steep than spawning suitability, or perhaps follow a different form. Potential spawners may simply go elsewhere to spawn, or the loss of some spawning events may not lead to lower recruitment (and thereby lower total abundance) if another factor is more limiting. Ongoing work to develop a WCT population model may help to explore the population effect of spawning suitability and other limiting factors at the population level.

This study presents data on spawning suitability relationships for WCT in relation to calcite; the models are an improvement on the initial models developed in 2018 (Hocking *et al*. 2019). Nevertheless, additional sampling may be required to resolve the uncertainties discussed here. The highest priority for future sampling would be on streams and mesohabitats with moderate CI and low to moderate levels of calcite concretion, especially calcite concretion scores between 0 and 1. Additional analyses could also be completed to account for calcite-specific effects to spawning suitability versus more broad mine-influences.

5. CONCLUSION

A redd presence-absence model and two different redd count models were developed to test if calcite conditions influence spawning habitat suitability for Westslope Cutthroat Trout in tributaries streams of the Elk River, B.C. The study in 2019 builds upon similar data collected in 2018 from five streams in the upper Fording River watershed and was effective at capturing a broader range of calcite conditions (CI range = 0 to 2.87) compared to the 2018 study (CI range = 0 to 1.66). The total number of redds observed in 2019 was 311, compared to 77 in 2018. However, redd counts in individual streams were lower in 2019 compared to 2018; for example, at Fish Pond Creek, Lower Greenhills Creek and Clode Creek.

Overall, based on the streams sampled in both years, redd presence and counts are negatively influenced by calcite concretion; few redds were observed in Erickson Creek, EVO Dry Creek, Corbin Creek, Upper Greenhills Creek, Lower Greenhills Creek and Clode Creek where concretion was observed. In contrast, moderate to high redd counts were observed in both mine-affected and reference streams with moderate to high calcite presence ($CI_{Pres} > 0.5$) but no concretion. In all models, calcite concretion outcompeted CI in explaining redd presence or counts, which suggests that concretion may be a better measure of spawning suitability than CI.

While the results presented here are more clear than those presented in 2018 (Hocking *et al.* 2019), there remains uncertainty in the spawning suitability curves based on the broad confidence intervals. Additional field work and analysis would be required to reduce uncertainties in the results presented and to improve the predictive ability of the spawning suitability response curves, particularly at low to moderate levels of concretion. At this time, the 2020 work is advancing, which will incorporate recommendations from this 2019 study.

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APPENDICES

Appendix A. Summary of 2019 Calcite Study Sampling by Date and Waypoints of Study Streams

LIST OF TABLES

Table 1. Start and end waypoints for calcite study streams in the Elk Valley.

Project	Stream Name	Study Reach Length (m)	Downstream UTM Coordinates			Upstream UTM Coordinates		
			Zone	Easting	Northing	Zone	Easting	Northing
CMO	Corbin Creek	593	11U	668205	5487121	11U	668609	5487433
	Michel Creek	1104	11U	667947	5487337	11U	668120	5486774
EVO	Erickson Creek	765	11U	659858	5505141	11U	660377	5505429
	EVO Dry Creek	1002	11U	659451	5517591	11U	659231	5517185
	Grave Creek	1490	11U	657320	5522629	11U	658128	5523407
	Harmer Creek	1451	11U	656529	5522137	11U	657686	5521641
FRO	Clode Creek	172	11U	650807	5564239	11U	650864	5564280
	Fish Pond Creek	1015	11U	650824	5564656	11U	651123	5564972
	Henretta Creek[1]	825	11U	652182	5566460	11U	652964	5566523
GHO	Lower Greenhills Creek	841	11U	653303	5545452	11U	653570	5545874
	Thompson Creek	1097	11U	648330	5550231	11U	648945	5550413
	Upper Greenhills Creek	937	11U	653707	5546112	11U	653980	5546843
LCO	LCO Dry Creek[1]	1113	11U	655858	5544779	11U	656445	5544724
SRO	Alexander Creek	1059	11U	664753	5518573	11U	664747	5519480
	Grace Creek	814	11U	653718	5538633	11U	653424	5538959
	Lizard Creek	891	11U	638042	5483169	11U	637572	5483342
	McCool Creek	837	11U	648204	5499803	11U	648213	5500574

[1]Study reach lengths and waypoints reflect 2019 surveys. 2018 data is included in analysis and in Appendix C.

Table 2. Sampling dates for habitat, water quality, gravel, calcite, and spawning surveys performed on calcite study streams in the Elk Valley.

Project	Waterbody	Sampling Type and Date[1]				
		FHAP	Redd Surveys[2, 3]	WQ and Velocity	Gravel	Calcite
CMO	Corbin Creek	11-May 12-May	1-Jun 19-Jun	19-Jun 20-Aug	20-Aug	20-Aug
	Michel Creek	20-Jun	20-Jun 12-Jul	20-Jun 12-Jul 19-Aug	19-Aug	19-Aug
EVO	EVO Dry Creek	25-Jun 12-Jul	27-30-May 10-13-Jun 24-28-Jun 2-5-Jul 9-12-Jul	24-Jun 25-Jun 12-Jul 19-Aug	19-Aug	19-Aug 21-Aug
	Erickson Creek	25-Jun 11-Jul	25-Jun 11-Jul	26-Jun 11-Jul 21-Aug	21-Aug	21-Aug
	Grave Creek	27-Jun 11-Jul 16-Oct	27-30-May 10-13-Jun 24-28-Jun 2-5-Jul 9-12-Jul	27-Jun 11-Jul 18-Aug 22-Aug 16-Oct	22-Aug 16-Oct	16-Aug 22-Aug
	Harmer Creek	24-Jun 28-Jun 17-Oct 18-Oct	27-30-May 10-13-Jun 24-28-Jun 2-5-Jul 9-12-Jul	24-Jun 28-Jun 20-Aug 17-Oct 18-Oct	20-Aug 17-Oct 18-Oct	20-Aug 17-Oct 18-Oct
FRO	Clode Creek	28-Jun-2018	8-Jul 15-Jul	26-Jun 15-Jul 13-Aug	13-Aug	13-Aug
	Fish Pond Creek	28-Jun-2018	27-Jun 8-Jul 16-Jul	26-Jun 27-Jun 16-Jul 14-Aug	14-Aug	14-Aug 15-Aug
	Henretta Creek	29-Jun-2018 18-Jun	18-Jun 15-Jul	18-Jun 15-Jul 14-Aug	13-Aug	13-Aug 15-Aug
GHO	Lower Greenhills Creek	26-Aug-2017 26-Jun	16-Jul	26-Jun 16-Jul 14-Aug	13-Aug	13-Aug
	Upper Greenhills Creek[3]	15-Jul 16-Jul	26-Jun 15-Jul 16-Jul	15-Jul 16-Jul 14-Aug	14-Aug	14-Aug
	Thompson Creek	13-May 14-May	30-May 5-Jul	30-May 17-Aug	15-Aug	15-Aug
LCO	LCO Dry Creek	8-Jun-2016	6-Jul 17-Jul	17-Jul 16-Aug	16-Aug	16-Aug 21-Aug
SRO	Alexander Creek	13-Jul 14-Jul	7-Jul 13-Jul 14-Jul	13-Jul 14-Jul 22-Aug	18-Aug 20-Aug 22-Aug	18-Aug 20-Aug
	Grace Creek	13-Jul	7-Jul 16-Jul	13-Jul 16-Jul 16-Aug	16-Aug	16-Aug
	Lizard Creek	18-Jun	31-May 18-Jun	18-Jun 18-Aug	18-Aug	18-Aug
	McCool Creek	20-Jun	20-Jun 5-Jul	20-Jun 17-Aug	17-Aug	17-Aug

[1]All dates are 2019 unless otherwise indicated

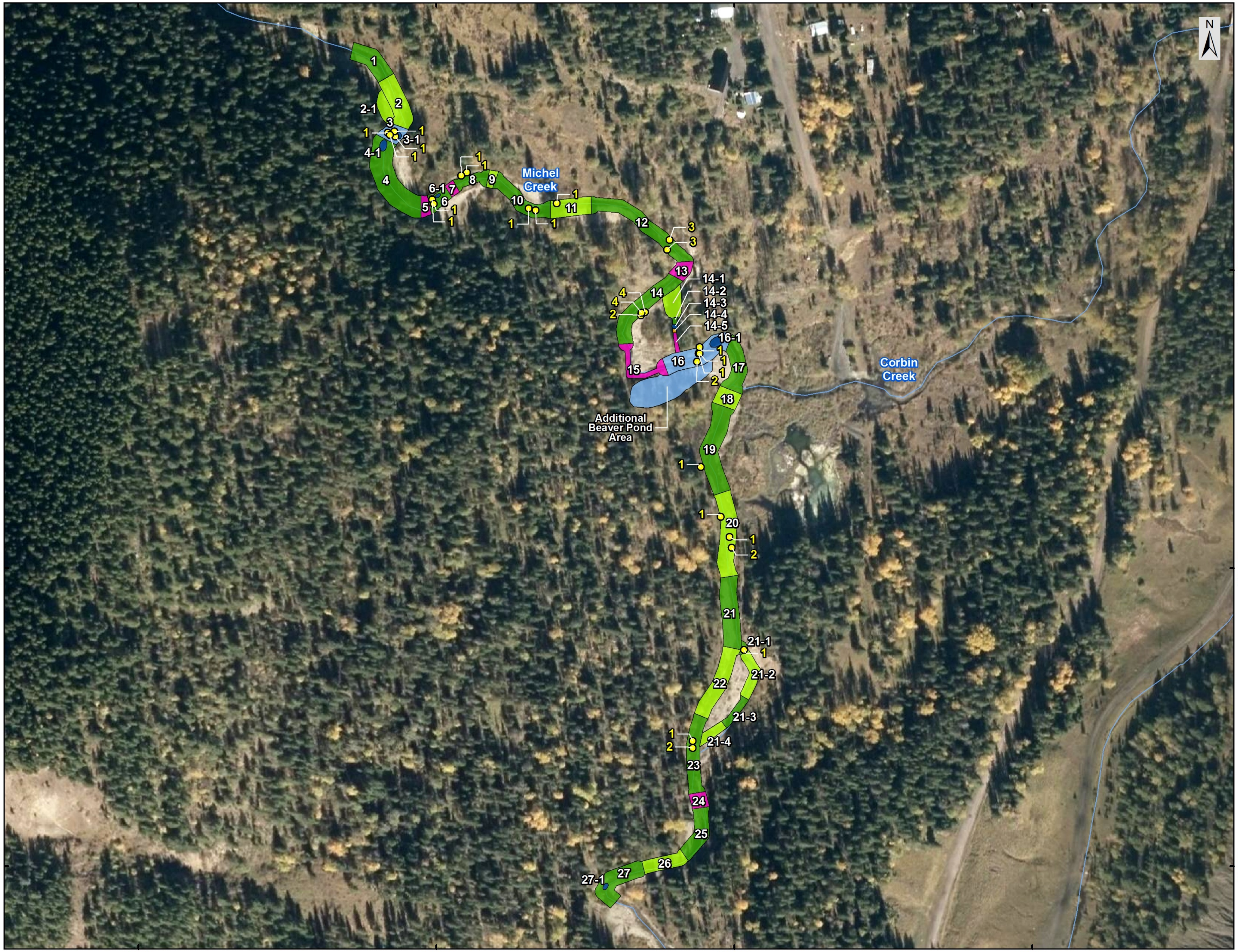
[2]Redd surveys on Grave, Harmer, and EVO Dry creeks completed by Scott Cope

[3]Turbid conditions and poor visibility due to rain event prevented identification of redds on survey July 5th, 2019

Appendix B. Summary Maps of FHAP, Redd and Calcite Surveys Completed in Tributaries of the Fording and Elk Rivers, 2019

LIST OF MAPS

Path: M:\Projects-Active\1229_EVWQP\MXD\Fisheries\1229_CBN_FHAP_3486_20191122.mxd



TECK COAL LTD.

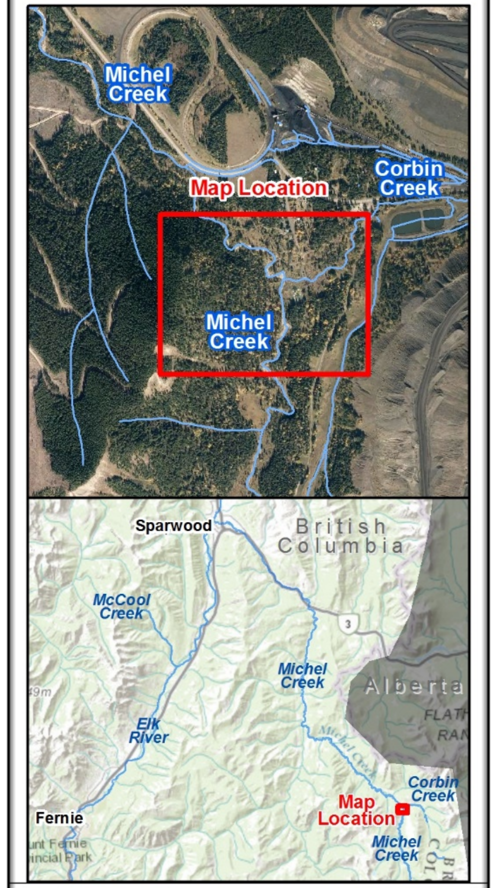
Michel Creek FHAP and Redd Survey

Legend

- Number of Redds Observed (2019)

FHAP Habitat Type

- Cascade
- Chute
- Glide
- Pool
- Riffle
- Run



MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 25 50 100 m

Scale: 1:2,500

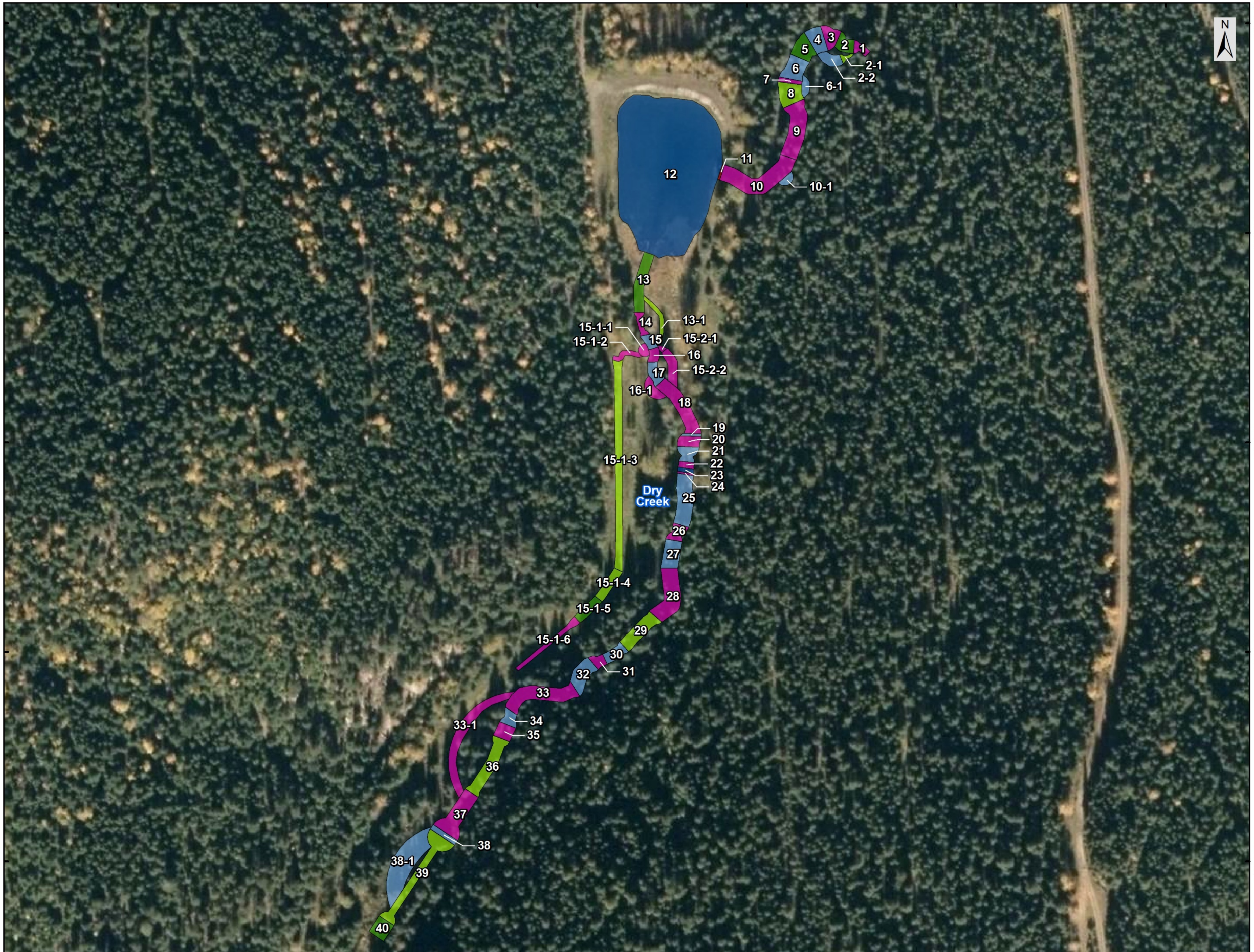
NO.	DATE	REVISION	BY
1	18/11/2019	1229_MIC_FHAPRedds_3486_20191118	CGA
2			
3			
4			
5			

Date Saved: 18/11/2019
Coordinate System: NAD 1983 UTM Zone 11N

ECOFISH RESEARCH

Map 2

Path: M:\Projects-Active\1229_EVWQP\MXD\Fisheries\1229_MIC_FHAPRedds_3486_20191118.mxd



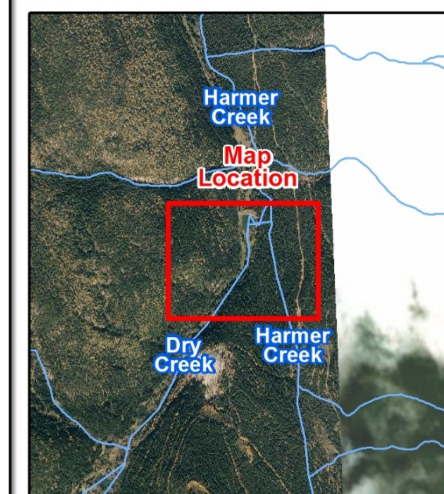
TECK COAL LTD.

EVO Dry Creek FHAP

Legend

FHAP Habitat Type

- Cascade
- Falls
- Glide
- Pool
- Riffle
- Run



MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 10 20 40 60 80 100 m

Scale: 1:1,800

NO.	DATE	REVISION	BY
1	19/08/2019	1229_DRY_FHAP_3336_20190722	CGA
2			
3			
4			
5			

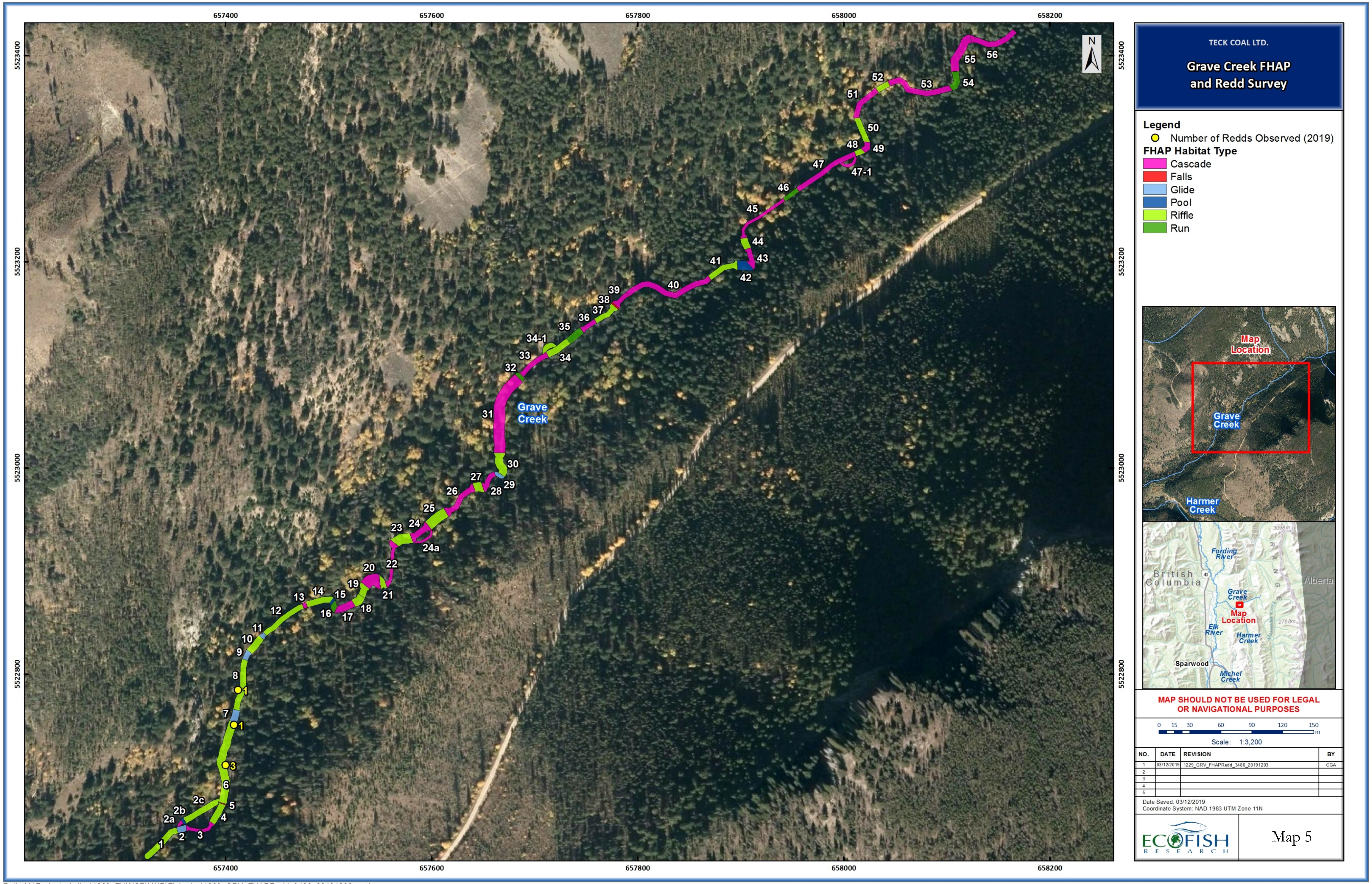
Date Saved: 19/08/2019
Coordinate System: NAD 1983 UTM Zone 11N

ECOFISH RESEARCH

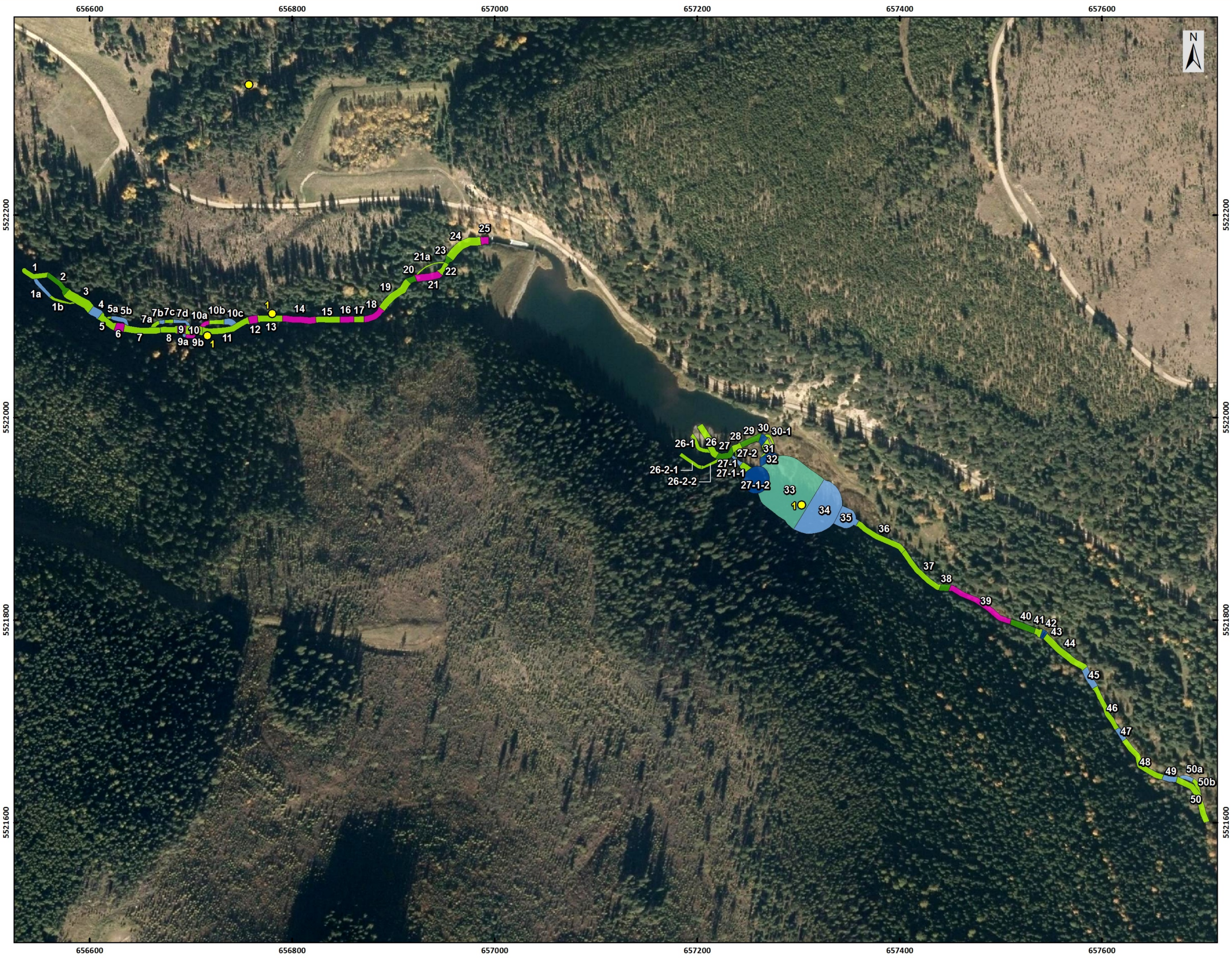
Map 3

Path: M:\Projects-Active\1229_EVWQP\MXD\Fisheries\1229_DRY_FHAP_3336_20190722.mxd

Path: M:\Projects-Active\1229_EVWQP\MXD\Fisheries\1229_ERK_FHAP_3335_20190719.mxd



Path: M:\Projects-Active\1229_EVWQP\MXD\Fisheries\1229_GRV_FHAPRedd_3486_20191203.mxd



TECK COAL LTD.

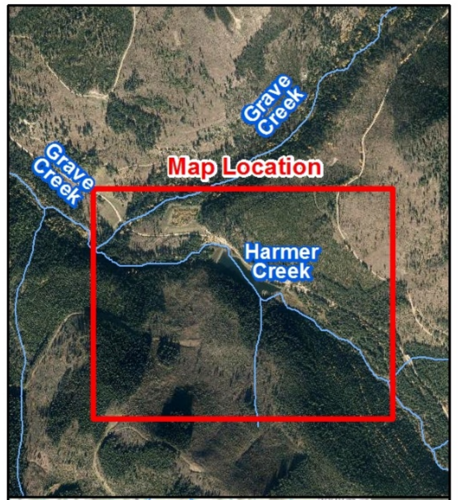
Harmer Creek FHAP and Redd Survey

Legend

Number of Redds Observed (2019)

FHAP Habitat Type

- Cascade
- Glide
- Pool
- Riffle
- Run
- Wetland



MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 25 50 100 150 200 m

Scale: 1:3,600

NO.	DATE	REVISION	BY
1	03/12/2019	1229_HMR_FHAP_3328_20190717	CGA
2			
3			
4			
5			

Date Saved: 03/12/2019
Coordinate System: NAD 1983 UTM Zone 11N

ECOFISH RESEARCH

Map 6

Path: M:\Projects-Active\1229_EVWQP\MXD\Fisheries\1229_HMR_FHAP_3328_20190717.mxd

TECK COAL LTD.

Clode Creek FHAP and Redd Survey

Legend

Number of Redds Observed (2018)

FHAP Type

- Glide
- Pool
- Riffle
- Run

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 10 20 m

Scale: 1:400

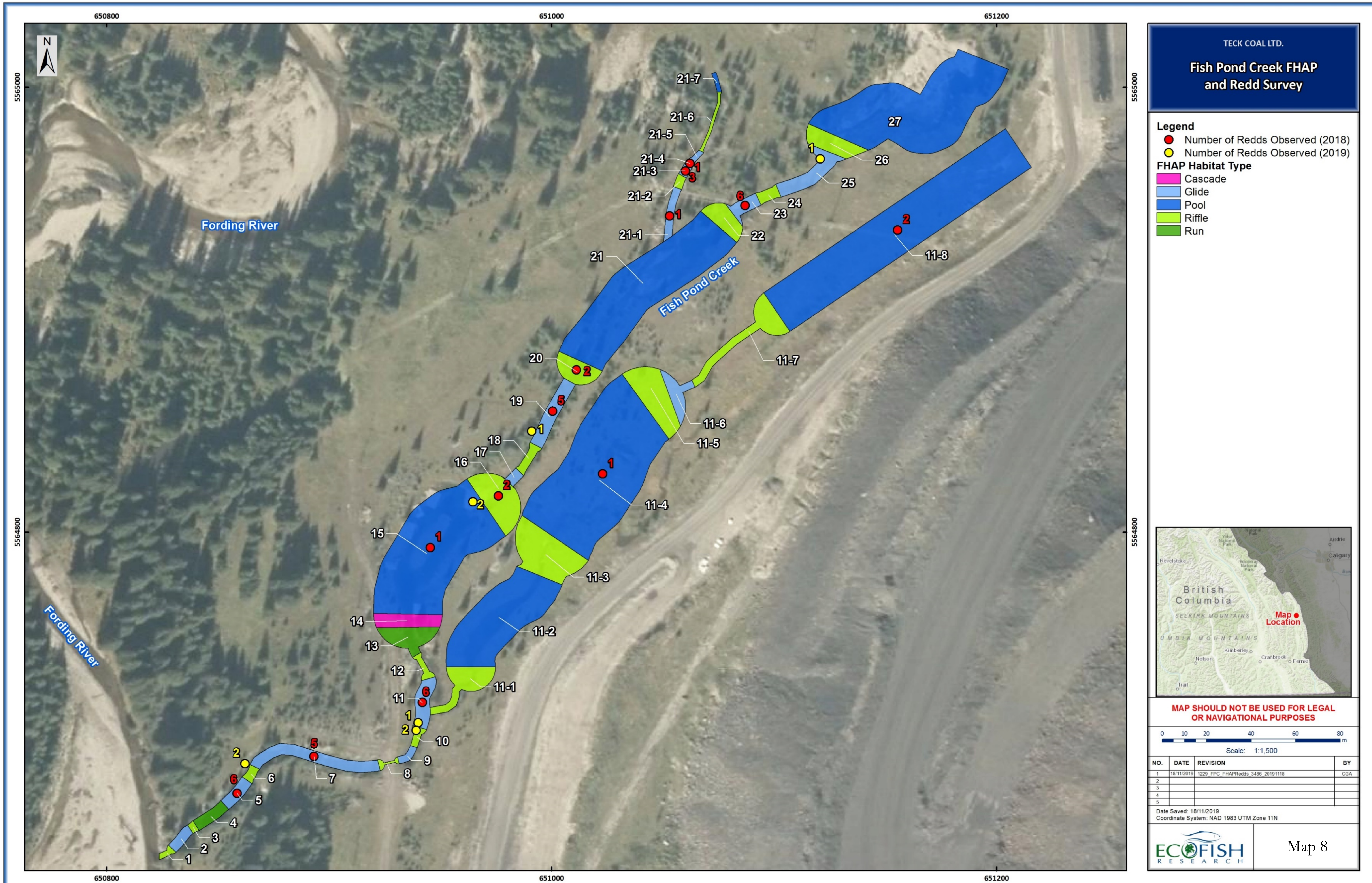
NO.	DATE	REVISION	BY
1	22/11/2019	1229_CLO_FHAPRedd_3486_20191122	CGA
2			
3			
4			
5			

Date Saved: 22/11/2019
Coordinate System: NAD 1983 UTM Zone 11N

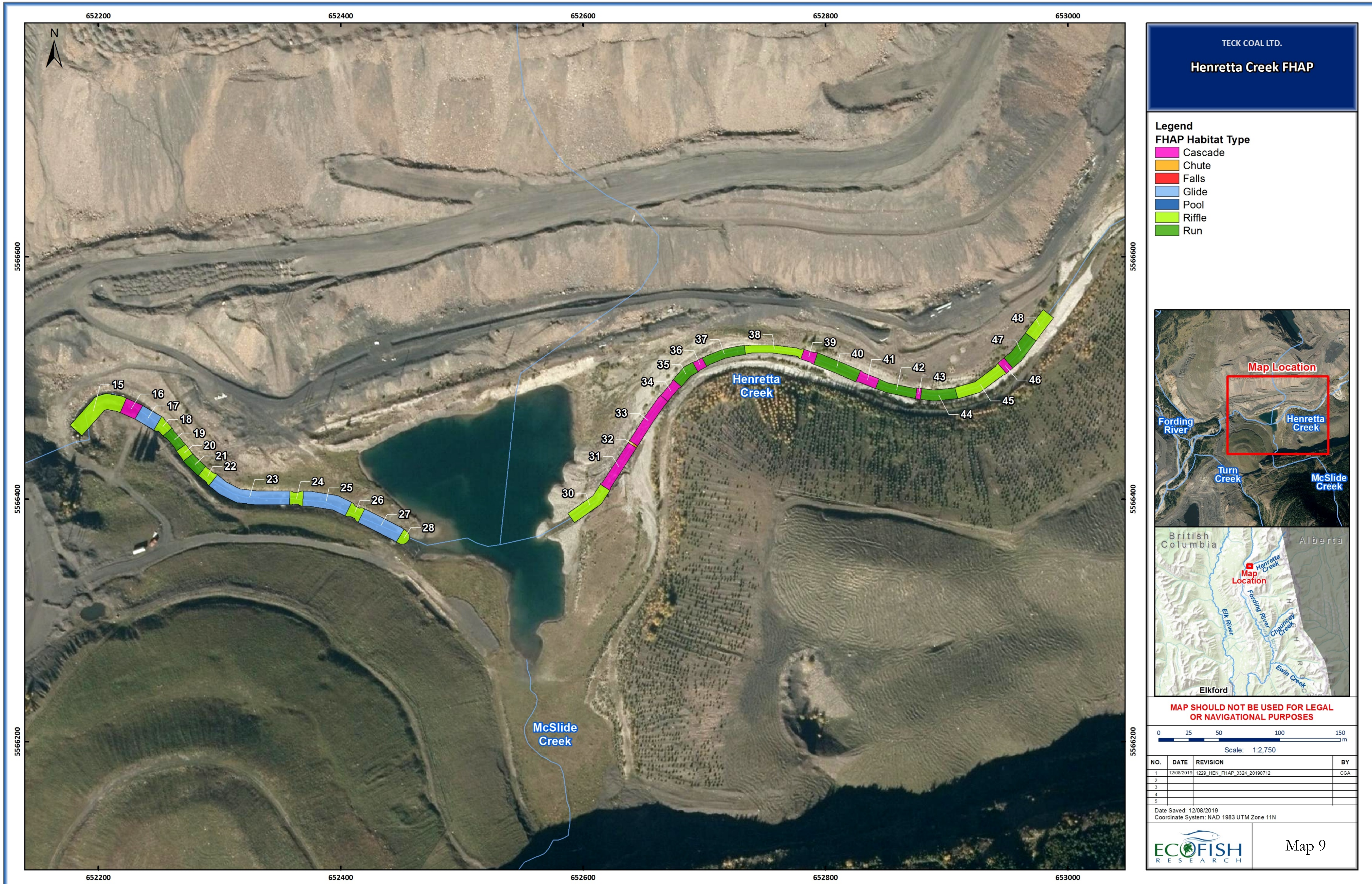
ECOFISH RESEARCH

Map 7

Path: M:\Projects-Active\1229_EVWQP\MXD\Fisheries\1229_CLO_FHAPRedd_3486_20191122.mxd



Path: M:\Projects-Active\1229_EVWQP\MXD\Fisheries\1229_FPC_FHAPRedds_3486_20191118.mxd



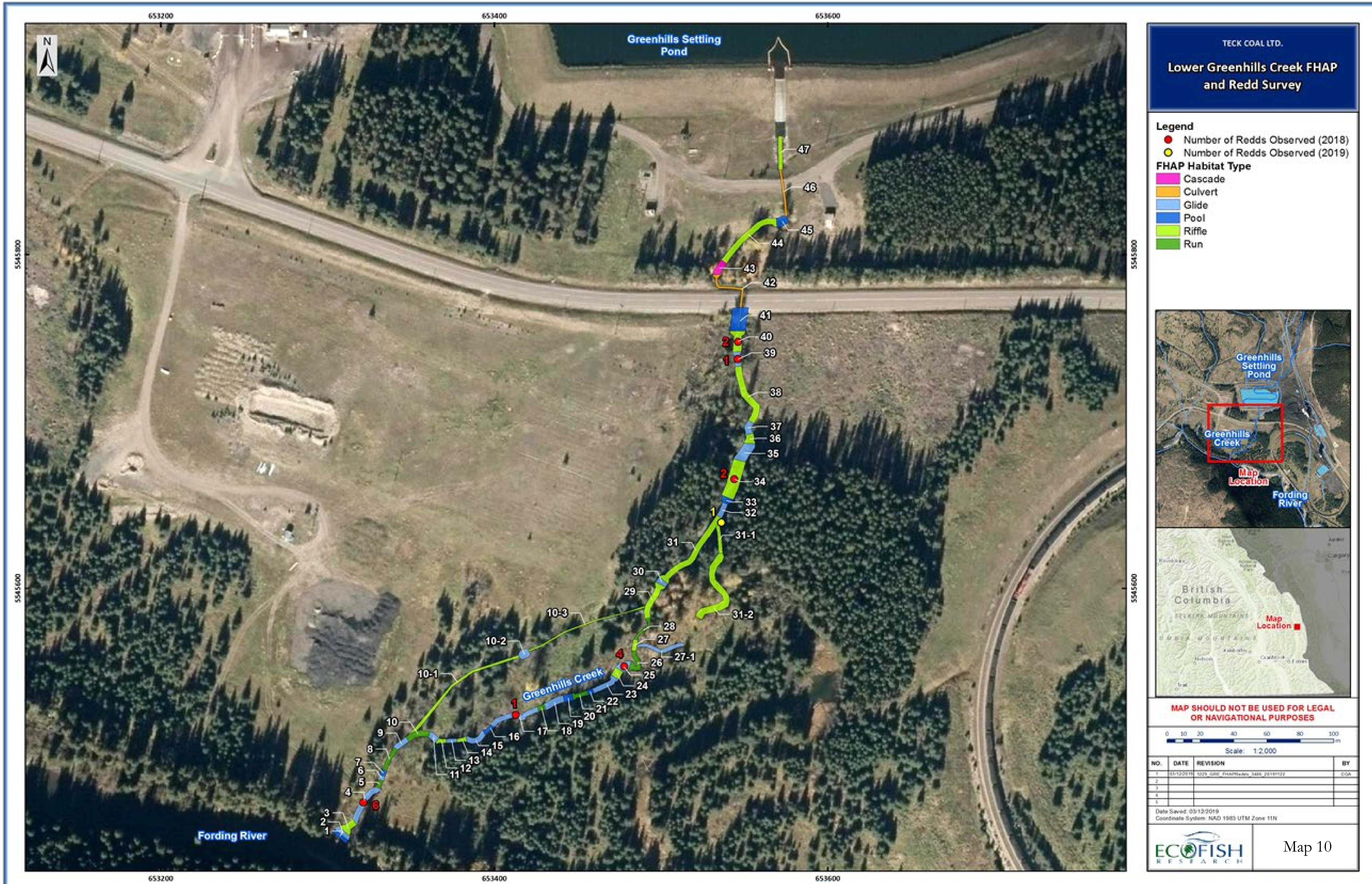
NO.	DATE	REVISION	BY
1	12/08/2019	1229_HEN_FHAP_3324_20190712	CGA
2			
3			
4			
5			

Date Saved: 12/08/2019
Coordinate System: NAD 1983 UTM Zone 11N

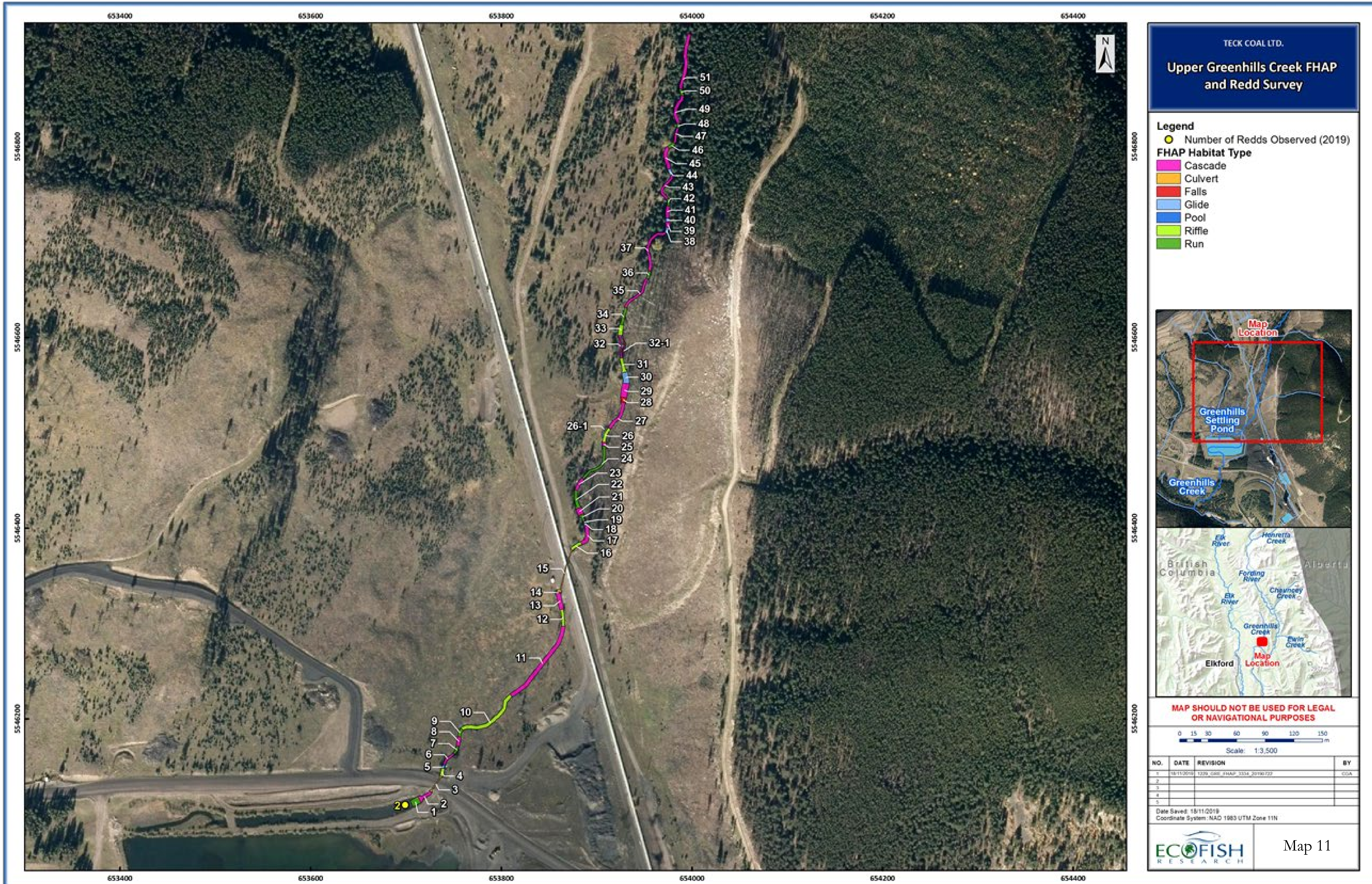
ECOFISH RESEARCH

Map 9

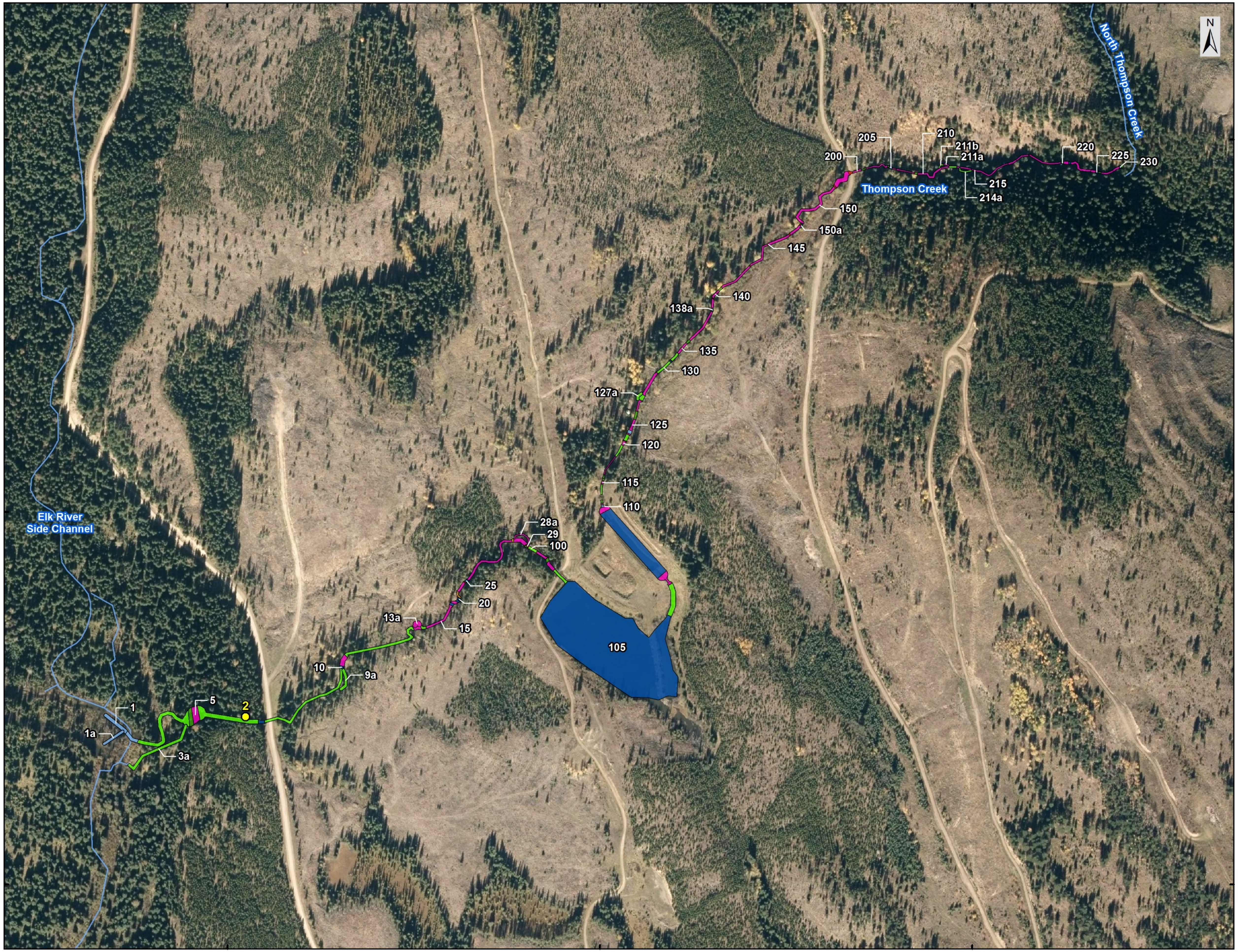
Path: M:\Projects-Active\1229_EVWQP\MXD\Fisheries\1229_HEN_FHAP_3324_20190712.mxd



Path: M:\Projects-Active\1229_EVWQP\MXD\Fisheries\1229_GRE_FHAPRedds_3486_20191122.mxd



Path: M:\Projects-Active\1229_EVWQP\MXD\Fisheries\1229_GRE_FHAP_3334_20190722.mxd



TECK COAL LTD.

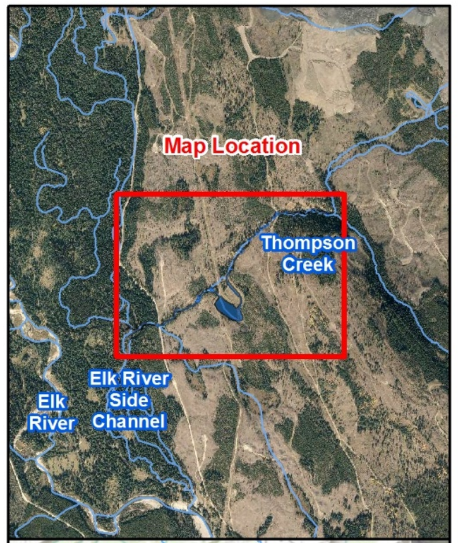
Thompson Creek FHAP and Redd Survey

Legend

- Number of Redds Observed (2019)

FHAP Habitat Type

- Cascade
- Chute
- Falls
- Glide
- Pool
- Riffle
- Run



MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 25 50 100 150 200 250 m

Scale: 1:5,000

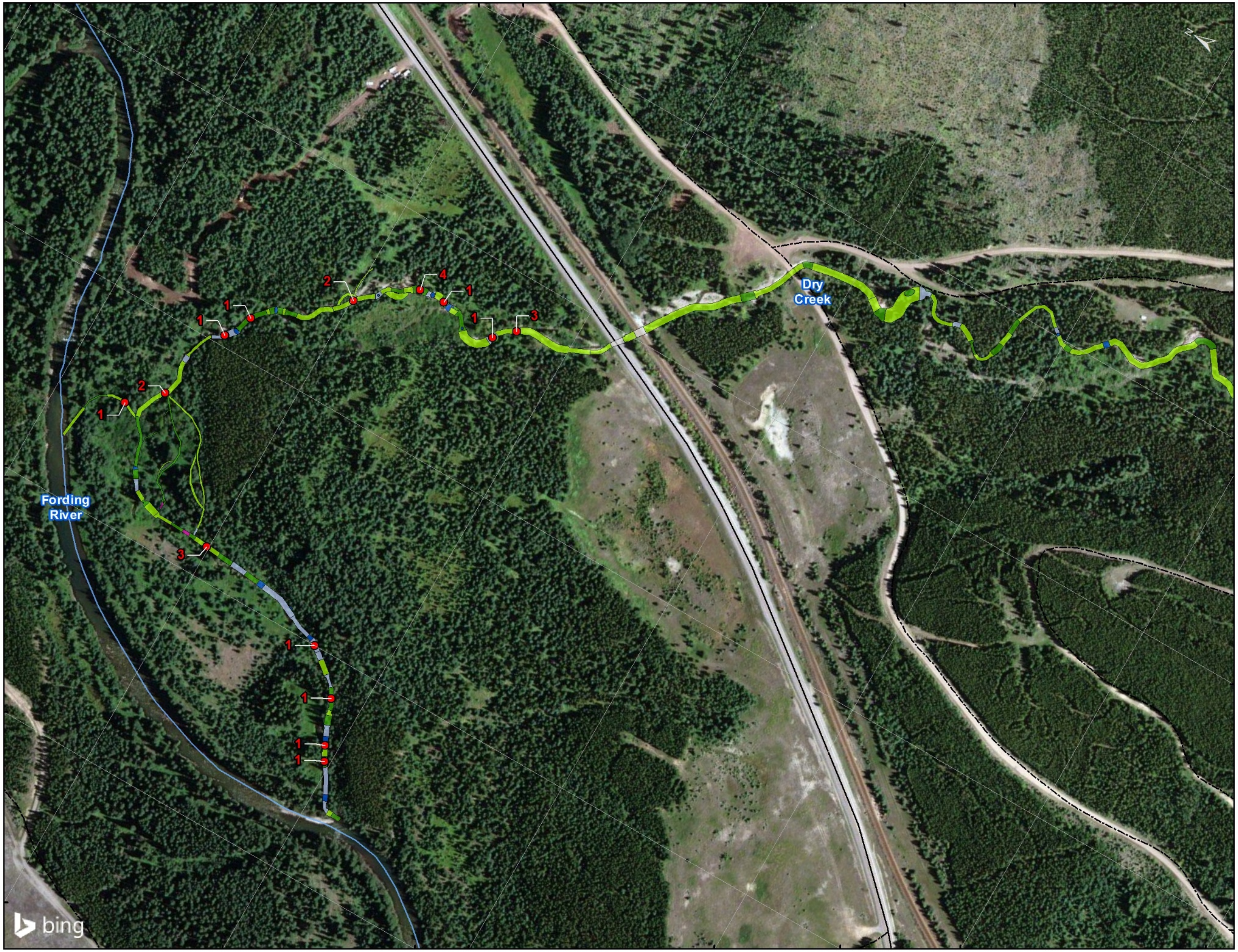
NO.	DATE	REVISION	BY
1	18/11/2019	1229_TMP_FHAPRedds_3486_20191118	
2			
3			
4			
5			

Date Saved: 18/11/2019
Coordinate System: NAD 1983 UTM Zone 11N

ECOFISH RESEARCH

Map 12

Path: M:\Projects-Active\1229_EVWQP\MXD\Fisheries\1229_TMP_FHAPRedds_3486_20191118.mxd



TECK COAL LTD.

LCO Dry Creek FHAP and Redd Survey

Legend

- Number of Redds Observed (2018)
- Reach Break

FHAP Type

- Cascade
- Glide
- Pool
- Riffle
- Run
- Unclassified
- Paved Road
- Rough/Loose Road

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 50 100 Meters

Scale: 1:3,500

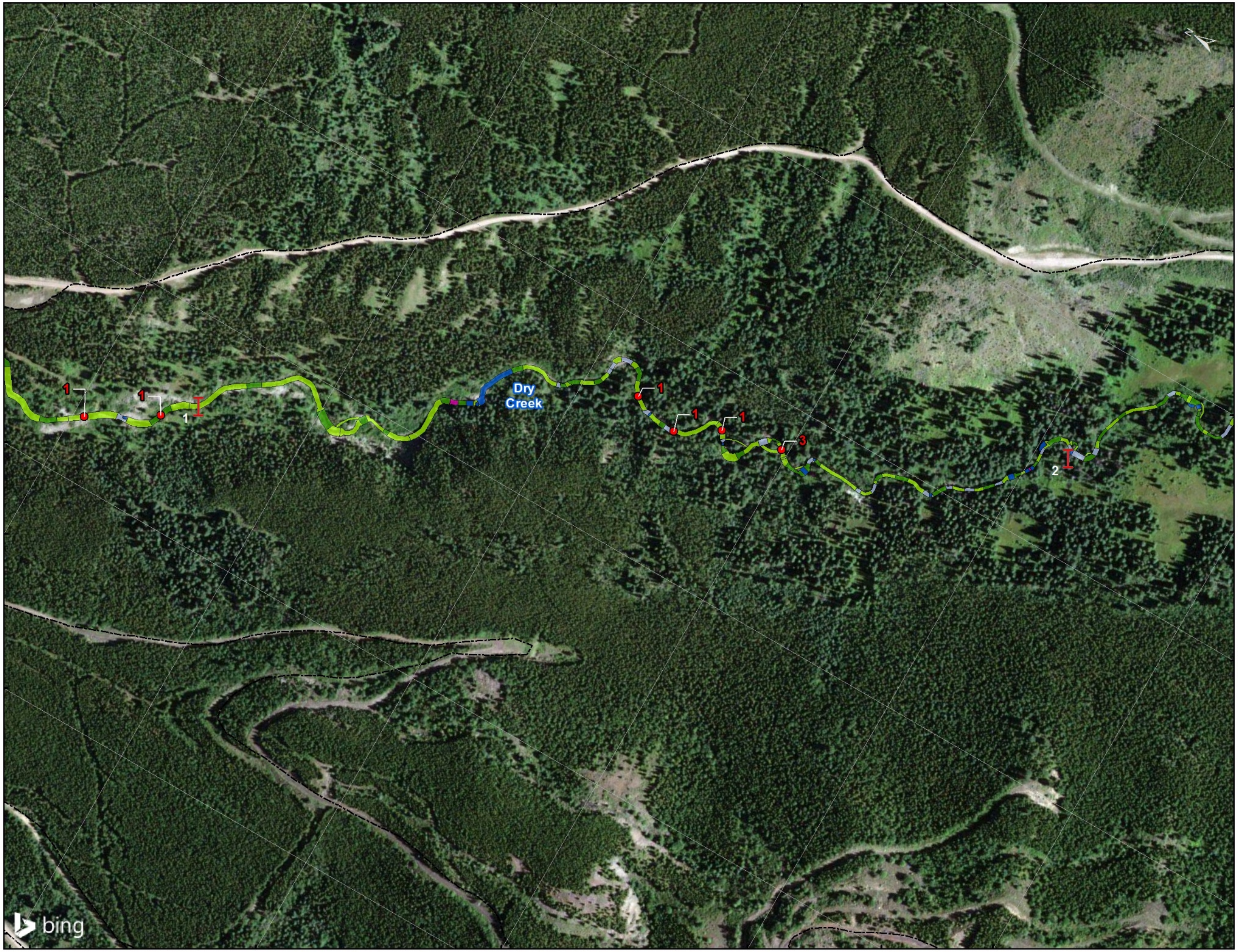
NO.	DATE	REVISION	BY
1	22/11/2019	1229_DRY_FHAPRedd_3486_20191122	CGA
2			
3			
4			
5			

Date Saved: 22/11/2019
Coordinate System: NAD 1983 UTM Zone 11N

ECOFISH RESEARCH

Map 13

Path: M:\Projects-Active\1224_DryCreek\MXD\Fisheries\1229_DRY_FHAPRedd_3486_20191122.mxd



TECK COAL LTD.

LCO Dry Creek FHAP and Redd Survey

Legend

- Number of Redds Observed (2018)
- Reach Break

FHAP Type

- Cascade
- Glide
- Pool
- Riffle
- Run
- Unclassified
- Rough/Loose Road

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 50 100 Meters

Scale: 1:3,500

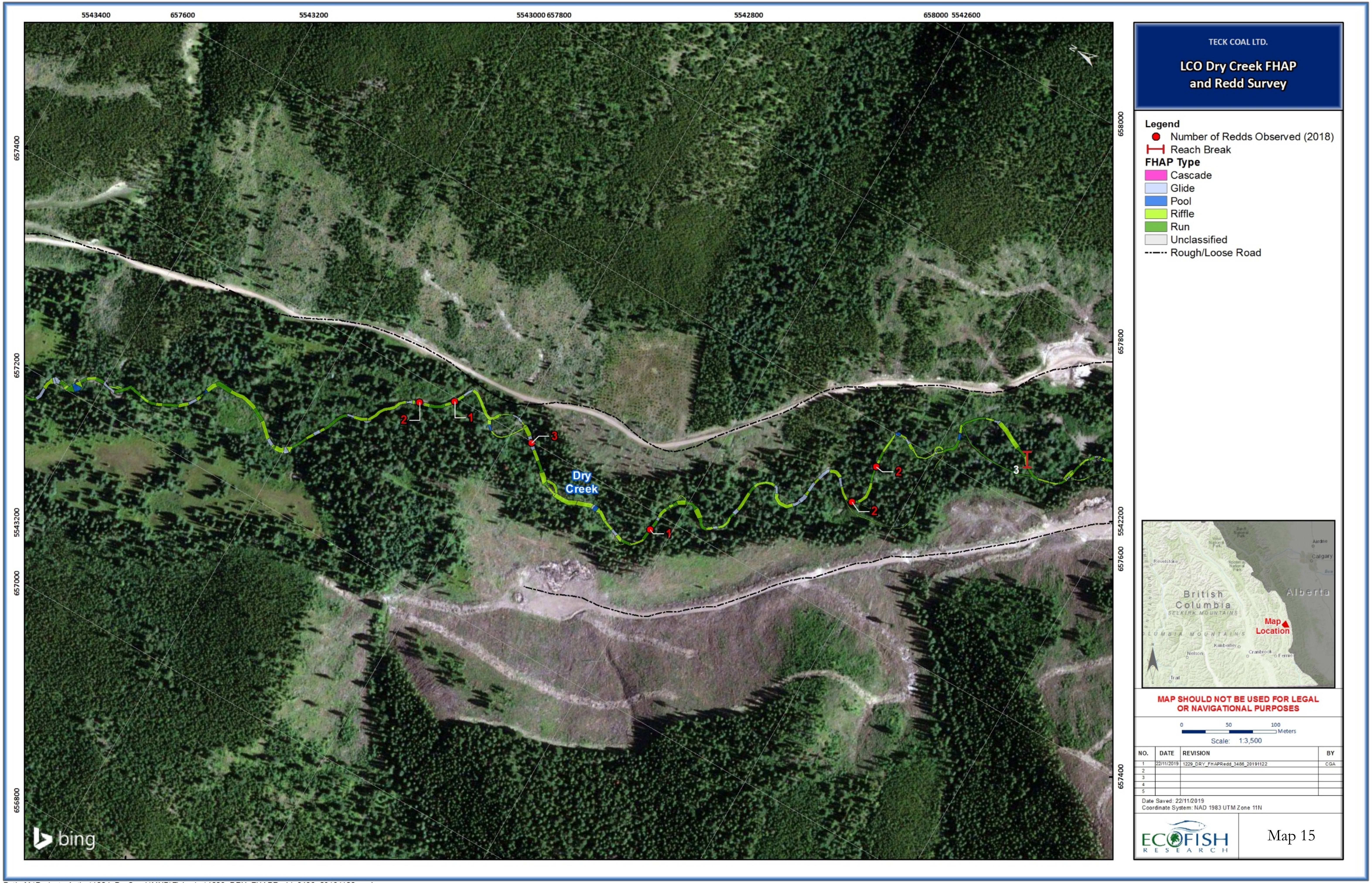
NO.	DATE	REVISION	BY
1	22/11/2019	1229_DRY_FHAPRedd_3486_20191122	CGA
2			
3			
4			
5			

Date Saved: 22/11/2019
Coordinate System: NAD 1983 UTM Zone 11N

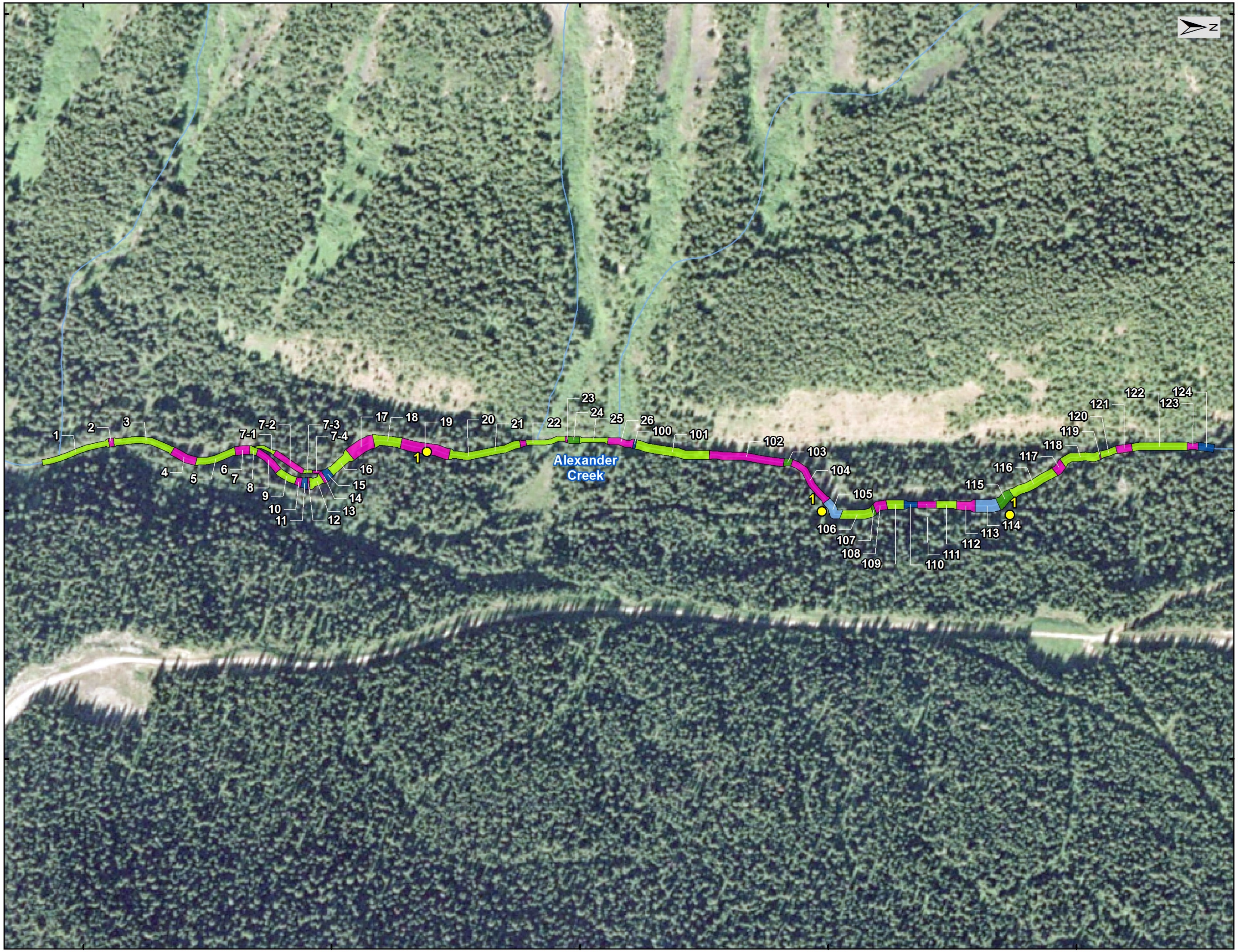
ECOFISH RESEARCH

Map 14

Path: M:\Projects-Active\1224_DryCreek\MXD\Fisheries\1229_DRY_FHAPRedd_3486_20191122.mxd



Path: M:\Projects-Active\1224_DryCreek\MXD\Fisheries\1229_DRY_FHAPRedd_3486_20191122.mxd



TECK COAL LTD.

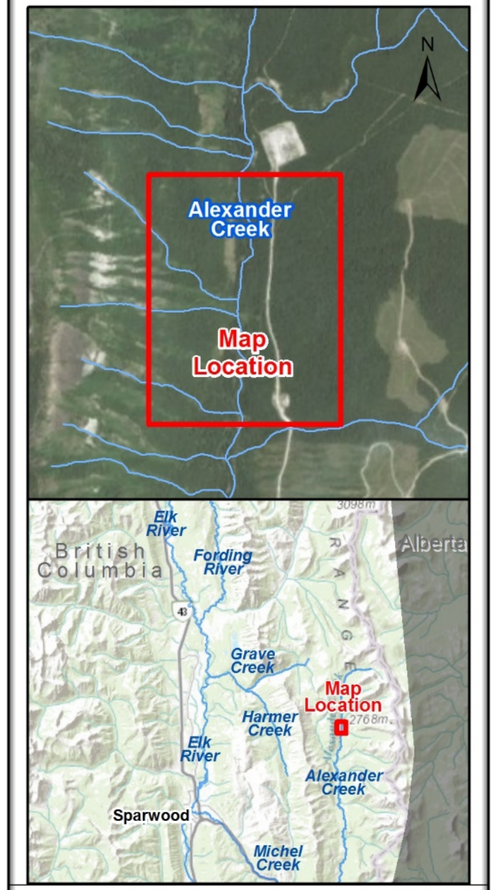
Alexander Creek FHAP and Redd Survey

Legend

- Number of Redds Observed (2019)

FHAP Habitat Type

- Cascade
- Glide
- Pool
- Riffle
- Run



MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 25 50 100 150 m

Scale: 1:3,000

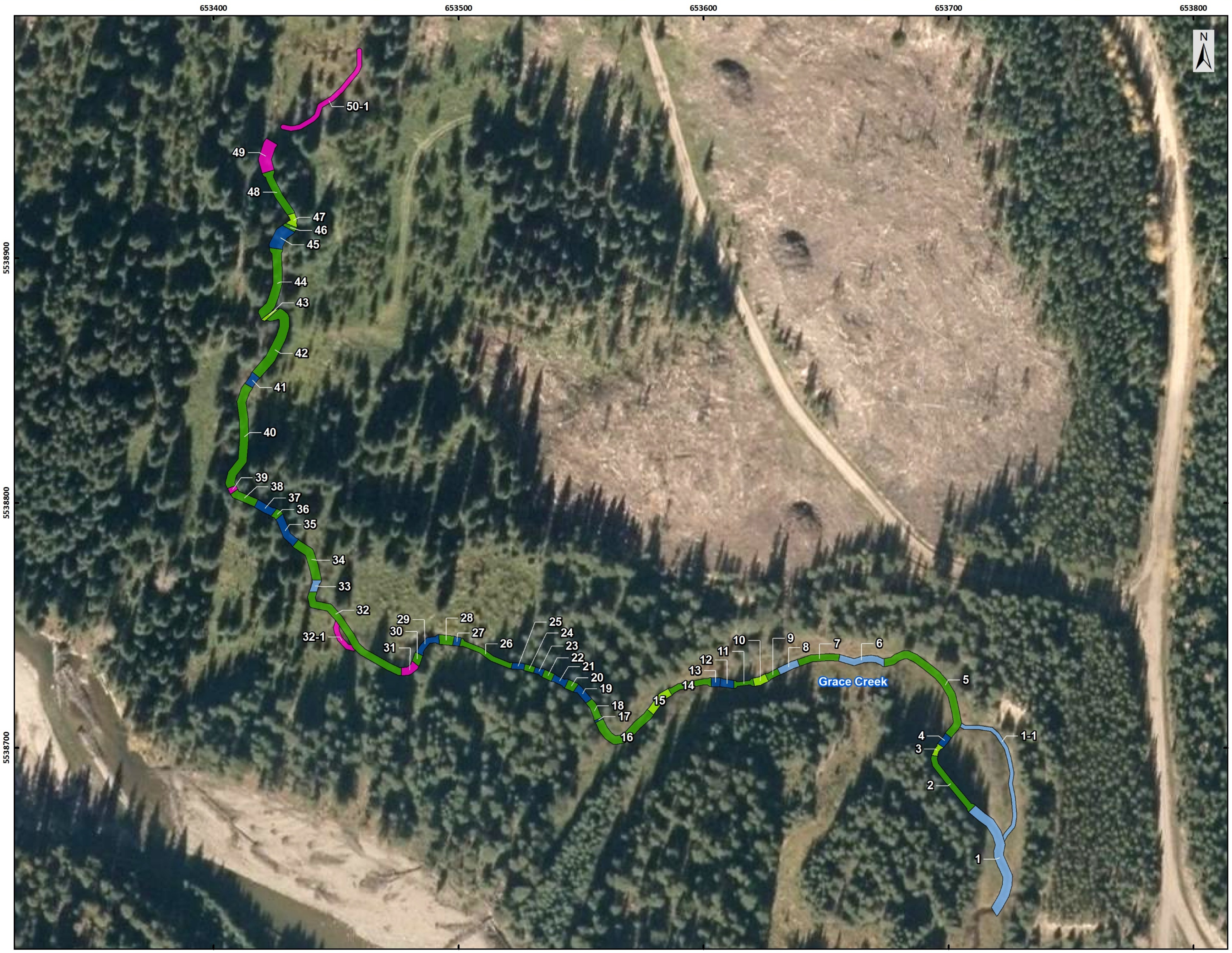
NO.	DATE	REVISION	BY
1	18/11/2019	1229_ALX_FHAP_3348_20190725	CGA
2			
3			
4			
5			

Date Saved: 18/11/2019
Coordinate System: NAD 1983 UTM Zone 11N

ECOFISH RESEARCH

Map 16

Path: M:\Projects-Active\1229_EVWQP\MXD\Fisheries\1229_ALX_FHAP_3348_20190725.mxd



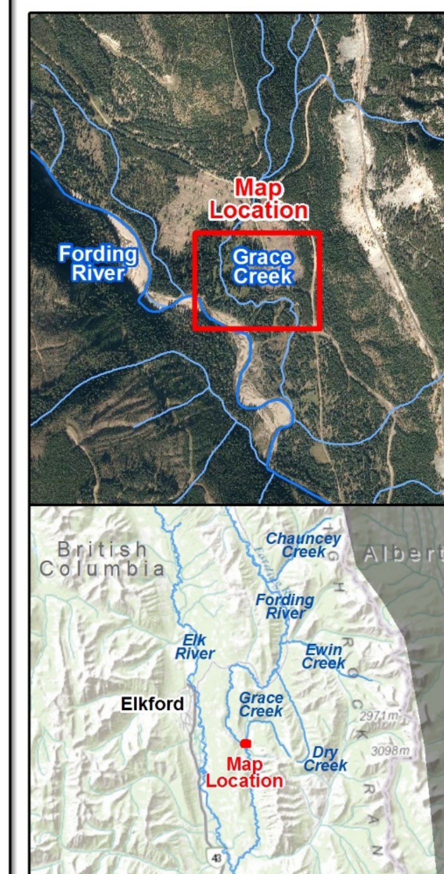
TECK COAL LTD.

Grace Creek FHAP

Legend

FHAP Habitat Type

- Cascade
- Glide
- Pool
- Riffle
- Run



MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 10 20 40 60 80 m

Scale: 1:1,500

NO.	DATE	REVISION	BY
1	29/07/2019	1229_GRC_FHAP_3349_20190729	CGA
2			
3			
4			
5			

Date Saved: 29/07/2019
Coordinate System: NAD 1983 UTM Zone 11N

ECOFISH RESEARCH

Map 17

Path: M:\Projects-Active\1229_EVWQP\MXD\Fisheries\1229_GRC_FHAP_3349_20190729.mxd

TECK COAL LTD.

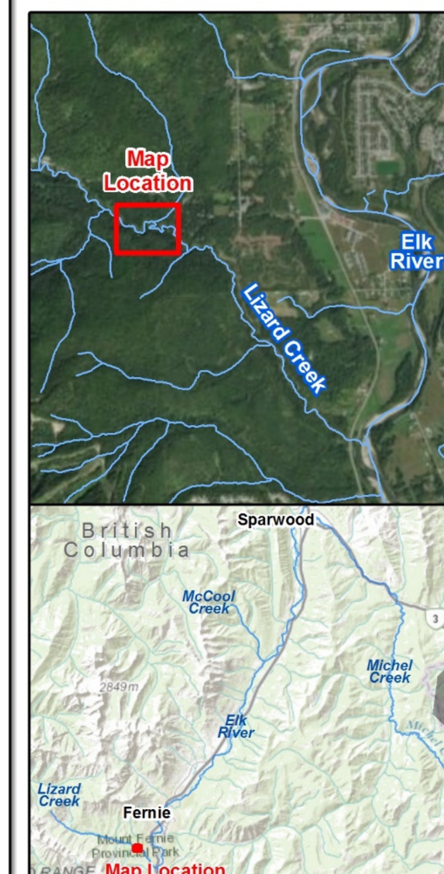
Lizard Creek FHAP and Redd Survey

Legend

- Number of Redds Observed (2019)

FHAP Habitat Type

- Cascade
- Falls
- Glide
- Pool
- Riffle
- Run



MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 10 20 40 60 80 m

Scale: 1:1,500

NO.	DATE	REVISION	BY
1	18/11/2019	1229_LZD_FHAPRedds_3486_20191118	CGA
2			
3			
4			
5			

Date Saved: 18/11/2019
Coordinate System: NAD 1983 UTM Zone 11N

ECOFISH RESEARCH

Map 18

Path: M:\Projects-Active\1229_EVWQP\MXD\Fisheries\1229_LZD_FHAPRedds_3486_20191118.mxd

TECK COAL LTD.

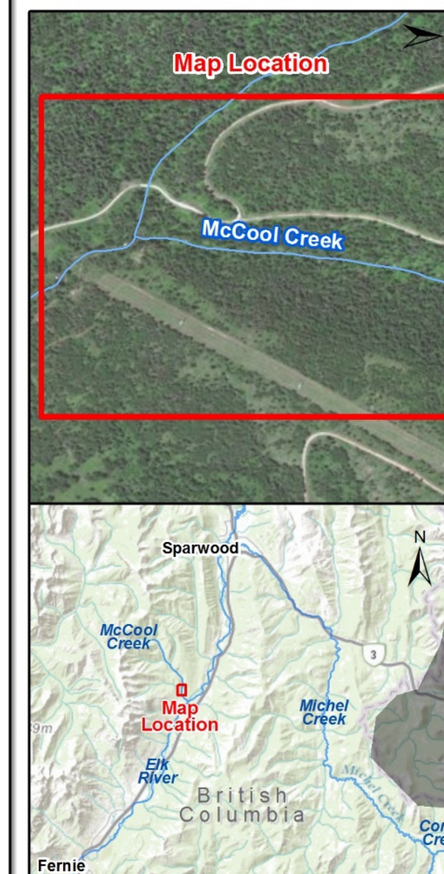
McCool Creek FHAP and Redd Survey

Legend

Number of Redds Observed (2019)

FHAP Habitat Type

- Cascade
- Falls
- Glide
- Pool
- Riffle
- Run



MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 25 50 100 m

Scale: 1:2,500

NO.	DATE	REVISION	BY
1	18/11/2019	1229_MCC_FHAPRedds_3486_20191118	
2			
3			
4			
5			

Date Saved: 18/11/2019
Coordinate System: NAD 1983 UTM Zone 11N

ECOFISH RESEARCH

Map 19

Path: M:\Projects-Active\1229_EVWQP\MXD\Fisheries\1229_MCC_FHAPRedds_3486_20191118.mxd

Appendix C. Summary of Habitat, Water Quality, and Spawning Data Collected in Tributaries of the Fording and Elk Rivers, 2019

LIST OF TABLES

Table 1. Alexander Creek habitat data, by habitat type, 2019.

Habitat Type	Number of Units	% of Total Habitat	Total Wetted Area (m^2)	Total Bankfull Area (m^2)	Mean Wetted Area (m^2)	Wetted Width (m)		Bankfull Width (m)		Wetted Depth (m)		Bankfull Depth (m)		Total Length (m)	Individual Length (m)		Gradient (%)		Weighted Gradient (%)
						Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		Mean	SD[1]	Mean	SD[1]	
Pool	5	5%	260	305	52	5.8	1.0	7.0	1.3	0.5	0.1	1.0	0.2	45	9.0	4.0	1	0	1
Glide	2	3%	164	184	82	7.9	1.6	8.9	2.3	0.3	0.1	0.6	0.2	21	10.5	0.7	1	1	1
Run	4	5%	309	327	77	6.2	1.3	6.6	1.4	0.4	0.1	0.7	0.3	51	12.8	3.8	2	1	1
Riffle	21	50%	2,839	3,348	135	4.9	1.5	6.0	1.5	0.3	0.1	0.6	0.3	547	26.0	16.1	2	1	3
Cascade	23	38%	2,152	2,653	94	5.4	2.0	6.6	2.1	0.2	0.1	0.7	0.2	395	17.2	15.9	8	2	6
Chute	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Falls	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Total	*55*	*100%*	*5,723*	*6,818*	*104*	*5.4*	*1.7*	*6.5*	*1.8*	*0.3*	*0.1*	*0.7*	*0.3*	*1,059*	*19.3*	*15.3*	*4*	*3*	*4*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 2. Alexander Creek water quality, calcite, gravel, and spawning data, by habitat type, 2019.

Habitat Type	Mean Velocity (m/s)		Mean Flow (cms)		Calcite Measures: CI		Calcite Measures: CC		Calcite Measures: CP		Mean Pebble Size (mm)		Gravel Prop. (%)		Water Temp. (°C)		DO (mg/L)		Spec. Cond/ (µS/cm)		pH		Total Redds	Redd Density (#/m^2)
	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		
Pool	0.17	0.07	0.41	0.10	0.25	0.30	0.00	0.00	0.25	0.30	60.5	25.1	1.42	1.99	7.2	0.6	9.3	0.2	233.5	1.8	8.4	0.1	0	0.000
Glide	0.34	0.05	0.56	0.02	0.32	0.40	0.00	0.00	0.32	0.40	66.5	1.9	0.24	0.12	7.2	0.8	9.4	0.0	235.4	0.0	8.5	0.0	1	0.005
Run	0.27	0.15	0.59	0.42	0.04	0.04	0.00	0.00	0.04	0.04	67.2	5.5	2.36	2.42	7.3	1.1	9.4	0.0	235.4	0.0	8.4	0.1	1	0.003
Riffle	0.35	0.16	0.42	0.20	0.09	0.14	0.00	0.00	0.09	0.14	88.4	28.2	1.81	2.09	7.8	0.7	9.5	0.1	235.7	1.4	8.4	0.1	0	0.000
Cascade	0.41	0.20	0.57	0.33	0.12	0.13	0.00	0.00	0.12	0.13	102.7	39.2	0.30	0.71	7.9	0.7	9.4	0.0	235.5	0.7	8.4	0.1	1	0.000
Chute	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Falls	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	*0.35*	*0.18*	*0.50*	*0.28*	*0.12*	*0.17*	*0.00*	*0.00*	*0.12*	*0.17*	*89.0*	*34.0*	*1.13*	*1.73*	*7.7*	*0.8*	*9.4*	*0.1*	*235.4*	*1.2*	*8.4*	*0.1*	*3*	*0.000*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 3. Clode Creek habitat data, by habitat type, 2019.

Habitat Type	Number of Units	% of Total Habitat	Total Wetted Area (m^2)	Total Bankfull Area (m^2)	Mean Wetted Area (m^2)	Wetted Width (m)		Bankfull Width (m)		Wetted Depth (m)		Bankfull Depth (m)		Total Length (m)	Individual Length (m)		Gradient (%)		Weighted Gradient (%)
						Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		Mean	SD[1]	Mean	SD[1]	
Pool	1	30%	198	220	198	9.0	-	10.0	-	0.6	-	1.5	-	22	22.0	-	0	-	0
Glide	4	56%	369	446	92	3.4	1.6	4.1	2.0	0.2	0.1	0.4	0.2	97	24.3	15.3	0	0	0
Run	1	10%	67	84	67	1.6	-	2.0	-	0.3	-	0.7	-	42	42.0	-	2	-	2
Riffle	2	4%	27	48	14	3.2	2.1	4.7	0.9	0.2	0.1	0.6	0.5	11	5.5	3.5	2	1	2
Cascade	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Chute	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Falls	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Total	*8*	*100%*	*662*	*798*	*83*	*3.8*	*2.5*	*4.7*	*2.7*	*0.3*	*0.2*	*0.6*	*0.4*	*172*	*21.5*	*15.5*	*1*	*1*	*1*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 4. Clode Creek water quality, calcite, gravel, and spawning data, by habitat type, 2019.

Habitat Type	Mean Velocity (m/s)		Mean Flow (cms)		Calcite Measures CI		CC		CP		Mean Pebble Size (mm)		Gravel Prop. (%)		Water Temp. (°C)		DO (mg/L)		Spec. Cond/ (µS/cm)		pH		Total Redds	Redd Density (#/m^2)
	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		
Pool	0.06	-	0.02	-	0.97	-	0.00	-	0.97	-	56.1	-	0.00	-	7.8	-	7.2	-	364.7	-	8.1	-	0	0.000
Glide	0.16	0.08	0.08	0.06	0.85	0.34	0.11	0.11	0.73	0.23	47.1	11.5	2.82	6.18	13.5	3.4	8.4	1.0	850.9	664.3	8.6	0.6	4	0.005
Run	0.19	0.01	0.07	0.02	1.58	0.12	0.60	0.09	0.98	0.02	65.3	14.8	0.00	0.00	16.2	2.2	8.9	0.8	1667.6	49.1	8.9	0.9	2	0.012
Riffle	0.43	-	0.13	-	1.35	0.82	0.47	0.66	0.88	0.16	57.2	10.5	0.63	0.89	15.3	-	8.3	0.0	1542.8	75.2	8.2	-	0	0.000
Cascade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chute	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Falls	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	*0.19*	*0.12*	*0.08*	*0.05*	*1.06*	*0.47*	*0.24*	*0.31*	*0.82*	*0.21*	*52.6*	*12.4*	*1.75*	*4.77*	*13.7*	*3.5*	*8.4*	*0.9*	*1061.8*	*650.2*	*8.5*	*0.6*	*6*	*0.005*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 5. Corbin Creek habitat data, by habitat type, 2019.

Habitat Type	Number of Units	% of Total Habitat	Total Wetted Area (m^2)	Total Bankfull Area (m^2)	Mean Wetted Area (m^2)	Wetted Width (m)		Bankfull Width (m)		Wetted Depth (m)		Bankfull Depth (m)		Total Length (m)	Individual Length (m)		Gradient (%)		Weighted Gradient (%)
						Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		Mean	SD[1]	Mean	SD[1]	
Pool	2	1%	28	58	14	4.2	3.3	8.9	6.3	0.5	0.2	1.5	0.1	6	3.0	0.7	0	0	0
Glide	1	16%	494	770	494	26.0	-	40.5	-	0.4	-	1.0	-	19	19.0	-	1	-	1
Run	4	8%	245	629	61	4.5	0.9	12.4	6.1	0.4	0.1	1.1	0.1	54	13.6	3.0	1	0	1
Riffle	8	74%	2,266	7,072	283	3.3	1.8	16.6	12.7	0.2	0.1	0.9	0.2	504	63.0	73.3	3	1	3
Cascade	1	1%	35	41	35	4.2	-	4.9	-	0.2	-	1.2	-	8	8.4	-	6	-	6
Chute	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Falls	1	0%	0	0	-	-	-	-	-	-	-	-	-	2	1.5	-	70	-	70
Total	*17*	*100%*	*3,068*	*8,569*	*192*	*5.2*	*5.8*	*15.4*	*12.0*	*0.3*	*0.2*	*1.0*	*0.2*	*593*	*34.9*	*55.8*	*6*	*17*	*3*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 6. Corbin Creek water quality, calcite, gravel, and spawning data, by habitat type, 2019.

Habitat Type	Mean Velocity (m/s)		Mean Flow (cms)		Calcite Measures CI		Calcite Measures CC		Calcite Measures CP		Mean Pebble Size (mm)		Gravel Prop. (%)		Water Temp. (°C)		DO (mg/L)		Spec. Cond/ (µS/cm)		pH		Total Redds	Redd Density (#/m^2)
	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		
Pool	0.06	0.08	0.16	0.23	1.87	-	0.87	-	1.00	-	75.5	-	0.00	0.00	10.6	0.0	8.6	0.0	1322.0	0.0	8.2	0.0	0	0.000
Glide	0.15	-	0.42	-	0.87	-	0.00	-	0.87	-	6.4	-	0.53	-	10.8	-	8.6	-	1322.0	-	8.3	-	0	0.000
Run	0.45	0.20	0.57	0.16	2.44	0.42	1.48	0.39	0.96	0.03	162.7	129.0	1.43	2.85	10.7	0.1	8.6	0.1	1322.6	1.2	8.2	0.0	0	0.000
Riffle	0.53	0.27	0.54	0.26	1.83	0.94	1.00	0.62	0.83	0.34	193.7	99.6	2.59	4.43	10.8	0.2	8.7	0.0	1321.7	0.8	8.5	0.4	0	0.000
Cascade	0.87	-	0.71	-	2.40	-	1.40	-	1.00	-	710.1	-	0.09	-	10.6	-	8.6	-	1322.0	-	8.2	-	0	0.000
Chute	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Falls	1.24	-	0.58	-	2.67	-	1.67	-	1.00	-	867.8	-	0.00	-	10.6	-	8.6	-	1322.0	-	8.3	-	0	-
Total	*0.49*	*0.33*	*0.51*	*0.23*	*2.05*	*0.79*	*1.15*	*0.60*	*0.90*	*0.24*	*247.3*	*232.8*	*1.50*	*3.29*	*10.7*	*0.2*	*8.6*	*0.0*	*1322.0*	*0.8*	*8.3*	*0.3*	*0*	*0.000*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 7. EVO Dry Creek habitat data, by habitat type, 2019.

Habitat Type	Number of Units	% of Total Habitat	Total Wetted Area (m^2)	Total Bankfull Area (m^2)	Mean Wetted Area (m^2)	Wetted Width (m)		Bankfull Width (m)		Wetted Depth (m)		Bankfull Depth (m)		Total Length (m)	Individual Length (m)		Gradient (%)		Weighted Gradient (%)
						Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		Mean	SD[1]	Mean	SD[1]	
Pool	2	32%	2,163	2,277	1,082	22.5	21.9	23.7	23.1	0.6	0.2	1.0	0.3	61	30.5	36.1	0	0	0
Glide	18	24%	1,612	1,866	90	6.3	2.7	7.1	3.0	0.3	0.1	0.5	0.2	250	13.9	8.3	1	1	1
Run	5	6%	400	461	80	6.0	2.2	6.9	2.3	0.3	0.1	0.5	0.2	76	15.2	9.7	1	1	2
Riffle	8	14%	944	1,080	118	4.1	2.9	4.6	3.1	0.3	0.2	0.4	0.2	275	34.4	34.8	3	2	3
Cascade	23	25%	1,696	1,888	74	5.3	2.6	5.9	2.6	0.2	0.1	0.4	0.2	339	14.7	13.8	23	32	10
Chute	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Falls	1	0%	5	5	5	4.5	-	5.0	-	0.1	-	0.2	-	1	1.0	-	150	-	150
Total	*57*	*100%*	*6,819*	*7,577*	*120*	*6.1*	*5.0*	*6.8*	*5.3*	*0.3*	*0.1*	*0.5*	*0.2*	*1,002*	*17.6*	*18.3*	*13*	*29*	*5*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 8. EVO Dry Creek water quality, calcite, gravel, and spawning data, by habitat type, 2019.

Habitat Type	Mean Velocity (m/s)		Mean Flow (cms)		Calcite Measures CI		CC		CP		Mean Pebble Size (mm)		Gravel Prop. (%)		Water Temp. (°C)		DO (mg/L)		Spec. Cond/ (µS/cm)		pH		Total Redds	Redd Density (#/m^2)
	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		
Pool	0.01	0.01	0.06	0.02	1.57	0.57	0.57	0.57	1.00	0.00	42.7	44.3	4.58	6.47	10.7	0.4	8.6	0.0	1453.3	0.0	8.4	0.0	0	0.000
Glide	0.07	0.06	0.11	0.15	1.78	0.34	0.79	0.33	0.99	0.02	19.5	14.4	0.43	1.30	10.3	1.4	8.7	0.1	1453.9	2.6	8.3	0.1	0	0.000
Run	0.20	0.10	0.30	0.25	1.67	0.41	0.69	0.38	0.98	0.04	37.0	10.0	1.07	2.39	10.8	2.1	8.7	0.7	1451.1	34.1	8.3	0.1	0	0.000
Riffle	0.22	0.13	0.19	0.20	1.88	0.24	0.88	0.24	1.00	0.00	33.4	14.9	0.00	0.00	10.6	1.4	8.6	0.0	1453.3	0.0	8.3	0.1	0	0.000
Cascade	0.22	0.20	0.14	0.11	2.17	0.24	1.17	0.23	1.00	0.01	32.8	18.3	0.06	0.20	10.4	1.0	8.6	0.2	1453.3	5.9	8.3	0.1	0	0.000
Chute	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Falls	0.33	-	0.57	-	2.40	-	1.40	-	1.00	-	-	-	0.00	-	9.7	-	8.6	-	1453.3	-	8.4	-	0	0.000
Total	*0.17*	*0.16*	*0.16*	*0.16*	*1.95*	*0.36*	*0.95*	*0.35*	*1.00*	*0.02*	*29.7*	*17.9*	*0.42*	*1.56*	*10.4*	*1.2*	*8.6*	*0.2*	*1453.3*	*10.1*	*8.3*	*0.1*	*0*	*0.000*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 9. LCO Dry Creek habitat data, by habitat type, 2019.

Habitat Type	Number of Units	% of Total Habitat	Total Wetted Area (m^2)	Total Bankfull Area (m^2)	Mean Wetted Area (m^2)	Wetted Width (m)		Bankfull Width (m)		Wetted Depth (m)		Bankfull Depth (m)		Total Length (m)	Individual Length (m)		Gradient (%)		Weighted Gradient (%)
						Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		Mean	SD[1]	Mean	SD[1]	
Pool	36	3%	597	691	17	3.6	1.6	4.3	1.8	0.6	0.1	1.0	0.2	165	4.6	1.6	0	0	0
Glide	71	12%	2,171	2,701	31	3.1	1.0	3.9	1.2	0.4	0.1	0.6	0.1	682	9.6	5.1	1	0	1
Run	103	24%	4,314	5,226	42	3.2	1.2	4.0	1.6	0.3	0.1	0.5	0.1	1,435	13.9	15.9	1	0	1
Riffle	165	60%	10,897	14,039	66	3.2	1.3	4.0	1.7	0.2	0.1	0.4	0.1	3,443	20.9	22.0	2	1	2
Cascade	4	0%	56	70	14	2.4	1.1	3.0	1.2	0.3	0.1	0.4	0.1	23	5.8	2.6	4	2	4
Chute	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Falls	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Total	*379*	*100%*	*18,035*	*22,728*	*48*	*3.2*	*1.2*	*4.0*	*1.6*	*0.3*	*0.1*	*0.5*	*0.2*	*5,748*	*15.2*	*17.8*	*2*	*1*	*2*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 10. LCO Dry Creek water quality, calcite, gravel, and spawning data, by habitat type, 2019.

Habitat Type	Mean Velocity (m/s)		Mean Flow (cms)		Calcite Measures CI		CC		CP		Mean Pebble Size (mm)		Gravel Prop. (%)		Water Temp. (°C)		DO (mg/L)		Spec. Cond/ (µS/cm)		pH		Total Redds	Redd Density (#/m^2)
	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		
Pool	0.23	0.17	0.23	0.16	0.48	0.36	0.00	0.00	0.48	0.36	44.9	24.2	0.05	0.12	7.8	1.7	9.8	0.7	371.2	23.0	8.6	0.1	1	0.004
Glide	0.29	0.14	0.20	0.13	0.46	0.34	0.00	0.01	0.46	0.35	44.2	18.4	2.22	3.36	8.2	2.2	9.5	0.8	381.2	27.8	8.6	0.1	7	0.006
Run	0.40	0.13	0.23	0.12	0.53	0.38	0.00	0.00	0.53	0.38	49.0	20.5	4.97	5.84	8.2	1.9	9.8	0.5	375.8	23.1	8.6	0.1	16	0.011
Riffle	0.45	0.20	0.26	0.17	0.58	0.39	0.00	0.00	0.58	0.39	60.7	21.4	4.05	6.62	7.8	1.1	9.8	0.4	374.2	18.8	8.6	0.2	14	0.003
Cascade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chute	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Falls	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	*0.36*	*0.18*	*0.23*	*0.15*	*0.52*	*0.37*	*0.00*	*0.01*	*0.52*	*0.37*	*51.0*	*21.7*	*3.13*	*5.31*	*8.0*	*1.7*	*9.7*	*0.6*	*375.8*	*22.7*	*8.6*	*0.2*	*38*	*0.005*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 11. Erickson Creek habitat data, by habitat type, 2019.

Habitat Type	Number of Units	% of Total Habitat	Total Wetted Area (m^2)	Total Bankfull Area (m^2)	Mean Wetted Area (m^2)	Wetted Width (m)		Bankfull Width (m)		Wetted Depth (m)		Bankfull Depth (m)		Total Length (m)	Individual Length (m)		Gradient (%)		Weighted Gradient (%)
						Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		Mean	SD[1]	Mean	SD[1]	
Pool	2	0%	12	0	6	3.6	0.4	-	-	0.9	0.2	1.3	-	4	1.8	0.4	1	0	1
Glide	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Run	7	14%	554	577	79	6.9	2.5	7.3	2.5	0.4	0.2	0.7	0.3	76	10.9	5.1	2	1	2
Riffle	5	9%	342	384	68	4.5	1.1	5.1	1.3	0.3	0.0	0.5	0.1	73	14.6	3.6	3	1	3
Cascade	28	76%	3,066	3,554	118	4.9	1.9	5.7	1.9	0.3	0.1	0.5	0.2	599	23.0	16.7	13	7	10
Chute	2	1%	35	66	17	3.3	2.9	6.1	4.9	0.2	0.1	0.4	0.1	12	6.0	1.4	36	17	38
Falls	1	0%	1	3	1	1.4	-	3.1	-	0.2	-	0.7	-	1	1.0	-	27	-	27
Total	*45*	*100%*	*4,010*	*4,584*	*93*	*4.9*	*2.1*	*5.9*	*2.2*	*0.4*	*0.2*	*0.6*	*0.3*	*765*	*17.8*	*14.9*	*11*	*10*	*9*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 12. Erickson Creek water quality, calcite, gravel, and spawning data, by habitat type, 2019.

Habitat Type	Mean Velocity (m/s)		Mean Flow (cms)		Calcite Measures CI		Calcite Measures CC		Calcite Measures CP		Mean Pebble Size (mm)		Gravel Prop. (%)		Water Temp. (°C)		DO (mg/L)		Spec. Cond/ (µS/cm)		pH		Total Redds	Redd Density (#/m^2)
	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		
Pool	0.19	0.24	0.63	0.84	2.13	0.24	1.13	0.24	1.00	0.00	2.0	-	0.00	0.00	7.5	1.1	9.7	0.0	1847.2	0.0	8.1	0.0	0	-
Glide	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Run	0.20	0.10	0.41	0.17	1.94	0.20	0.98	0.15	0.96	0.07	56.5	59.3	0.00	0.00	7.0	0.7	9.7	0.0	1847.2	0.0	8.2	0.0	0	0.000
Riffle	0.34	0.06	0.44	0.24	1.97	0.16	0.99	0.15	0.98	0.02	58.5	56.8	0.00	0.00	6.8	0.7	9.7	0.0	1834.9	27.5	8.1	0.1	0	0.000
Cascade	0.45	0.24	0.42	0.34	2.09	0.16	1.11	0.15	0.99	0.02	81.6	79.2	0.00	0.00	7.1	0.7	9.7	0.1	1849.5	11.1	8.1	0.1	0	0.000
Chute	0.69	0.06	0.24	0.29	2.22	0.02	1.22	0.02	1.00	0.00	50.0	0.0	0.00	0.00	7.8	0.1	9.7	0.0	1847.2	0.0	8.2	0.0	0	0.000
Falls	0.60	-	0.09	-	2.37	-	1.37	-	1.00	-	-	-	0.00	-	7.2	-	9.7	-	1847.2	-	8.2	-	0	0.000
Total	*0.40*	*0.23*	*0.41*	*0.32*	*2.07*	*0.18*	*1.08*	*0.16*	*0.98*	*0.03*	*70.3*	*70.1*	*0.00*	*0.00*	*7.1*	*0.7*	*9.7*	*0.1*	*1847.2*	*12.9*	*8.1*	*0.1*	*0*	*0.000*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 13. Fish Pond Creek habitat data, by habitat type, 2019.

Habitat Type	Number of Units	% of Total Habitat	Total Wetted Area (m^2)	Total Bankfull Area (m^2)	Mean Wetted Area (m^2)	Wetted Width (m)		Bankfull Width (m)		Wetted Depth (m)		Bankfull Depth (m)		Total Length (m)	Individual Length (m)		Gradient (%)		Weighted Gradient (%)
						Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		Mean	SD[1]	Mean	SD[1]	
Pool	7	87%	13,082	13,559	1,869	23.1	10.6	24.0	11.1	1.4	0.9	2.3	1.4	491	70.1	35.5	0	0	0
Glide	13	8%	1,158	1,276	89	4.3	1.4	4.7	1.3	0.4	0.2	0.8	0.3	251	19.3	16.5	0	0	0
Run	2	1%	135	142	67	4.6	0.6	4.9	0.5	0.3	0.1	0.8	0.1	29	14.5	2.1	1	0	1
Riffle	19	4%	651	741	34	2.9	1.2	3.3	1.2	0.2	0.1	0.5	0.2	238	12.5	10.8	2	1	2
Cascade	1	0%	21	23	21	3.5	-	3.8	-	0.2	-	0.5	-	6	6.0	-	4	-	4
Chute	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Falls	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Total	*42*	*100%*	*15,047*	*15,741*	*358*	*6.8*	*8.5*	*7.3*	*8.8*	*0.5*	*0.6*	*0.9*	*0.9*	*1,015*	*24.2*	*27.6*	*1*	*1*	*1*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 14. Fish Pond Creek water quality, calcite, gravel, and spawning data, by habitat type, 2019.

Habitat Type	Mean Velocity (m/s)		Mean Flow (cms)		Calcite Measures CI		Calcite Measures CC		Calcite Measures CP		Mean Pebble Size (mm)		Gravel Prop. (%)		Water Temp. (°C)		DO (mg/L)		Spec. Cond/ (µS/cm)		pH		Total Redds	Redd Density (#/m^2)
	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		
Pool	0.09	0.06	0.09	0.05	0.23	0.20	0.00	0.00	0.23	0.20	52.1	15.1	4.32	6.18	8.1	1.4	7.8	0.7	338.0	15.0	8.0	0.1	3	0.000
Glide	0.14	0.13	0.13	0.12	0.29	0.31	0.00	0.01	0.29	0.30	54.7	25.8	5.00	8.05	8.5	1.5	8.3	0.8	342.6	13.3	8.1	0.2	35	0.014
Run	0.31	0.06	0.30	0.02	0.87	0.05	0.00	0.00	0.87	0.05	115.9	12.5	7.52	7.36	7.6	0.2	8.0	1.0	339.0	1.6	8.1	0.0	0	0.000
Riffle	0.43	0.22	0.20	0.15	0.28	0.35	0.00	0.00	0.28	0.35	83.0	42.7	2.67	4.69	7.9	0.8	8.1	0.8	338.5	11.8	8.1	0.2	9	0.008
Cascade	0.86	-	0.49	-	0.07	-	0.00	-	0.07	-	90.1	-	0.00	-	7.8	-	7.3	-	338.9	-	8.2	-	0	0.000
Chute	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Falls	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	*0.27*	*0.23*	*0.17*	*0.14*	*0.29*	*0.32*	*0.00*	*0.01*	*0.29*	*0.32*	*68.8*	*36.3*	*3.92*	*6.42*	*8.2*	*1.2*	*8.1*	*0.8*	*340.0*	*12.5*	*8.1*	*0.2*	*47*	*0.002*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 15. Grace Creek habitat data, by habitat type, 2019.

Habitat Type	Number of Units	% of Total Habitat	Total Wetted Area (m^2)	Total Bankfull Area (m^2)	Mean Wetted Area (m^2)	Wetted Width (m)		Bankfull Width (m)		Wetted Depth (m)		Bankfull Depth (m)		Total Length (m)	Individual Length (m)		Gradient (%)		Weighted Gradient (%)
						Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		Mean	SD[1]	Mean	SD[1]	
Pool	14	11%	255	256	18	3.3	0.8	3.3	0.8	0.4	0.1	0.8	0.1	76	5.4	1.9	1	0	1
Glide	5	10%	249	292	50	2.6	0.8	2.9	0.8	0.2	0.1	0.4	0.1	112	22.4	21.3	1	0	1
Run	25	71%	1,699	1,785	68	3.0	0.7	3.2	0.7	0.2	0.1	0.5	0.1	565	22.6	16.4	2	0	2
Riffle	5	5%	130	133	26	2.9	0.7	2.9	0.6	0.1	0.0	0.3	0.0	47	9.4	4.9	2	0	2
Cascade	3	2%	56	58	19	3.9	1.1	4.1	1.0	0.3	0.0	0.7	0.1	14	4.7	0.6	10	10	9
Chute	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Falls	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Total	*52*	*100%*	*2,389*	*2,523*	*46*	*3.1*	*0.8*	*3.2*	*0.7*	*0.2*	*0.1*	*0.5*	*0.2*	*814*	*15.7*	*15.3*	*2*	*3*	*2*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 16. Grace Creek water quality, calcite, gravel, and spawning data, by habitat type, 2019.

Habitat Type	Mean Velocity (m/s)		Mean Flow (cms)		Calcite Measures CI		CC		CP		Mean Pebble Size (mm)		Gravel Prop. (%)		Water Temp. (°C)		DO (mg/L)		Spec. Cond/ (µS/cm)		pH		Total Redds	Redd Density (#/m^2)
	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		
Pool	0.45	0.10	0.22	0.05	0.10	0.15	0.00	0.00	0.10	0.15	20.2	9.3	3.42	3.68	7.5	1.0	10.5	0.0	397.7	0.0	8.5	0.0	0	0.000
Glide	0.32	0.22	0.15	0.09	0.09	0.09	0.00	0.00	0.09	0.09	14.1	11.1	3.80	4.81	6.6	0.8	10.6	0.0	398.1	0.9	8.3	0.3	0	0.000
Run	0.45	0.11	0.21	0.06	0.13	0.15	0.00	0.00	0.13	0.15	27.6	13.0	19.68	15.37	7.7	1.1	10.5	0.1	397.6	0.3	8.4	0.0	0	0.000
Riffle	0.57	0.07	0.20	0.01	0.41	0.35	0.00	0.00	0.41	0.35	48.4	23.0	10.17	10.67	7.6	1.5	10.5	0.0	397.7	0.0	8.5	0.0	0	0.000
Cascade	0.43	0.20	0.28	0.04	0.07	0.12	0.00	0.00	0.07	0.12	43.3	28.3	4.17	3.33	8.7	0.9	10.5	0.0	397.7	0.0	8.4	0.0	0	0.000
Chute	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Falls	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	*0.45*	*0.13*	*0.21*	*0.06*	*0.14*	*0.19*	*0.00*	*0.00*	*0.14*	*0.19*	*27.1*	*16.4*	*12.74*	*###*	*7.6*	*1.1*	*10.5*	*0.0*	*397.7*	*0.3*	*8.4*	*0.1*	*0*	*0.000*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 17. Grave Creek habitat data, by habitat type, 2019.

Habitat Type	Number of Units	% of Total Habitat	Total Wetted Area (m^2)	Total Bankfull Area (m^2)	Mean Wetted Area (m^2)	Wetted Width (m)		Bankfull Width (m)		Wetted Depth (m)		Bankfull Depth (m)		Total Length (m)	Individual Length (m)		Gradient (%)		Weighted Gradient (%)
						Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		Mean	SD[1]	Mean	SD[1]	
Pool	3	1%	45	66	15	5.3	1.6	7.7	1.5	0.3	0.2	0.7	0.3	9	2.8	0.8	0	0	0
Glide	5	2%	138	228	28	3.3	0.9	5.3	1.4	0.3	0.1	0.7	0.1	40	8.0	3.0	1	0	1
Run	5	5%	274	352	55	4.5	1.1	5.9	1.0	0.2	0.1	0.6	0.2	58	11.6	5.7	2	1	2
Riffle	24	42%	2,521	4,016	110	4.1	1.5	6.5	1.9	0.2	0.1	0.6	0.2	611	26.6	18.7	3	1	3
Cascade	24	50%	3,035	4,234	126	3.9	1.9	5.4	2.2	0.2	0.1	0.6	0.2	768	32.0	20.2	6	1	5
Chute	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Falls	3	0%	20	27	7	4.0	3.8	5.8	3.2	0.2	0.1	0.5	0.2	4	1.3	0.6	117	58	100
Total	*64*	*100%*	*6,034*	*8,922*	*96*	*4.1*	*1.7*	*6.0*	*2.0*	*0.2*	*0.1*	*0.6*	*0.2*	*1,490*	*23.6*	*19.6*	*9*	*26*	*4*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 18. Grave Creek water quality, calcite, gravel, and spawning data, by habitat type, 2019.

Habitat Type	Mean Velocity (m/s)		Mean Flow (cms)		Calcite Measures CI		Calcite Measures CC		Calcite Measures CP		Mean Pebble Size (mm)		Gravel Prop. (%)		Water Temp. (°C)		DO (mg/L)		Spec. Cond/ (µS/cm)		pH		Total Redds	Redd Density (#/m^2)
	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		
Pool	0.31	-	0.51	-	0.03	0.02	0.00	0.00	0.03	0.02	46.6	23.2	0.60	0.90	8.0	-	9.6	0.0	290.5	0.0	8.4	-	0	0.000
Glide	0.43	-	0.46	-	0.07	0.06	0.00	0.00	0.07	0.06	61.7	3.4	0.60	0.79	5.8	-	9.6	0.0	290.5	0.0	8.4	-	0	0.000
Run	0.43	0.07	0.45	0.11	0.01	0.01	0.00	0.00	0.01	0.01	66.3	12.1	1.95	2.64	8.2	1.1	9.6	0.2	291.7	2.8	8.3	0.2	0	0.000
Riffle	0.50	0.15	0.57	0.29	0.06	0.07	0.00	0.00	0.06	0.07	66.3	15.2	1.19	1.75	7.4	1.6	9.6	0.2	290.4	0.5	8.4	0.0	5	0.001
Cascade	0.65	0.19	0.79	0.78	0.04	0.07	0.00	0.00	0.04	0.07	88.5	22.7	1.30	1.37	7.8	1.6	9.7	0.3	290.3	1.7	8.4	0.0	0	0.000
Chute	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Falls	0.39	-	1.25	-	0.00	0.00	0.00	0.00	0.00	0.00	41.2	46.2	0.00	0.00	7.6	-	9.6	0.0	290.5	0.0	8.5	-	0	0.000
Total	*0.54*	*0.20*	*0.66*	*0.58*	*0.05*	*0.06*	*0.00*	*0.00*	*0.05*	*0.06*	*72.8*	*23.2*	*1.13*	*1.56*	*7.6*	*1.5*	*9.6*	*0.3*	*290.5*	*1.3*	*8.4*	*0.1*	*5*	*0.001*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 19. Harmer Creek habitat data, by habitat type, 2019.

Habitat Type	Number of Units	% of Total Habitat	Total Wetted Area (m^2)	Total Bankfull Area (m^2)	Mean Wetted Area (m^2)	Wetted Width (m)		Bankfull Width (m)		Wetted Depth (m)		Bankfull Depth (m)		Total Length (m)	Individual Length (m)		Gradient (%)		Weighted Gradient (%)
						Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		Mean	SD[1]	Mean	SD[1]	
Pool	5	11%	798	842	160	9.8	9.9	10.9	10.0	0.6	0.3	0.8	0.3	52	10.4	9.4	0	0	0
Glide	14	12%	915	2,855	65	3.9	1.6	8.5	13.8	0.2	0.1	0.5	0.1	220	15.7	8.7	1	0	1
Run	7	8%	591	653	84	5.0	0.7	5.7	0.6	0.3	0.1	0.6	0.1	116	16.6	7.7	2	1	2
Riffle	36	54%	4,005	4,854	114	4.2	2.0	5.2	2.0	0.2	0.1	0.5	0.1	863	24.0	15.6	3	1	3
Cascade	11	15%	1,088	1,223	99	5.5	1.3	6.3	1.5	0.2	0.1	0.5	0.2	200	18.2	17.1	5	1	5
Chute	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Falls	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Total	*73*	*100%*	*7,397*	*10,427*	*103*	*4.8*	*3.2*	*6.4*	*6.7*	*0.3*	*0.1*	*0.5*	*0.2*	*1,451*	*19.9*	*14.2*	*2*	*2*	*3*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 20. Harmer Creek water quality, calcite, gravel, and spawning data, by habitat type, 2019.

Habitat Type	Mean Velocity (m/s)		Mean Flow (cms)		Calcite Measures CI		CC		CP		Mean Pebble Size (mm)		Gravel Prop. (%)		Water Temp. (°C)		DO (mg/L)		Spec. Cond/ (µS/cm)		pH		Total Redds	Redd Density (#/m^2)
	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		
Pool	0.33	0.30	0.61	0.48	0.85	0.13	0.00	0.00	0.85	0.13	47.0	11.5	1.81	3.37	7.1	0.1	9.8	0.0	590.0	0.0	8.4	0.0	1	0.001
Glide	0.16	0.11	0.34	0.36	0.81	0.30	0.00	0.00	0.81	0.30	54.3	28.8	0.32	0.57	7.1	0.3	9.7	0.2	587.4	10.0	8.4	0.1	4	0.001
Run	0.50	0.12	0.69	0.36	0.93	0.10	0.00	0.00	0.93	0.10	63.7	25.0	5.81	9.17	7.0	0.5	9.7	0.2	585.6	11.9	8.4	0.1	0	0.000
Riffle	0.51	0.21	0.55	0.34	0.93	0.18	0.01	0.03	0.92	0.18	62.3	27.2	4.86	16.82	6.9	0.4	9.8	0.1	589.3	3.9	8.4	0.1	9	0.002
Cascade	0.57	0.19	0.72	0.30	1.00	0.07	0.02	0.07	0.98	0.03	104.4	58.8	0.29	0.38	7.0	0.4	9.8	0.2	598.7	28.6	8.4	0.1	0	0.000
Chute	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Falls	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	*0.46*	*0.23*	*0.58*	*0.35*	*0.89*	*0.24*	*0.01*	*0.03*	*0.88*	*0.24*	*64.7*	*37.5*	*3.06*	*12.03*	*7.0*	*0.4*	*9.8*	*0.1*	*590.0*	*12.6*	*8.4*	*0.1*	*15*	*0.001*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 21. Henretta Creek habitat data, by habitat type, 2019.

Habitat Type	Number of Units	% of Total Habitat	Total Wetted Area (m^2)	Total Bankfull Area (m^2)	Mean Wetted Area (m^2)	Wetted Width (m)		Bankfull Width (m)		Wetted Depth (m)		Bankfull Depth (m)		Total Length (m)	Individual Length (m)		Gradient (%)		Weighted Gradient (%)
						Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		Mean	SD[1]	Mean	SD[1]	
Pool	1	2%	323	323	323	17.0	-	17.0	-	2.5	-	4.2	-	19	19.0	-	0	-	0
Glide	8	26%	3,643	4,193	455	12.8	1.4	14.7	2.7	0.7	0.1	1.2	0.3	294	36.8	20.0	0	0	0
Run	11	19%	2,730	3,003	248	9.9	1.8	10.8	3.4	0.7	0.2	1.0	0.4	273	24.8	6.4	1	1	1
Riffle	18	38%	5,360	6,516	298	10.2	4.2	11.9	4.4	0.4	0.1	0.7	0.3	525	29.2	20.2	3	1	2
Cascade	11	15%	2,068	2,210	188	8.8	2.2	9.4	2.3	0.5	0.1	0.7	0.3	247	22.5	14.4	5	1	5
Chute	1	0%	14	15	14	7.0	-	7.5	-	0.3	-	0.4	-	2	2.0	-	8	-	8
Falls	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Total	*50*	*100%*	*14,138*	*16,260*	*283*	*10.3*	*3.3*	*11.6*	*3.9*	*0.6*	*0.3*	*0.9*	*0.6*	*1,360*	*27.2*	*16.9*	*2*	*2*	*2*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 22. Henretta Creek water quality, calcite, gravel, and spawning data, by habitat type, 2019.

Habitat Type	Mean Velocity (m/s)		Mean Flow (cms)		Calcite Measures CI		Calcite Measures CC		Calcite Measures CP		Mean Pebble Size (mm)		Gravel Prop. (%)		Water Temp. (°C)		DO (mg/L)		Spec. Cond/ (µS/cm)		pH		Total Redds	Redd Density (#/m^2)
	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		
Pool	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Glide	0.33	0.06	1.69	0.84	0.00	0.01	0.00	0.00	0.00	0.01	56.4	9.3	2.31	4.05	7.5	1.4	9.2	0.5	361.0	43.8	8.3	0.3	1	0.000
Run	0.38	0.10	2.29	0.80	0.12	0.30	0.00	0.01	0.12	0.30	84.7	32.8	4.09	6.76	7.6	1.1	9.4	0.4	323.6	42.7	8.2	0.4	0	0.000
Riffle	0.77	0.31	2.44	1.12	0.15	0.30	0.00	0.01	0.15	0.29	86.3	44.7	7.84	20.43	7.2	1.4	9.5	0.4	328.6	40.2	8.1	0.3	0	0.000
Cascade	0.93	0.25	3.31	1.13	0.01	0.03	0.00	0.00	0.01	0.03	182.3	60.3	0.41	0.87	7.2	0.6	9.6	0.0	315.7	12.3	8.1	0.1	0	0.000
Chute	1.44	-	2.86	-	0.00	-	0.00	-	0.00	-	137.3	-	0.00	-	7.3	-	9.6	-	311.6	-	7.9	-	0	0.000
Falls	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	*0.65*	*0.35*	*2.46*	*1.09*	*0.08*	*0.23*	*0.00*	*0.01*	*0.08*	*0.22*	*102.4*	*60.5*	*4.02*	*12.28*	*7.3*	*1.1*	*9.4*	*0.4*	*330.0*	*38.6*	*8.2*	*0.3*	*1*	*0.000*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 23. Lizard Creek habitat data, by habitat type, 2019.

Habitat Type	Number of Units	% of Total Habitat	Total Wetted Area (m²)	Total Bankfull Area (m²)	Mean Wetted Area (m²)	Wetted Width (m)		Bankfull Width (m)		Wetted Depth (m)		Bankfull Depth (m)		Total Length (m)	Individual Length (m)		Gradient (%)		Weighted Gradient (%)
						Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		Mean	SD[1]	Mean	SD[1]	
Pool	9	6%	297	360	33	4.3	1.8	5.2	2.5	0.7	0.2	1.4	0.4	63	7.0	2.8	1	0	1
Glide	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Run	20	44%	2,250	3,504	113	5.8	1.8	9.1	3.2	0.3	0.1	0.7	0.2	394	19.7	6.1	1	0	1
Riffle	15	44%	2,261	3,769	151	5.7	2.0	9.2	2.9	0.2	0.1	0.5	0.2	392	26.1	21.1	2	1	2
Cascade	3	5%	280	339	93	7.3	2.2	8.6	1.4	0.2	0.1	0.5	0.1	41	13.7	9.7	5	1	5
Chute	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Falls	1	0%	4	5	4	3.5	-	4.5	-	-	-	-	-	1	1.0	-	125	-	125
Total	*48*	*100%*	*5,091*	*7,976*	*106*	*5.5*	*2.0*	*8.3*	*3.2*	*0.4*	*0.2*	*0.8*	*0.4*	*891*	*18.6*	*14.3*	*4*	*18*	*2*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 24. Lizard Creek water quality, calcite, gravel, and spawning data, by habitat type, 2019.

Habitat Type	Mean Velocity (m/s)		Mean Flow (cms)		Calcite Measures CI		Calcite Measures CC		Calcite Measures CP		Mean Pebble Size (mm)		Gravel Prop. (%)		Water Temp. (°C)		DO (mg/L)		Spec. Cond/ (µS/cm)		pH		Total Redds	Redd Density (#/m²)
	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		
Pool	0.13	0.10	0.41	0.34	0.32	0.27	0.00	0.00	0.32	0.27	43.4	22.9	0.55	0.98	13.2	2.2	10.3	0.0	436.0	0.0	8.9	0.1	6	0.017
Glide	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Run	0.38	0.12	0.57	0.24	0.62	0.23	0.00	0.00	0.62	0.23	63.8	19.0	19.28	15.87	13.4	2.1	10.3	0.1	436.0	0.5	8.9	0.0	137	0.039
Riffle	0.47	0.18	0.78	0.70	0.64	0.16	0.00	0.00	0.64	0.16	71.7	15.6	11.19	16.57	13.4	2.1	10.4	0.2	436.0	0.0	8.9	0.1	53	0.014
Cascade	0.56	0.33	0.61	0.18	0.73	0.25	0.00	0.00	0.73	0.25	99.4	16.2	1.43	2.48	14.5	1.1	10.3	0.0	436.0	0.0	8.9	0.0	0	0.000
Chute	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Falls	-	-	-	-	0.70	-	0.00	-	0.70	-	2.0	-	0.00	-	-	-	10.3	-	436.0	-	-	-	0	0.000
Total	*0.37*	*0.20*	*0.61*	*0.45*	*0.58*	*0.24*	*0.00*	*0.00*	*0.58*	*0.24*	*63.4*	*24.1*	*11.72*	*15.56*	*13.4*	*2.1*	*10.3*	*0.1*	*436.0*	*0.3*	*8.9*	*0.1*	*196*	*0.025*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 25. Lower Greenhills Creek habitat data, by habitat type, 2019.

Habitat Type	Number of Units	% of Total Habitat	Total Wetted Area (m^2)	Total Bankfull Area (m^2)	Mean Wetted Area (m^2)	Wetted Width (m)		Bankfull Width (m)		Wetted Depth (m)		Bankfull Depth (m)		Total Length (m)	Individual Length (m)		Gradient (%)		Weighted Gradient (%)
						Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		Mean	SD[1]	Mean	SD[1]	
Pool	8	12%	210	264	26	3.3	2.5	5.2	3.2	0.5	0.2	1.0	0.4	46	5.7	3.6	0	0	0
Glide	18	28%	497	760	28	2.4	1.1	4.2	1.6	0.2	0.1	0.6	0.1	212	11.8	9.1	1	1	1
Run	7	8%	141	206	20	1.9	0.5	2.7	0.7	0.2	0.1	0.7	0.2	80	11.4	5.3	2	1	2
Riffle	17	49%	869	1,416	51	2.2	0.9	3.6	1.7	0.1	0.0	0.4	0.2	460	27.1	23.2	3	1	3
Cascade	4	4%	66	88	33	1.9	1.6	2.4	1.6	0.1	0.0	0.4	0.0	44	22.0	18.4	6	5	3
Chute	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Falls	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Total	*54*	*100%*	*1,783*	*2,733*	*34*	*2.4*	*1.3*	*3.8*	*2.0*	*0.2*	*0.2*	*0.6*	*0.3*	*841*	*16.2*	*16.6*	*2*	*2*	*2*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 26. Lower Greenhills Creek water quality, calcite, gravel, and spawning data, by habitat type, 2019.

Habitat Type	Mean Velocity (m/s)		Mean Flow (cms)		Calcite Measures: CI		Calcite Measures: CC		Calcite Measures: CP		Mean Pebble Size (mm)		Gravel Prop. (%)		Water Temp. (°C)		DO (mg/L)		Spec. Cond/ (µS/cm)		pH		Total Redds	Redd Density (#/m^2)
	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		
Pool	0.15	0.13	0.22	0.12	0.50	0.53	0.07	0.14	0.43	0.42	42.7	50.1	0.26	0.42	13.2	0.9	8.6	0.0	1184.7	0.0	8.5	0.0	0	0.000
Glide	0.22	0.13	0.14	0.06	0.52	0.40	0.06	0.16	0.45	0.29	41.5	27.4	0.60	0.74	13.5	1.2	8.9	0.6	1248.1	123.0	8.4	0.1	6	0.006
Run	0.22	0.14	0.14	0.07	0.17	0.10	0.00	0.00	0.17	0.10	17.1	13.1	0.51	0.89	13.0	0.7	8.6	0.1	1189.5	12.7	8.5	0.0	0	0.000
Riffle	0.32	0.17	0.14	0.08	0.86	0.61	0.27	0.34	0.60	0.34	69.2	48.6	0.84	1.40	13.9	1.4	8.9	0.6	1242.1	116.4	8.4	0.2	5	0.003
Cascade	0.55	-	0.31	-	1.97	-	1.10	-	0.87	-	89.9	-	0.00	0.00	14.0	-	8.6	0.0	1184.7	0.0	8.5	-	0	0.000
Chute	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Falls	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	*0.25*	*0.15*	*0.15*	*0.08*	*0.62*	*0.54*	*0.14*	*0.27*	*0.47*	*0.34*	*48.6*	*40.6*	*0.55*	*0.97*	*13.6*	*1.2*	*8.8*	*0.6*	*1228.2*	*105.2*	*8.4*	*0.1*	*11*	*0.003*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 27. McCool Creek habitat data, by habitat type, 2019.

Habitat Type	Number of Units	% of Total Habitat	Total Wetted Area (m^2)	Total Bankfull Area (m^2)	Mean Wetted Area (m^2)	Wetted Width (m)		Bankfull Width (m)		Wetted Depth (m)		Bankfull Depth (m)		Total Length (m)	Individual Length (m)		Gradient (%)		Weighted Gradient (%)
						Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		Mean	SD[1]	Mean	SD[1]	
Pool	9	3%	90	96	10	3.3	0.8	3.5	0.9	0.5	0.1	0.7	0.2	28	3.1	0.9	0	0	0
Glide	1	1%	21	22	21	3.0	-	3.1	-	0.5	-	0.6	-	7	7.0	-	1	-	1
Run	12	15%	470	497	39	3.8	0.6	4.0	0.6	0.3	0.1	0.4	0.1	130	10.8	11.9	2	1	3
Riffle	15	43%	1,325	1,534	88	3.5	1.2	3.9	1.3	0.2	0.0	0.3	0.1	344	22.9	18.8	3	0	3
Cascade	10	38%	1,164	1,273	116	3.7	0.9	4.1	1.1	0.3	0.0	0.4	0.1	328	32.8	25.0	6	1	5
Chute	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Falls	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Total	*47*	*100%*	*3,069*	*3,422*	*65*	*3.6*	*0.9*	*3.9*	*1.0*	*0.3*	*0.1*	*0.4*	*0.2*	*837*	*17.8*	*19.5*	*3*	*2*	*4*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 28. McCool Creek water quality, calcite, gravel, and spawning data, by habitat type, 2019.

Habitat Type	Mean Velocity (m/s)		Mean Flow (cms)		Calcite Measures CI		CC		CP		Mean Pebble Size (mm)		Gravel Prop. (%)		Water Temp. (°C)		DO (mg/L)		Spec. Cond/ (µS/cm)		pH		Total Redds	Redd Density (#/m^2)
	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		
Pool	0.39	0.13	0.29	0.15	0.82	0.12	0.00	0.00	0.82	0.12	62.4	13.9	1.17	1.94	7.5	0.7	10.3	0.1	411.2	1.0	8.5	0.0	0	0.000
Glide	0.45	-	0.39	-	0.93	-	0.00	-	0.93	-	55.4	-	0.00	-	8.4	-	10.3	-	411.7	-	8.5	-	0	0.000
Run	0.42	0.11	0.31	0.12	0.86	0.08	0.00	0.00	0.86	0.08	63.9	11.1	1.16	1.16	7.5	0.7	10.3	0.0	412.2	1.6	8.4	0.0	10	0.020
Riffle	0.46	0.15	0.25	0.11	0.77	0.17	0.00	0.00	0.77	0.17	71.1	11.2	1.01	0.95	7.2	0.8	10.3	0.0	411.7	0.0	8.4	0.0	8	0.005
Cascade	0.49	0.09	0.33	0.09	0.88	0.09	0.00	0.00	0.88	0.09	77.0	9.3	1.64	2.05	7.9	0.6	10.2	0.1	411.5	0.4	8.5	0.0	3	0.002
Chute	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Falls	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	*0.44*	*0.12*	*0.29*	*0.12*	*0.83*	*0.13*	*0.00*	*0.00*	*0.83*	*0.13*	*68.5*	*12.4*	*1.19*	*1.47*	*7.5*	*0.7*	*10.3*	*0.0*	*411.7*	*1.0*	*8.5*	*0.0*	*21*	*0.006*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 29. Michel Creek habitat data, by habitat type, 2019.

Habitat Type	Number of Units	% of Total Habitat	Total Wetted Area (m^2)	Total Bankfull Area (m^2)	Mean Wetted Area (m^2)	Wetted Width (m)		Bankfull Width (m)		Wetted Depth (m)		Bankfull Depth (m)		Total Length (m)	Individual Length (m)		Gradient (%)		Weighted Gradient (%)
						Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		Mean	SD[1]	Mean	SD[1]	
Pool	6	2%	157	167	26	4.1	1.7	4.4	1.6	0.8	0.1	1.7	0.5	35	5.8	2.7	1	0	1
Glide	2	7%	536	592	268	11.5	0.7	12.8	1.0	0.4	0.1	0.8	0.2	48	24.0	22.6	1	0	1
Run	16	48%	3,457	5,946	216	5.7	1.9	9.3	3.2	0.4	0.1	1.0	0.3	579	36.2	20.8	1	0	1
Riffle	11	36%	2,543	3,778	231	7.1	2.6	10.8	2.8	0.3	0.1	0.6	0.1	361	32.8	17.1	2	1	2
Cascade	6	6%	460	527	77	7.0	3.7	8.4	4.5	0.3	0.1	0.6	0.1	79	13.2	7.4	5	1	5
Chute	1	0%	2	6	2	1.0	-	2.3	-	0.1	-	0.3	-	2	2.4	-	30	-	30
Falls	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Total	*42*	*100%*	*7,155*	*11,015*	*170*	*6.2*	*2.9*	*8.9*	*3.8*	*0.4*	*0.2*	*0.9*	*0.5*	*1,104*	*26.3*	*20.0*	*3*	*5*	*2*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 30. Michel Creek water quality, calcite, gravel, and spawning data, by habitat type, 2019.

Habitat Type	Mean Velocity (m/s)		Mean Flow (cms)		Calcite Measures CI		CC		CP		Mean Pebble Size (mm)		Gravel Prop. (%)		Water Temp. (°C)		DO (mg/L)		Spec. Cond/ (µS/cm)		pH		Total Redds	Redd Density (#/m^2)
	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		
Pool	0.16	0.13	0.69	0.76	0.47	0.39	0.00	0.00	0.47	0.39	47.8	30.0	1.23	1.74	8.3	0.7	9.3	0.1	560.6	157.9	8.4	0.0	0	0.000
Glide	0.40	0.16	1.72	0.42	0.60	0.14	0.00	0.00	0.60	0.14	43.0	6.0	59.74	76.53	8.6	1.4	9.3	0.0	625.1	0.0	8.3	0.0	9	0.015
Run	0.57	0.14	1.24	0.61	0.80	0.16	0.00	0.00	0.80	0.16	64.2	13.4	29.55	36.02	8.6	0.9	9.2	0.2	456.0	198.0	8.4	0.1	27	0.005
Riffle	0.66	0.11	1.17	0.69	0.76	0.17	0.00	0.01	0.75	0.17	71.9	10.3	9.86	12.12	8.4	1.1	9.2	0.2	449.2	202.1	8.4	0.0	5	0.001
Cascade	0.87	0.16	1.69	1.09	0.65	0.29	0.00	0.00	0.65	0.29	71.7	17.9	7.48	17.54	8.6	0.8	9.3	0.1	560.6	157.9	8.3	0.0	0	0.000
Chute	1.35	-	0.14	-	0.00	-	0.00	-	0.00	-	43.4	-	0.00	-	-	-	9.3	-	625.1	-	-	-	0	0.000
Falls	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	*0.60*	*0.26*	*1.22*	*0.76*	*0.68*	*0.27*	*0.00*	*0.01*	*0.68*	*0.27*	*63.0*	*18.8*	*17.93*	*30.19*	*8.5*	*0.9*	*9.2*	*0.2*	*496.2*	*184.5*	*8.4*	*0.0*	*41*	*0.004*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 31. Thompson Creek habitat data, by habitat type, 2019.

Habitat Type	Number of Units	% of Total Habitat	Total Wetted Area (m^2)	Total Bankfull Area (m^2)	Mean Wetted Area (m^2)	Wetted Width (m)		Bankfull Width (m)		Wetted Depth (m)		Bankfull Depth (m)		Total Length (m)	Individual Length (m)		Gradient (%)		Weighted Gradient (%)
						Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		Mean	SD[1]	Mean	SD[1]	
Pool	7	4%	83	120	12	3.0	0.8	4.6	0.6	0.4	0.2	1.0	0.2	27	3.8	2.0	0	0	0
Glide	3	9%	193	8,100	64	2.1	1.2	100.0	0.0	0.2	0.1	1.2	0.1	81	27.0	8.2	0	1	0
Run	2	1%	22	141	11	1.9	0.6	10.8	8.8	0.2	0.0	0.7	0.1	12	5.9	1.6	1	1	1
Riffle	9	52%	1,110	22,734	123	1.7	0.7	25.3	42.3	0.2	0.1	0.8	0.1	635	70.6	50.4	2	1	2
Cascade	12	33%	689	1,316	57	2.1	0.7	5.7	4.7	0.2	0.1	0.7	0.1	327	27.3	28.2	9	4	10
Chute	2	1%	16	19	8	1.7	0.7	2.1	-	0.2	0.1	0.7	-	11	5.6	4.8	33	11	28
Falls	5	0%	4	2	2	1.9	0.0	4.5	-	-	-	-	-	5	1.0	0.5	117	55	129
Total	*40*	*100%*	*2,115*	*32,432*	*57*	*2.1*	*0.9*	*18.8*	*33.8*	*0.2*	*0.1*	*0.8*	*0.2*	*1,097*	*27.4*	*37.7*	*20*	*42*	*5*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 32. Thompson Creek water quality, calcite, gravel, and spawning data, by habitat type, 2019.

Habitat Type	Mean Velocity (m/s)		Mean Flow (cms)		Calcite Measures CI		Calcite Measures CC		Calcite Measures CP		Mean Pebble Size (mm)		Gravel Prop. (%)		Water Temp. (°C)		DO (mg/L)		Spec. Cond/ (µS/cm)		pH		Total Redds	Redd Density (#/m^2)
	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		
Pool	0.08	0.03	0.05	0.02	0.82	0.22	0.00	0.00	0.82	0.22	58.5	18.3	0.60	0.50	14.4	0.1	-	-	-	-	8.2	0.0	0	0.000
Glide	0.10	0.10	0.02	0.03	0.04	0.08	0.00	0.00	0.04	0.08	6.0	4.4	0.35	0.61	6.8	0.6	-	-	-	-	8.1	0.0	0	0.000
Run	0.31	0.06	0.04	0.01	0.48	0.49	0.00	0.00	0.48	0.49	50.3	23.8	2.18	0.11	14.2	0.4	-	-	-	-	8.3	0.1	0	0.000
Riffle	0.18	0.08	0.04	0.02	0.64	0.41	0.00	0.00	0.64	0.41	44.1	21.9	8.93	7.76	13.8	1.6	-	-	-	-	8.2	0.1	2	0.000
Cascade	0.35	0.05	0.04	0.03	0.78	0.26	0.01	0.03	0.78	0.26	58.9	16.9	0.72	0.92	13.5	3.0	-	-	-	-	8.2	0.1	0	0.000
Chute	-	-	-	-	0.95	0.02	0.00	0.00	0.95	0.02	68.5	5.1	0.00	0.00	-	-	-	-	-	-	-	-	0	0.000
Falls	0.43	0.04	0.03	0.01	0.97	0.03	0.00	0.00	0.97	0.03	67.8	-	0.00	0.00	14.3	0.1	-	-	-	-	8.2	0.0	0	0.000
Total	*0.24*	*0.13*	*0.04*	*0.02*	*0.70*	*0.35*	*0.00*	*0.02*	*0.70*	*0.35*	*50.8*	*23.0*	*2.46*	*5.03*	*13.2*	*2.9*	-	-	-	-	*8.2*	*0.1*	*2*	*0.000*

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 33. Upper Greenhills Creek habitat data, by habitat type, 2019.

Habitat Type	Number of Units	% of Total Habitat	Total Wetted Area (m^2)	Total Bankfull Area (m^2)	Mean Wetted Area (m^2)	Wetted Width (m)		Bankfull Width (m)		Wetted Depth (m)		Bankfull Depth (m)		Total Length (m)	Individual Length (m)		Gradient (%)		Weighted Gradient (%)
						Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		Mean	SD[1]	Mean	SD[1]	
Pool	2	1%	39	43	19	4.0	1.5	4.4	1.6	0.5	0.0	0.9	0.0	9	4.5	2.1	0	0	0
Glide	6	6%	158	176	26	3.0	1.5	3.4	1.6	0.2	0.1	0.5	0.1	50	8.3	4.9	1	1	2
Run	12	15%	432	490	36	2.9	1.2	3.3	1.4	0.2	0.0	0.4	0.0	142	11.8	7.9	2	1	2
Riffle	7	17%	467	533	67	3.1	0.5	3.5	0.5	0.2	0.0	0.4	0.1	148	21.1	21.4	3	0	3
Cascade	23	61%	1,710	1,985	74	3.1	1.2	3.6	1.3	0.2	0.0	0.4	0.1	587	25.5	22.2	7	2	7
Chute	0	0%	0	0	0	0.0	-	0.0	-	0.0	-	0.0	-	0	0.0	-	-	-	-
Falls	1	0%	5	5	5	4.7	-	5.1	-	-	-	-	-	1	1.0	-	150	-	150
Total	***51***	***100%***	***2,811***	***3,233***	***55***	***3.1***	***1.2***	***3.5***	***1.3***	***0.2***	***0.1***	***0.4***	***0.1***	***937***	***18.4***	***18.7***	***7***	***21***	***5***

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Table 34. Upper Greenhills Creek water quality, calcite, gravel, and spawning data, by habitat type, 2019.

Habitat Type	Mean Velocity (m/s)		Mean Flow (cms)		Calcite Measures CI		Calcite Measures CC		Calcite Measures CP		Mean Pebble Size (mm)		Gravel Prop. (%)		Water Temp. (°C)		DO (mg/L)		Spec. Cond/ (µS/cm)		pH		Total Redds	Redd Density (#/m^2)
	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		
Pool	0.16	0.14	0.09	0.02	1.58	0.49	0.58	0.49	1.00	0.00	57.4	0.3	0.24	0.33	7.5	0.2	9.4	0.0	1252.8	0.0	8.6	0.1	0	0.000
Glide	0.19	0.09	0.13	0.08	1.49	0.19	0.56	0.20	0.93	0.06	52.4	12.5	1.34	1.83	8.3	0.3	9.4	0.0	1252.8	0.0	8.5	0.1	0	0.000
Run	0.34	0.17	0.16	0.06	1.78	0.35	0.85	0.30	0.93	0.06	54.5	15.3	1.31	2.54	8.1	0.6	9.4	0.2	1253.9	4.4	8.6	0.1	2	0.004
Riffle	0.34	0.07	0.16	0.04	1.75	0.38	0.83	0.35	0.92	0.06	53.1	15.7	1.32	1.43	7.8	0.4	9.4	0.0	1252.4	1.1	8.5	0.1	0	0.000
Cascade	0.40	0.14	0.16	0.06	1.84	0.34	0.92	0.28	0.92	0.09	62.6	17.1	1.52	1.66	8.1	0.5	9.4	0.1	1252.4	5.4	8.6	0.1	0	0.000
Chute	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Falls	-	-	-	-	1.93	-	1.03	-	0.90	-	50.4	-	0.00	-	8.1	-	9.4	-	1252.8	-	8.5	-	0	0.000
Total	***0.34***	***0.15***	***0.15***	***0.06***	***1.77***	***0.34***	***0.85***	***0.31***	***0.93***	***0.08***	***57.8***	***15.7***	***1.29***	***1.81***	***8.1***	***0.5***	***9.4***	***0.1***	***1252.8***	***4.1***	***8.6***	***0.1***	***2***	***0.001***

[1]There are no standard deviations when habitat data was collected for only one unit or that unit was not present within the site.

Appendix D. HTML Viewer for Mesohabitat Scale Data in Calcite Study Streams, 2019

LIST OF LINKS

Link 1. HTML Viewer for Mesohabitat Scale Data in Calcite Study Streams, 2019.

https://ecofish.egnyte.com/dl/tDyATgwNiT

Appendix E. Data Infilling Procedures for Grave, Harmer, and Thompson Creeks

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1. ADDITIONAL SAMPLING AT GRAVE AND HARMER CREEKS

In the expanded reaches of Grave and Harmer Creeks, the water quality and hydrology data collected in October 2019 were not representative of the spawning period. In order to estimate data that are more representative of spawning conditions, water quality and hydrology data were collected in October 2019 in the originally sampled reaches as well. This October data were then compared to the data collected in June/July 2019 to assess the amount of change in water quality and hydrology parameters. For each parameter in each stream, a linear relationship was fit across all mesohabitat units, representing the average change in conditions from June/July to October.

These linear relationships were then applied to the October data in the expanded reaches to provide an estimate of what conditions would have been in these reaches during the spawning period (Table 1). In doing this, there are some key assumptions that have been made:

- The degree of change in conditions in the expanded reaches is the same as the degree of change in the original reaches;
- The degree of change in conditions within a given reach is similar across all mesohabitat units; and
- Water quality and hydrology parameters change linearly between June/July and October.

Parameters that were adjusted included pH, water temperature, conductivity, wetted width, velocity, and depth.

Figure 1. Change in pH between June/July sampling, and October sampling in the original study reaches of Grave and Harmer Creeks. Overall relationship is plotted in black.

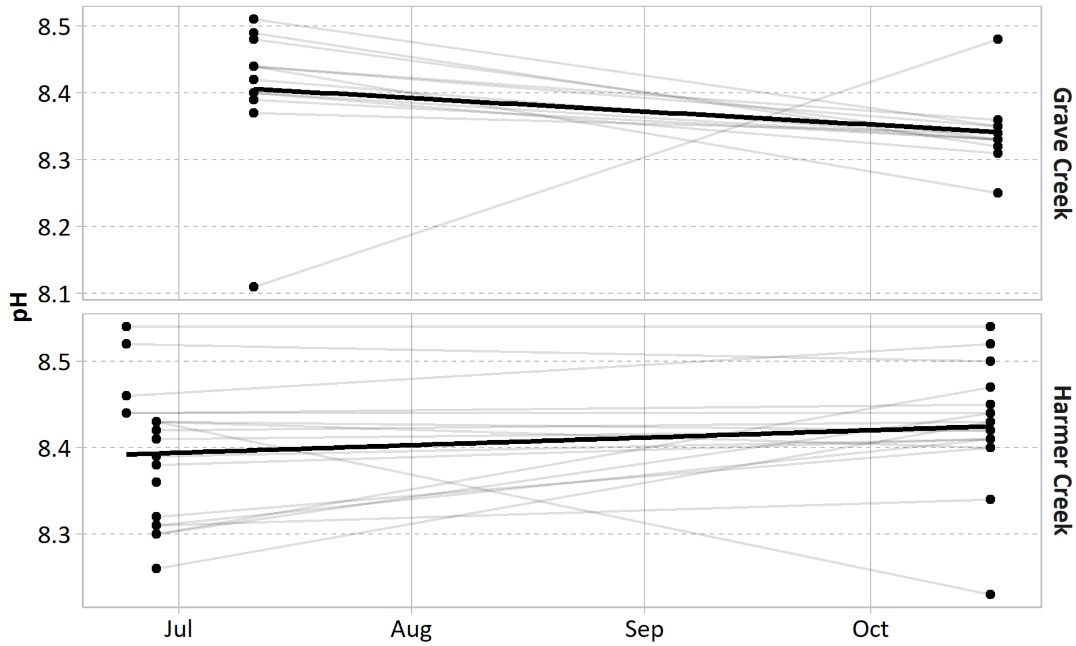

Figure 2. Change in water temperature between June/July sampling, and October sampling in the original study reaches of Grave and Harmer Creeks. Overall relationship is plotted in black.

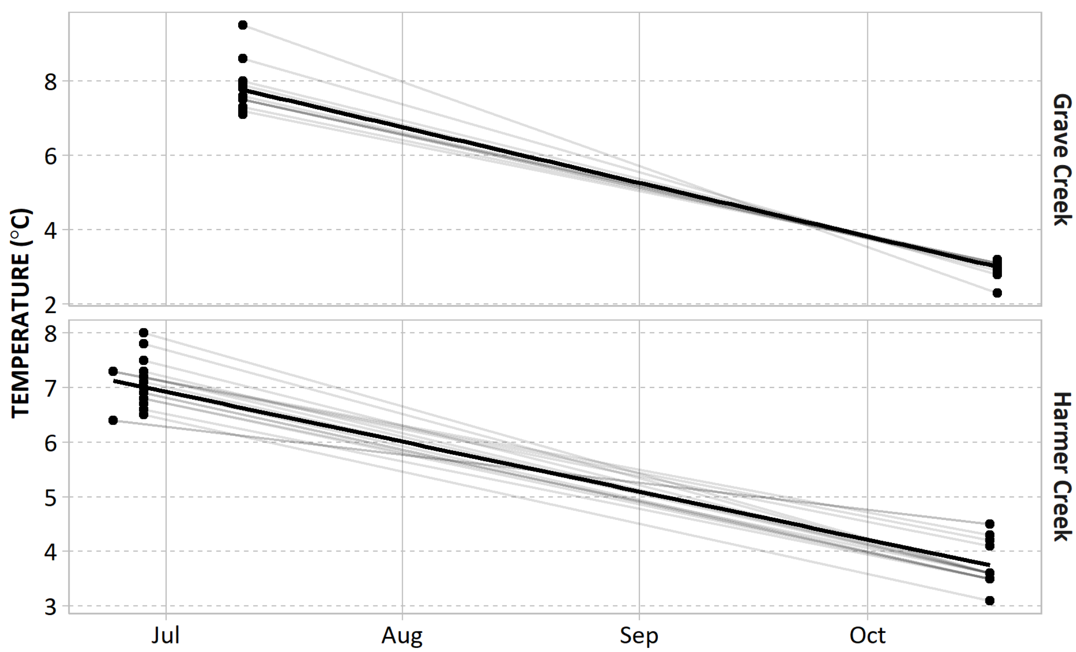

Figure 3. **Change in conductivity between June/July sampling, and October sampling in the original study reaches of Grave and Harmer Creeks. Overall relationship is plotted in black.**

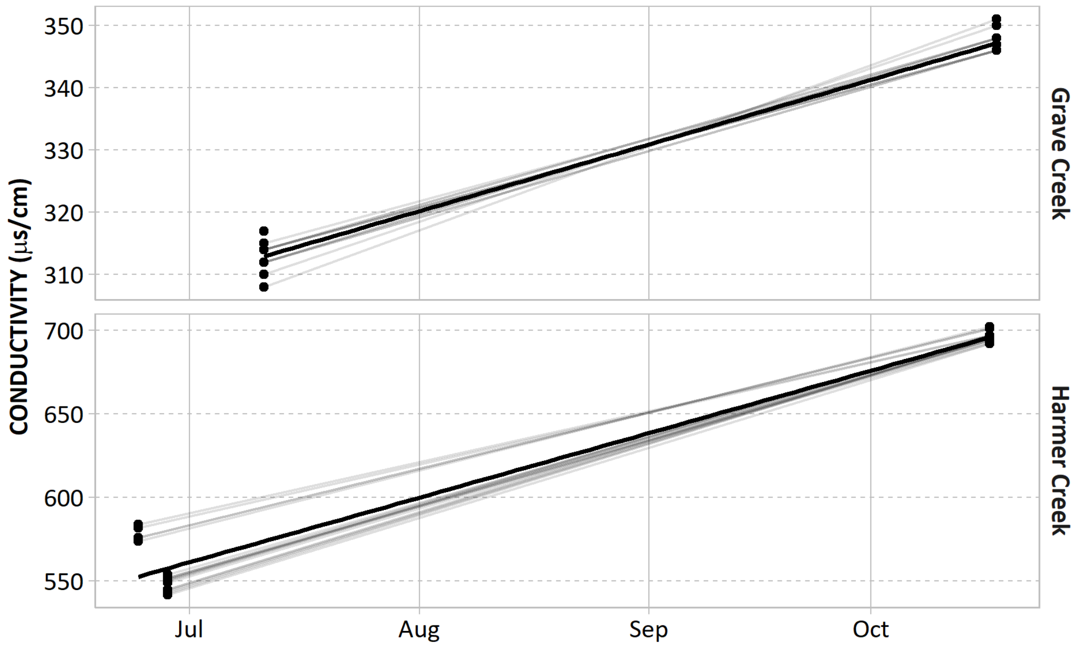

Figure 4. **Change in wetted width between June/July sampling, and October sampling in the original study reaches of Grave and Harmer Creeks. Overall relationship is plotted in black.**

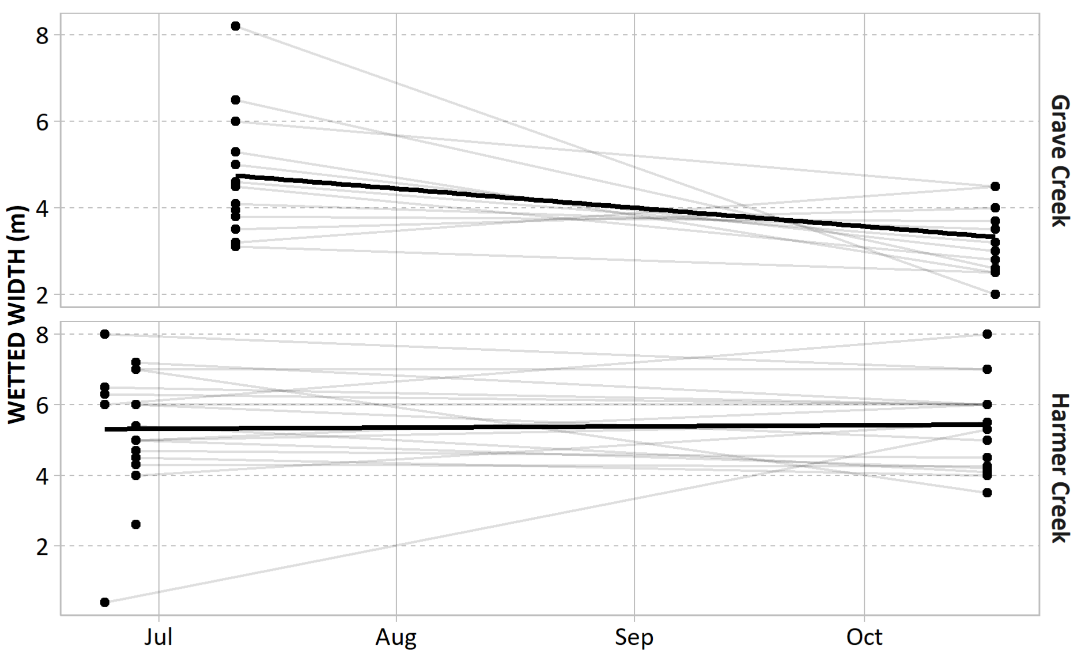

Figure 5. Change in water velocity between June/July sampling, and October sampling in the original study reaches of Grave and Harmer Creeks. Overall relationship is plotted in black.

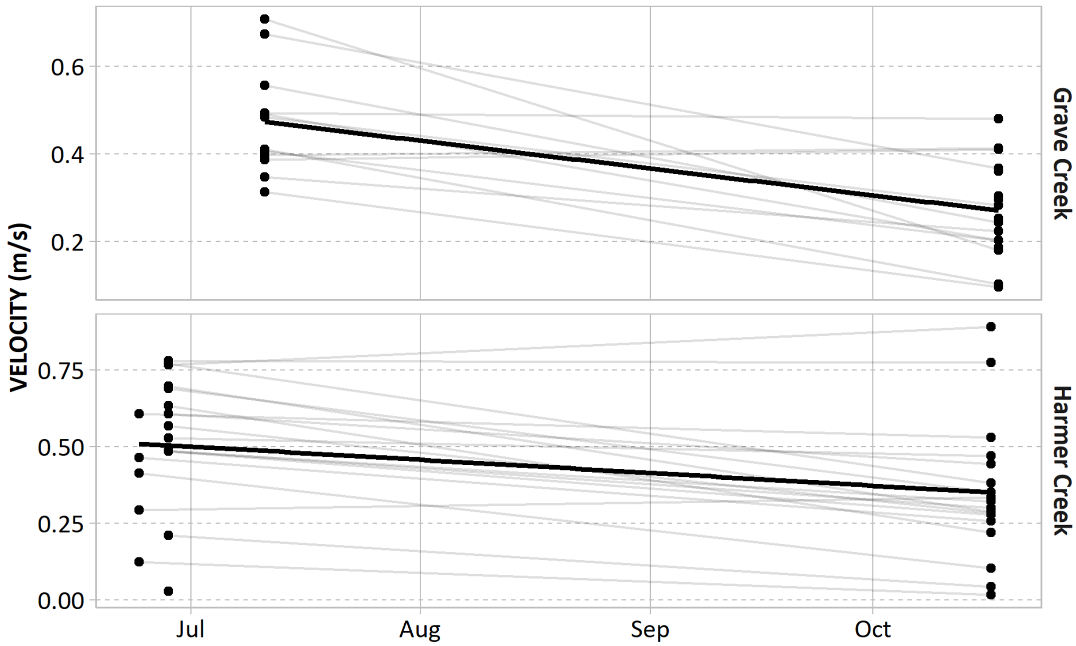

Figure 6. Change in water depth between June/July sampling, and October sampling in the original study reaches of Grave and Harmer Creeks. Overall relationship is plotted in black.

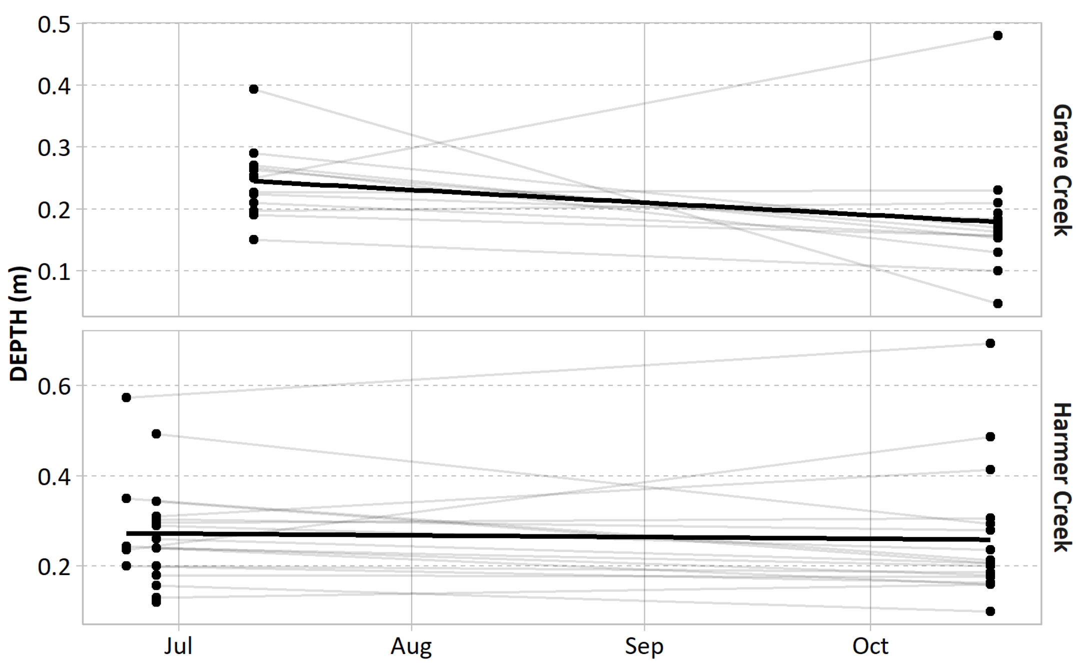

Table 1. Summary of predicted change in water quality and hydrology parameters from October sampling to June/July sampling.

Stream	Parameter	Units	Predicted Change from October to June/July[1]
Grave Creek	pH	-	+0.06
	Water Temperature	°C	+4.76
	Conductivity	µS/cm	-34.3
	Wetted Width	m	+1.42
	Water Velocity	m/s	+0.20
	Water Depth	m	+0.07
Harmer Creek	pH	-	-0.03
	Water Temperature	°C	+2.47
	Conductivity	µS/cm	-105
	Wetted Width	m	-0.09
	Water Velocity	m/s	+0.12
	Water Depth	m	+0.01

[1]Predicted change was calculated using the slope of a linear regression representing the change in parameter per month. Spawning period conditions were assumed to have occurred 3 months prior to October data.

2. ESTIMATION OF HYDROLOGY DATA AT THOMPSON CREEK

Estimation of the missing hydrology data at Thompson Creek was completed by comparing instream flow (IFS) data collected during the spawning period on June 16, 2019, to hydrology data collected in August 2019. Since the IFS data was not collected for each mesohabitat unit, the data were assessed by habitat type. The parameters estimated in this process included wetted width, velocity, and depth. Firstly, the IFS data were summarized by habitat type across the 16 transects where IFS data were collected. Next, the hydrology data collected in each mesohabitat unit in August 2019 were summarized by habitat type. The mean parameter values from the IFS data set where then divided by the mean parameter values from the August survey data to compute an adjustment factor. This adjustment factor was then applied to the August survey data at the mesohabitat unit scale to yield estimated parameter values corresponding to the spawning period. In all cases except pool depth and riffle wetted width, hydrology parameters were estimated to be lower during the spawning period than in August (Table 2). Additionally, the IFS transects did not include any chutes, falls, or runs; these habitat types were assumed to have the same adjustment factor as cascades (for chutes and falls), and glides (for runs). Key assumptions that were made as part of this estimation process include the following:

- The hydrology of individual mesohabitat units is expected to be similar to the hydrology of their corresponding mesohabitat type;
- Chute and Falls mesohabitat units are expected to behave similarly to Cascade mesohabitat units;
- Run mesohabitat units are expected to behave similarly to Glide mesohabitat units;
- IFS transects are representative of individual mesohabitat units; and
- IFS sampling accurately captured the variability of all mesohabitat units in Thompson Creek.

Table 2. Summary of hydrology data adjustment factors for Thompson Creek.

Mesohabitat	Mean IFS Data (June 2019)				Mean Survey Data (August 2019)				Adjustment Factor		
Type	# of Transects	Wetted Width (m)	Velocity (m/s)	Depth (m)	# of Mesohabitat Units	Wetted Width (m)	Velocity (m/s)	Depth (m)	Wetted Width	Velocity	Depth
Cascade	6	1.83	0.35	0.0614	10	2.19	0.54	0.15	0.84	0.66	0.42
Chute[1]	0	n/a	n/a	n/a	2	1.40	0.52	0.14	0.84	0.66	0.42
Falls[1]	0	n/a	n/a	n/a	4	2.68	0.58	0.09	0.84	0.66	0.42
Glide	1	1.97	0.10	0.154	3	2.53	0.12	0.20	0.78	0.85	0.77
Pool	4	2.86	0.09	0.224	6	2.90	0.18	0.17	0.99	0.48	1.30
Riffle	5	2.14	0.18	0.0863	9	1.96	0.32	0.13	1.09	0.56	0.68
Run[1]	0	n/a	n/a	n/a	2	1.40	0.37	0.15	0.78	0.85	0.77

[1]These mesohabitat types were not sampled as part of IFS sampling. Chute and Falls units are assumed to have the same adjustment factors as Cascade units, and Run units are assumed to have the same adjustment factor as Glide units.

Appendix F. Modelling Results with Calcite Index Used as a Predictor Variable

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Figure 1. **Model averaged coefficients (with 95% confidence intervals) indicating the most important variables predicting redd presence. Values in the x-axis are estimates of model parameters. RVI = Relative Variable Importance scores, where a score of 1 indicates that a predictor variable occurs in all top models with ΔAICc < 4.**

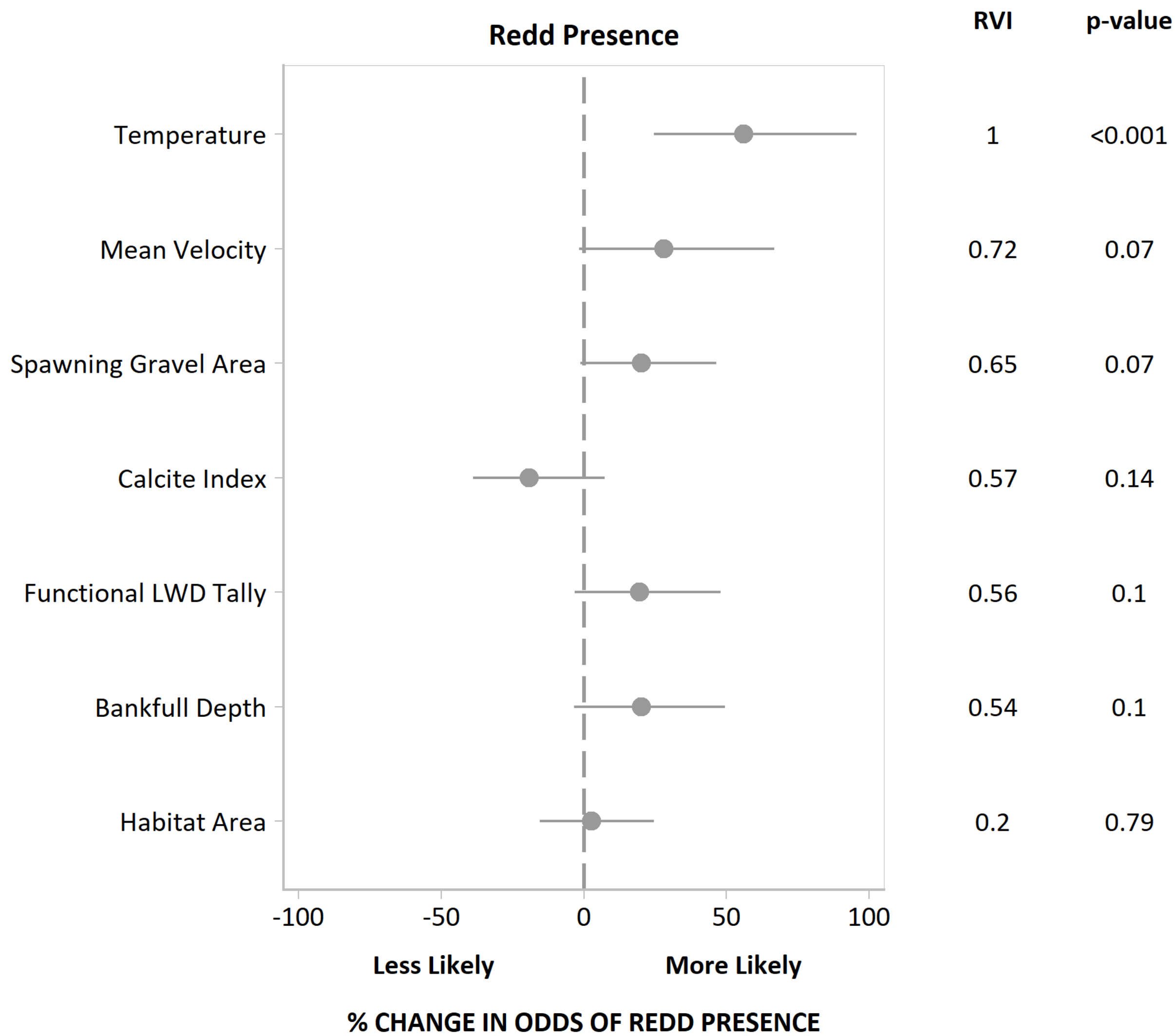


Figure 2. (a) Average calcite index (CI) score at mesohabitat units with redds present and with redds absent in tributaries of the Elk River, B.C. (b) Probability of redd presence versus CI. The solid line represents the predicted probability of redd presence as a function of CI, where all other predictors are held at their means (estimated from a logistic regression model: model averaged parameter estimates for calcite shown in Figure 1). The points represent the observed probability of redd presence by stream (p = # of units with redds present / total # of units in the stream).

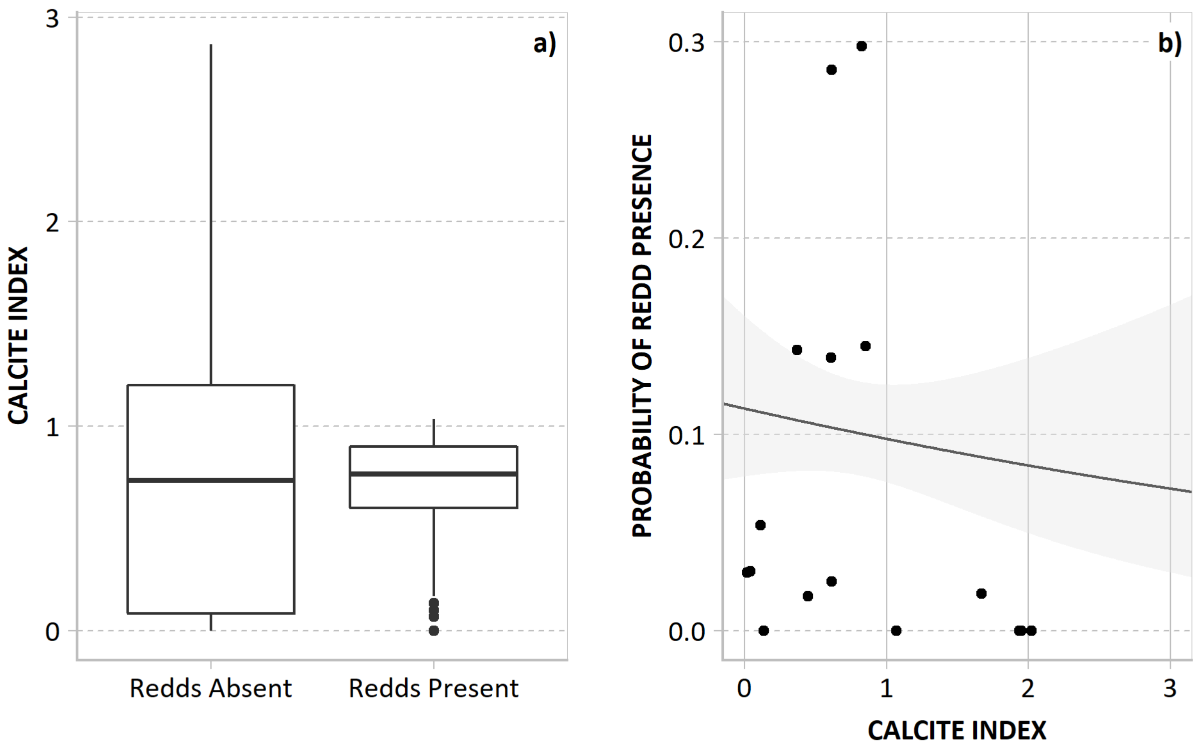


Table 1. **Top models that best predict Westslope Cutthroat Trout redd presence in tributaries of the Elk River, B.C. Models are ranked by Δ Akaike Information Criterion (ΔAICc) scores. The model with the lowest ΔAICc is the best model. Model weights (range 0-1) are also shown, which provide an estimate of the likelihood that a given model is the best model compared to the other top models in the model set.**

Model	ΔAICc	Weight
Redd Presence ~ Bankfull Depth + Functional LWD Tally + Mean Velocity + Spawning Gravel + Temperature	0.00	0.07
Redd Presence ~ Bankfull Depth + Mean Velocity + Spawning Gravel + Temperature	0.62	0.05
Redd Presence ~ Bankfull Depth + CI + Functional LWD Tally + Mean Velocity + Spawning Gravel + Temperature	0.75	0.05
Redd Presence ~ Bankfull Depth + CI + Mean Velocity + Spawning Gravel + Temperature	1.09	0.04
Redd Presence ~ CI + Functional LWD Tally + Mean Velocity + Spawning Gravel + Temperature	1.17	0.04
Redd Presence ~ Functional LWD Tally + Mean Velocity + Spawning Gravel + Temperature	1.26	0.04
Redd Presence ~ CI + Functional LWD Tally + Mean Velocity + Temperature	1.38	0.03
Redd Presence ~ Bankfull Depth + CI + Functional LWD Tally + Mean Velocity + Temperature	1.41	0.03
Redd Presence ~ Bankfull Depth + Functional LWD Tally + Mean Velocity + Temperature	1.51	0.03
Redd Presence ~ CI + Mean Velocity + Spawning Gravel + Temperature	1.64	0.03
Redd Presence ~ CI + Functional LWD Tally + Spawning Gravel + Temperature	1.70	0.03
Redd Presence ~ Bankfull Depth + CI + Mean Velocity + Temperature	1.71	0.03
Redd Presence ~ CI + Mean Velocity + Temperature	1.80	0.03
Redd Presence ~ CI + Spawning Gravel + Temperature	1.83	0.03

Figure 3. Model averaged coefficients (with 95% confidence intervals) indicating the most important variables predicting Westslope Cutthroat Trout redd counts in tributaries of the Elk River, B.C. Values in the x-axis are estimates of model parameters. RVI = Relative Variable Importance scores, where a score of 1 indicates that a predictor variable occurs in all top models with ΔAICc < 4.

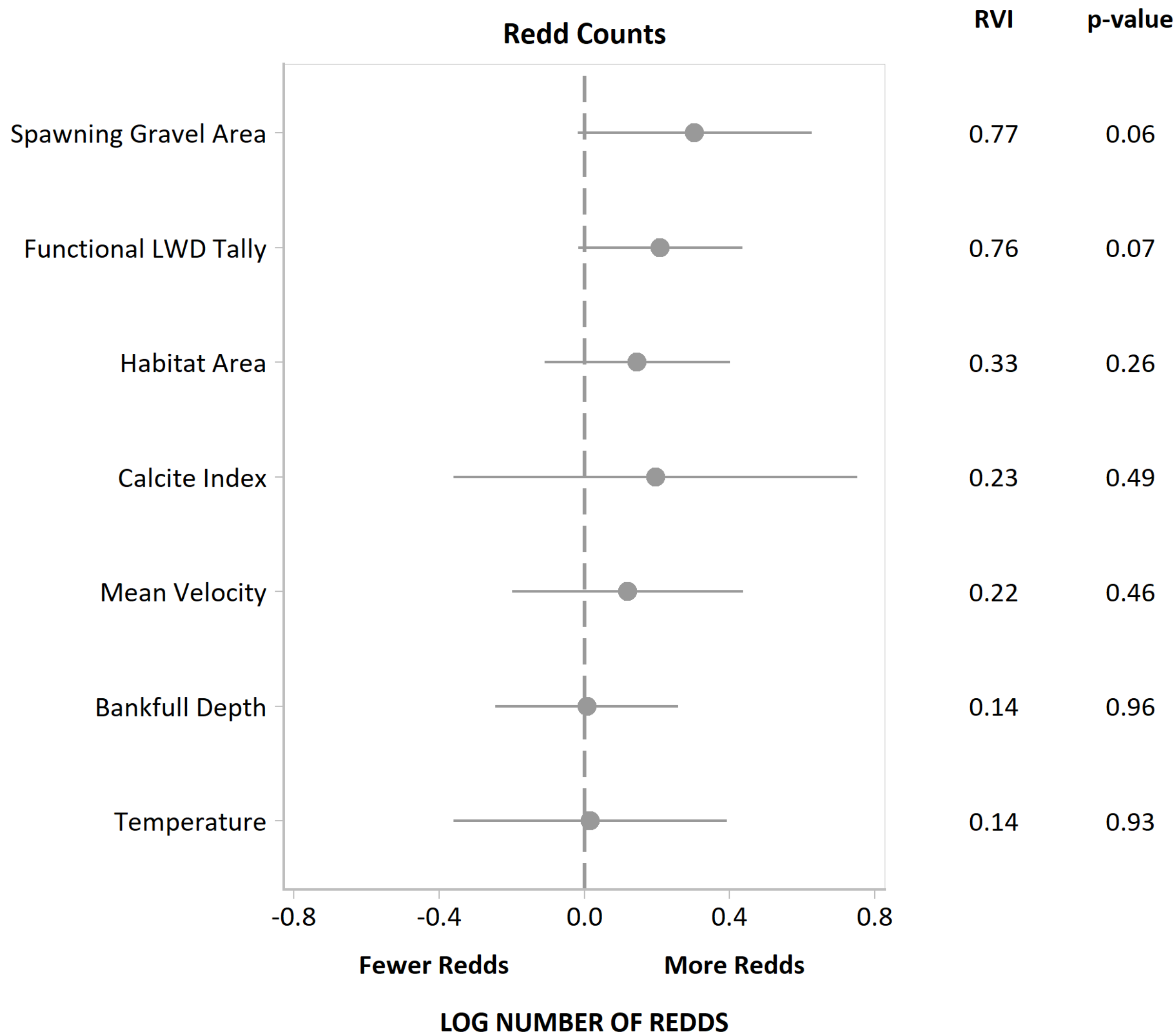


Figure 4. Westslope Cutthroat Trout redd counts as a function of CI and the mean regression fit to the data, with all other predictors held at their means.

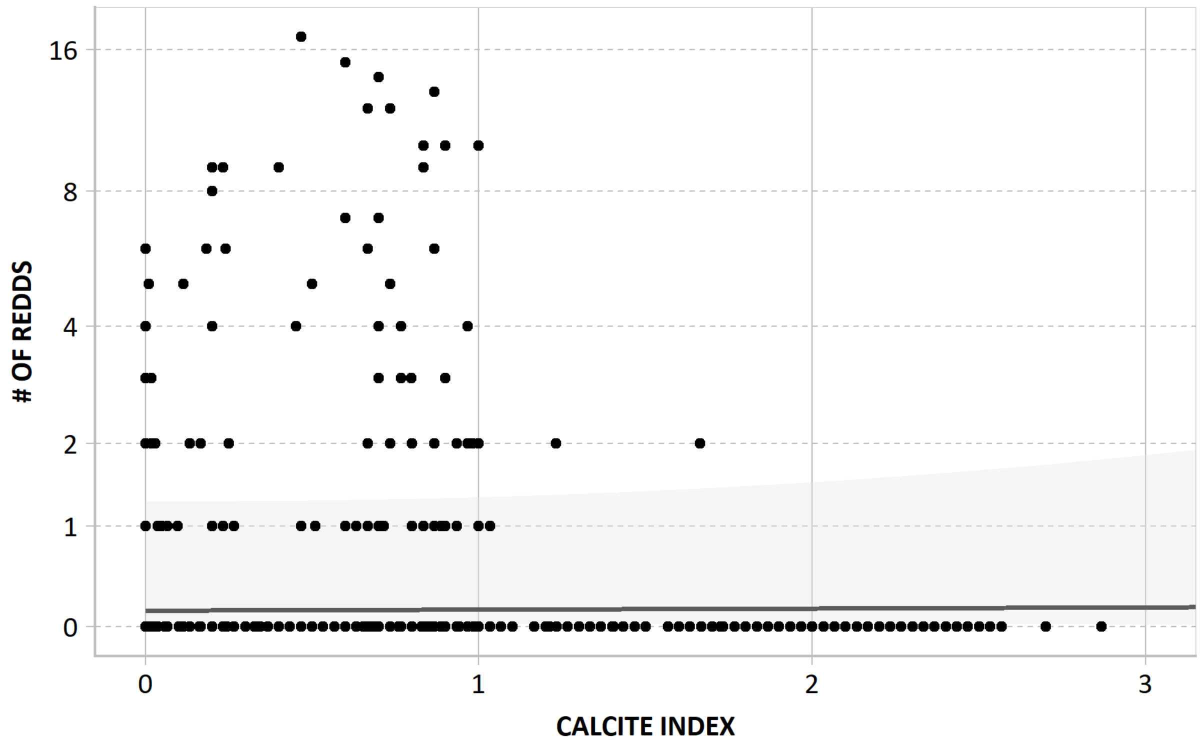


Table 2. Top models that best predict Westslope Cutthroat Trout mean redd counts in the upper Fording River watershed. Models are ranked by Δ Akaike Information Criterion (ΔAICc) scores. The model with the lowest ΔAICc is the best model. Model weights (range 0-1) are also shown, which provide an estimate of the likelihood that a given model is the best model compared to the other top models in the model set.

Model	ΔAICc	Weight
Redd Count ~ Functional LWD Tally + Spawning Gravel	0.00	0.11
Redd Count ~ Habitat Area + Functional LWD Tally + Spawning Gravel	0.89	0.07
Redd Count ~ Functional LWD Tally	1.32	0.05
Redd Count ~ Functional LWD Tally + Mean Velocity + Spawning Gravel	1.43	0.05
Redd Count ~ Spawning Gravel	1.54	0.05
Redd Count ~ CI + Functional LWD Tally + Spawning Gravel	1.59	0.05

Table 3. Top model that best predicts Westslope Cutthroat Trout redd counts in the upper Fording River watershed, modelled using quantile regression. The model with the lowest ΔAICc is the best model. Model weights (range 0-1) are also shown, which provide an estimate of the likelihood that a given model is the best model compared to the other top models in the model set.

Model	ΔAICc	Weight
Redd Count (90th quantile) ~ CI + Habitat Area + Mean Velocity + Temperature + Spawning Gravel	0.00	0.11
Redd Count (90th quantile) ~ CI + Habitat Area + Bankfull Depth + Mean Velocity + Temperature + Spawning Gravel	0.89	0.07
Redd Count (90th quantile) ~ CI + Habitat Area + Functional LWD Tally + Mean Velocity + Temperature + Spawning Gravel	1.32	0.05

Figure 5. Model averaged coefficients (with 95% confidence intervals) indicating the most important variables describing redd count, modelled using quantile regression models. Values in the x-axis are estimates of model parameters.

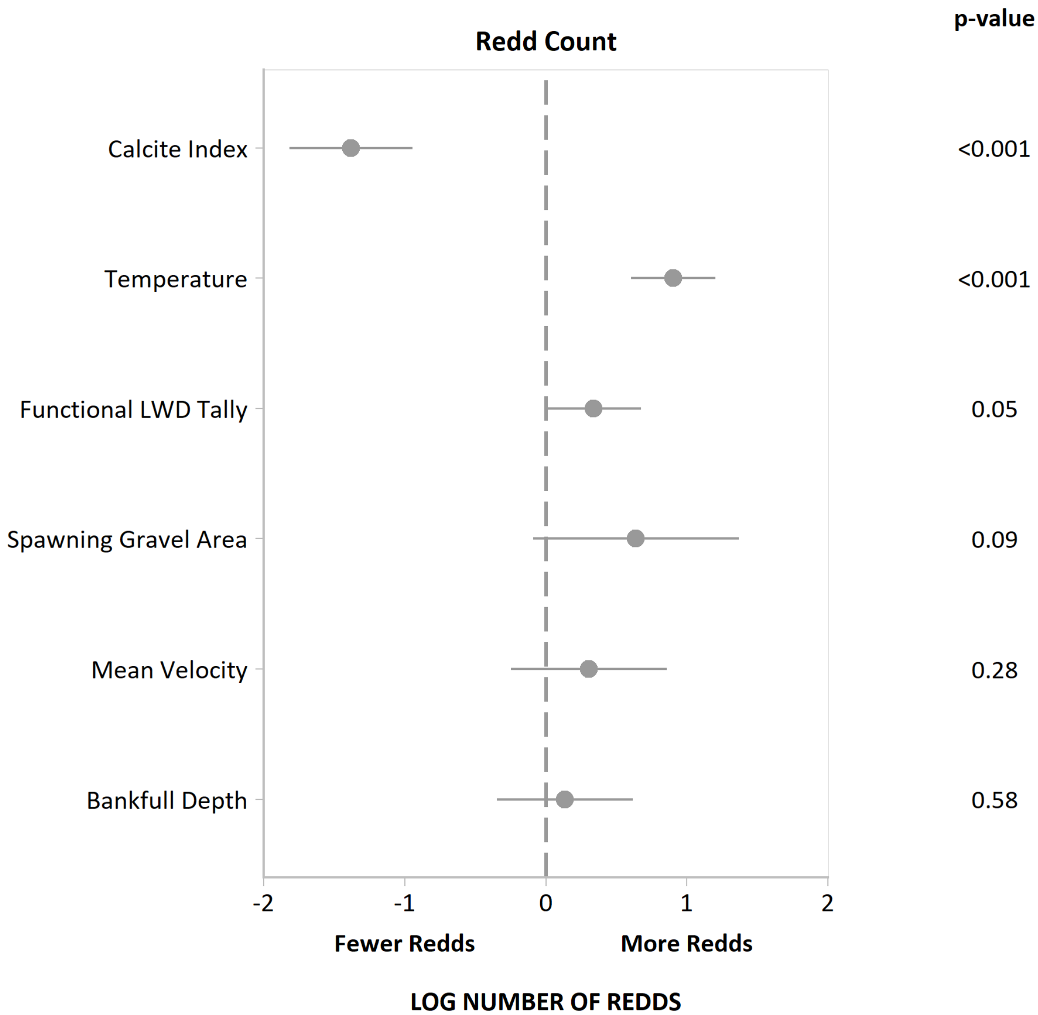
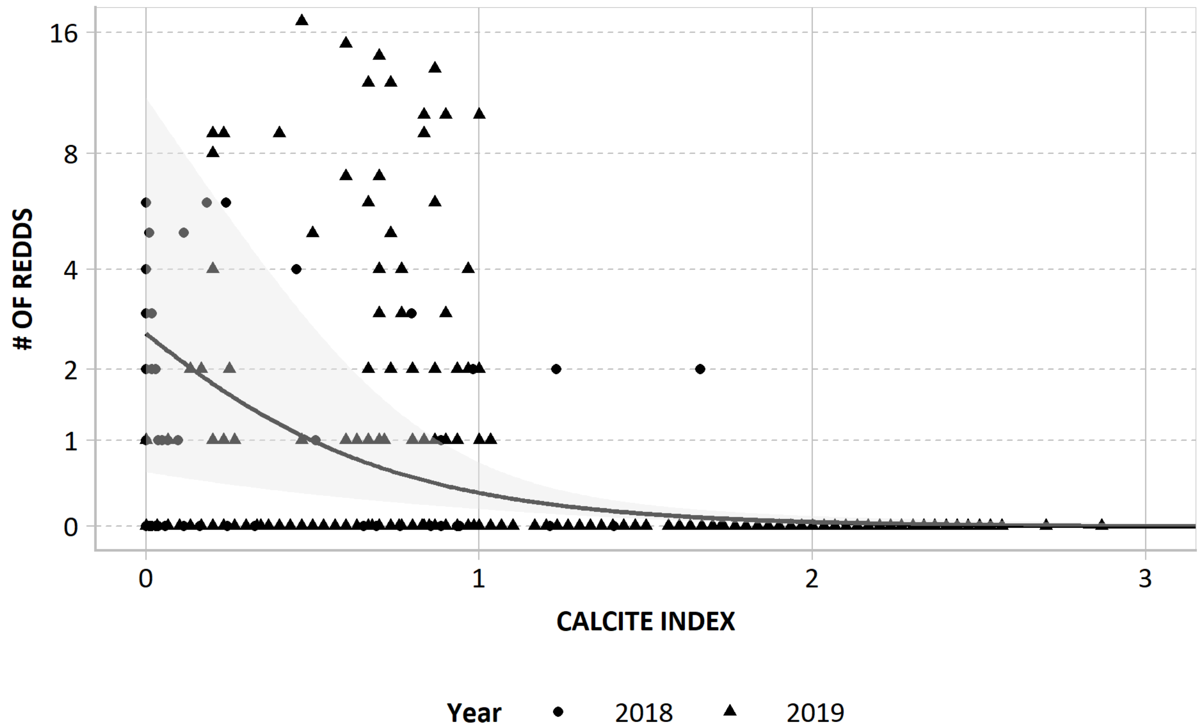


Figure 6. Westslope Cutthroat Trout redd count as a function of CI and the 90th quantile regression fit to the data, with all other predictors held at their means.



Appendix G. Photographs of Westslope Cutthroat Trout Redds taken during 2019 spawner surveys as part of the 2019 Calcite Effects Program.

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Photo 2. Westslope Cutthroat Trout redd observed in Alexander Creek (2/3), on July 14, 2019.

Photo 3. Westslope Cutthroat Trout redd observed in Alexander Creek (3/3), on July 14, 2019.

2. FISH POND CREEK

Photo 4. Westslope Cutthroat Trout redd observed in Fish Pond Creek (1/9), on June 27, 2019.

Photo 5. Westslope Cutthroat Trout and two redds observed in Fish Pond Creek (2-3/9), on July 8, 2019.

Photo 6. Two Westslope Cutthroat Trout redds observed in Fish Pond Creek (4-5/9), July 8, 2019.

Photo 7. Two Westslope Cutthroat Trout redds observed in Fish Pond Creek (6-7/9), July 8, 2019.

Photo 8. Westslope Cutthroat Trout redd observed in Fish Pond Creek (8/9), July 16, 2019.

Photo 9. Westslope Cutthroat Trout redd observed in Fish Pond Creek (9/9), July 16, 2019.

3. LOWER GREEN HILLS CREEK

Photo 10. Westslope Cutthroat Trout redd observed in Lower Green Hills Creek (1/1), July 16, 2019.

4. UPPER GREEN HILLS CREEK

Photo 11. Two Westslope Cutthroat Trout redds observed in Upper Greenhills Creek (1-2/2), July 15, 2019.

5. LCO DRY CREEK

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Photo 13. Two Westslope Cutthroat Trout redds observed in LCO Dry Creek (2-3/15), July 6, 2019.

Photo 14. Westslope Cutthroat Trout redd observed in LCO Dry Creek (4/15), July 6, 2019.

Photo 15. **Two Westslope Cutthroat Trout redds observed in LCO Dry Creek (5-6/15), July 6, 2019.**

Photo 16. **Westslope Cutthroat Trout redd observed in LCO Dry Creek (7/15), July 6, 2019.**

Photo 17. Westslope Cutthroat Trout redd observed in LCO Dry Creek (8/15), July 6, 2019.

Photo 18. Westslope Cutthroat Trout redd observed in LCO Dry Creek (9/15), July 6, 2019.

Photo 19. **Westslope Cutthroat Trout redd observed in LCO Dry Creek (10/15), July 6 , 2019.**

Photo 20. **Westslope Cutthroat Trout redd observed in LCO Dry Creek (11/15), July 6, 2019.**

Photo 21. Westslope Cutthroat Trout redd observed in LCO Dry Creek (12/15), July 6, 2019.

Photo 22. Two Westslope Cutthroat Trout redds observed in LCO Dry Creek (13-14/15), July 17, 2019.

Photo 23. Westslope Cutthroat Trout redd observed in LCO Dry Creek (15/15), July 17, 2019.

Photo 24. Westslope Cutthroat Trout redd observed in Lizard Creek (1/196), May 31, 2019.

Photo 25. **Three Westslope Cutthroat Trout redds observed in Lizard Creek (2-4/196), May 31, 2019.**

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Photo 30. **Two Westslope Cutthroat Trout redds observed in Lizard Creek (10-11/196), May 31, 2019.**

Photo 31. Two Westslope Cutthroat Trout redds observed in Lizard Creek (12-13/196), May 31, 2019.

Photo 32. Three Westslope Cutthroat Trout redds observed in Lizard Creek (14-16/196), May 31, 2019.

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Photo 34. Westslope Cutthroat Trout redd observed in Lizard Creek (18/196), May 31, 2019.

Photo 35. **Two Westslope Cutthroat Trout redd observed in Lizard Creek (19-20/196), May 31, 2019.**

Photo 36. **Westslope Cutthroat Trout redd observed in Lizard Creek (21/196), May 31, 2019.**

Photo 37. Three Westslope Cutthroat Trout redds observed in Lizard Creek (22-24/196), May 31, 2019.

Photo 38. Three Westslope Cutthroat Trout redds observed in Lizard Creek (25-27/196), May 31, 2019.

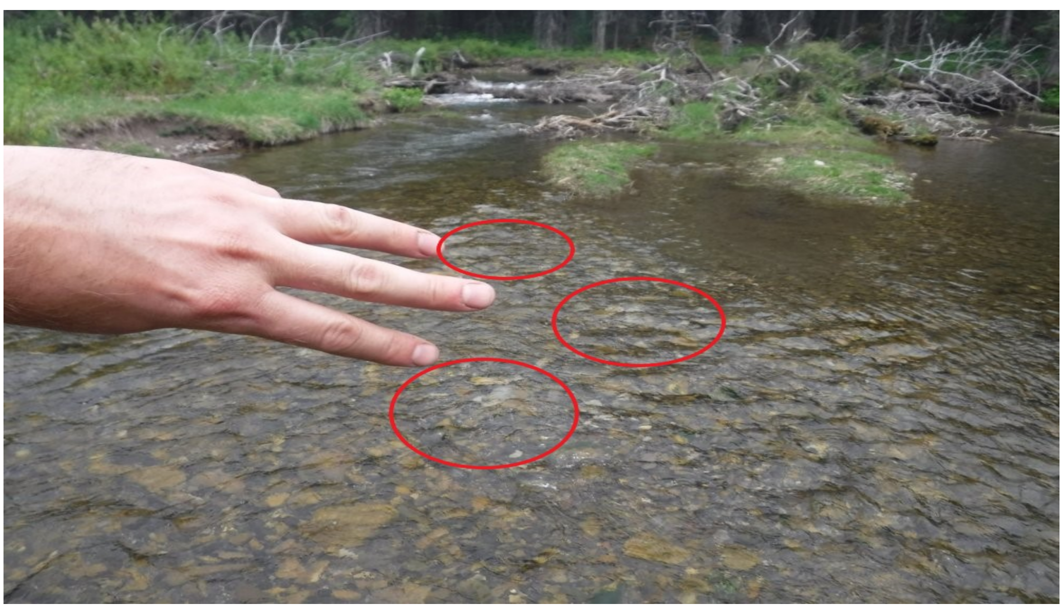

Photo 39. Three Westslope Cutthroat Trout redds observed in Lizard Creek (28-30/196), May 31, 2019.

Photo 40. Two Westslope Cutthroat Trout redds observed in Lizard Creek (31-32/196), May 31, 2019.

Photo 41. Two Westslope Cutthroat Trout redds observed in Lizard Creek (33-34/196), May 31, 2019.

Photo 42. Two Westslope Cutthroat Trout redds observed in Lizard Creek (35-36/196), May 31, 2019.

Photo 43. Westslope Cutthroat Trout redd observed in Lizard Creek (37/196), May 31, 2019.

Photo 44. Westslope Cutthroat Trout redd observed in Lizard Creek (38/196), May 31, 2019.

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Photo 51. Westslope Cutthroat Trout redd observed in Lizard Creek (50/196), May 31, 2019.

Photo 52. Two Westslope Cutthroat Trout redds observed in Lizard Creek (51-52/196), May 31, 2019.

Photo 53. Westslope Cutthroat Trout redd observed in Lizard Creek (53/196), May 31, 2019.

Photo 54. Westslope Cutthroat Trout redd observed in Lizard Creek (54/196), May 31, 2019.

Photo 55. Westslope Cutthroat Trout redd observed in Lizard Creek (55/196), May 31, 2019.

Photo 56. Westslope Cutthroat Trout redd observed in Lizard Creek (56/196), May 31, 2019.

Photo 57. Westslope Cutthroat Trout redd observed in Lizard Creek (57/196), May 31, 2019.

Photo 58. Five Westslope Cutthroat Trout redds observed in Lizard Creek (58-62/196), May 31, 2019.

Photo 59. Westslope Cutthroat Trout redd observed in Lizard Creek (63/196), May 31, 2019.

Photo 60. Westslope Cutthroat Trout redd observed in Lizard Creek (64/196), May 31, 2019.

Photo 61. Westslope Cutthroat Trout redd observed in Lizard Creek (65/196), May 31, 2019.

Photo 62. Westslope Cutthroat Trout redd observed in Lizard Creek (66/196), May 31, 2019.

Photo 63. Westslope Cutthroat Trout redds observed in Lizard Creek (67-71/196), May 31, 2019.

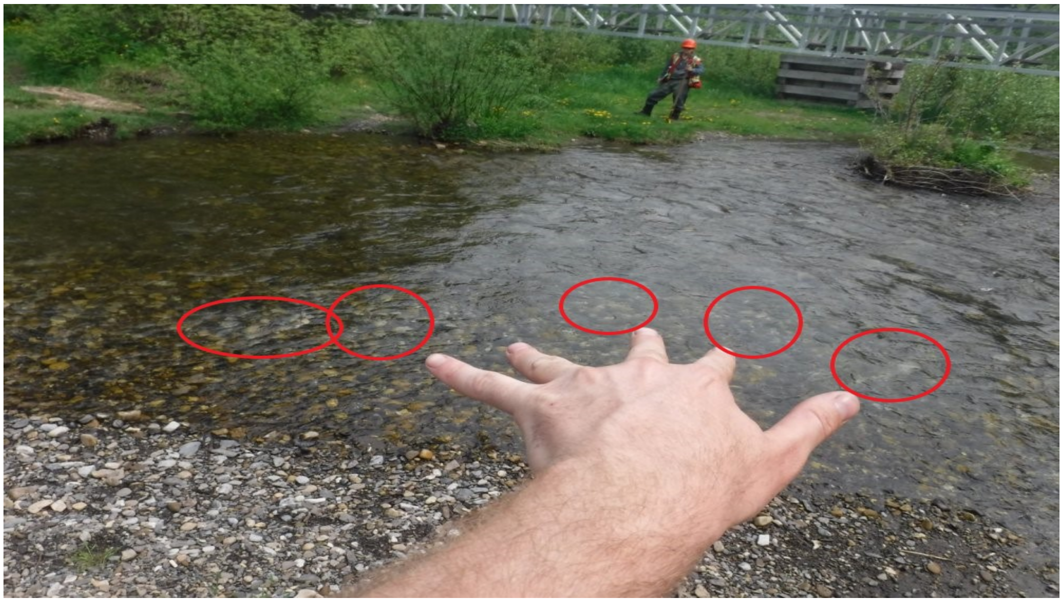

Photo 64. Five Westslope Cutthroat Trout redds observed in Lizard Creek (72-76/196), May 31, 2019.

Photo 65. Three Westslope Cutthroat Trout redds observed in Lizard Creek (77-79/196), May 31, 2019.

Photo 66. Two Westslope Cutthroat Trout redds observed in Lizard Creek (80-81/196), May 31, 2019.

Photo 67. Westslope Cutthroat Trout redd observed in Lizard Creek (82/196), May 31, 2019.

Photo 68. Westslope Cutthroat Trout redd observed in Lizard Creek (83/196), May 31, 2019.

Photo 69. Two Westslope Cutthroat Trout redds observed in Lizard Creek (84-85/196), May 31, 2019.

Photo 70. Two Westslope Cutthroat Trout redds observed in Lizard Creek (86-87/196), May 31, 2019.

Photo 71. Two Westslope Cutthroat Trout redds observed in Lizard Creek (88-89/196), May 31, 2019.

Photo 72. Two Westslope Cutthroat Trout redds observed in Lizard Creek (90-91/196), May 31, 2019.

Photo 73. Five Westslope Cutthroat Trout redds observed in Lizard Creek (92-96/196), May 31, 2019.

Photo 74. Westslope Cutthroat Trout redd observed in Lizard Creek (97/196), May 31, 2019.

Photo 75. Westslope Cutthroat Trout redd observed in Lizard Creek (98/196), May 31, 2019.

Photo 76. Three Westslope Cutthroat Trout redds observed in Lizard Creek (99-101/196), May 31, 2019.

Photo 77. Westslope Cutthroat Trout redd observed in Lizard Creek (102/196), May 31, 2019.

Photo 78. Westslope Cutthroat Trout redd observed in Lizard Creek (103/196), May 31, 2019.

Photo 79. Two Westslope Cutthroat Trout redds observed in Lizard Creek (104-105/196), May 31, 2019.

Photo 80. Westslope Cutthroat Trout redd observed in Lizard Creek (106/196), May 31, 2019.

Photo 81. Westslope Cutthroat Trout on redd observed in Lizard Creek (107/196), May 31, 2019.

Photo 82. Three Westslope Cutthroat Trout redds observed in Lizard Creek (108-110/196), June 18, 2019.

Photo 83. Five Westslope Cutthroat Trout redds observed in Lizard Creek (111-115/196), June 18, 2019.

Photo 84. Three Westslope Cutthroat Trout redds observed in Lizard Creek (116-118/196), June 18, 2019.

Photo 85. Five Westslope Cutthroat Trout redds observed in Lizard Creek (119-123/196), June 18, 2019.

Photo 86. Westslope Cutthroat Trout redd observed in Lizard Creek (124/196), June 18, 2019.

Photo 87. Westslope Cutthroat Trout redd observed in Lizard Creek (125/196), June 18, 2019.

Photo 88. Seven Westslope Cutthroat Trout redds observed in Lizard Creek (126-32/196), June 18, 2019.

Photo 89. Three Westslope Cutthroat Trout redds observed in Lizard Creek (136/196), June 18, 2019.

Photo 90. Westslope Cutthroat Trout redd observed in Lizard Creek (137/196), June 18, 2019.

Photo 91. Two Westslope Cutthroat Trout redds observed in Lizard Creek (138-139/196), June 18, 2019.

Photo 92. Two Westslope Cutthroat Trout redds observed in Lizard Creek (140-141/196), June 18, 2019.

Photo 93. Westslope Cutthroat Trout redd observed in Lizard Creek (142/196), June 18, 2019.

Photo 94. Westslope Cutthroat Trout redd observed in Lizard Creek (143/196), June 18, 2019.

Photo 95. Two Westslope Cutthroat Trout redds observed in Lizard Creek (144-145/196), June 18, 2019.

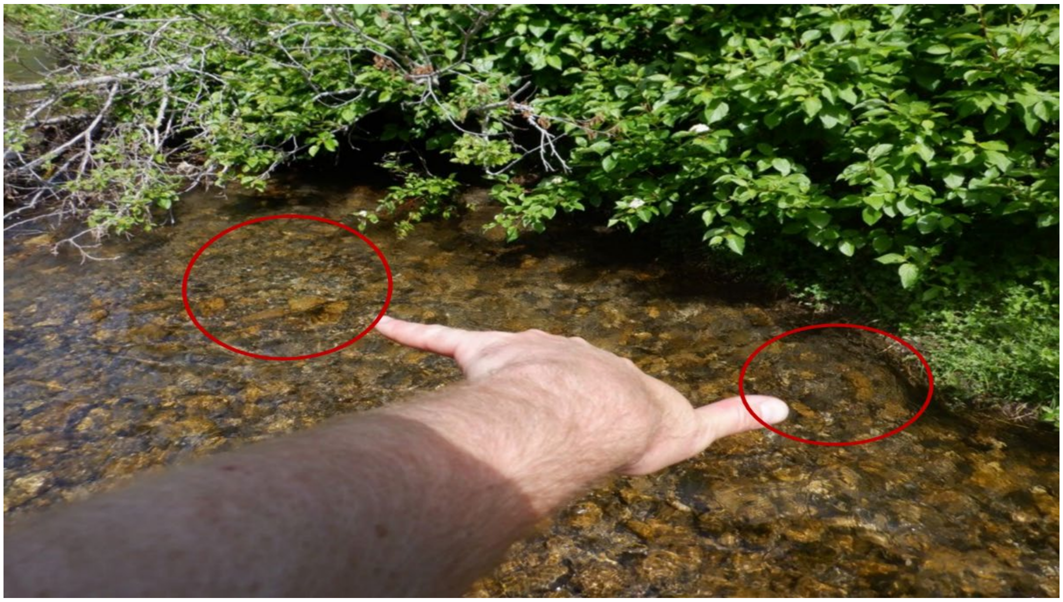

Photo 96. Four Westslope Cutthroat Trout redds observed in Lizard Creek (146-149/196), June 18, 2019.

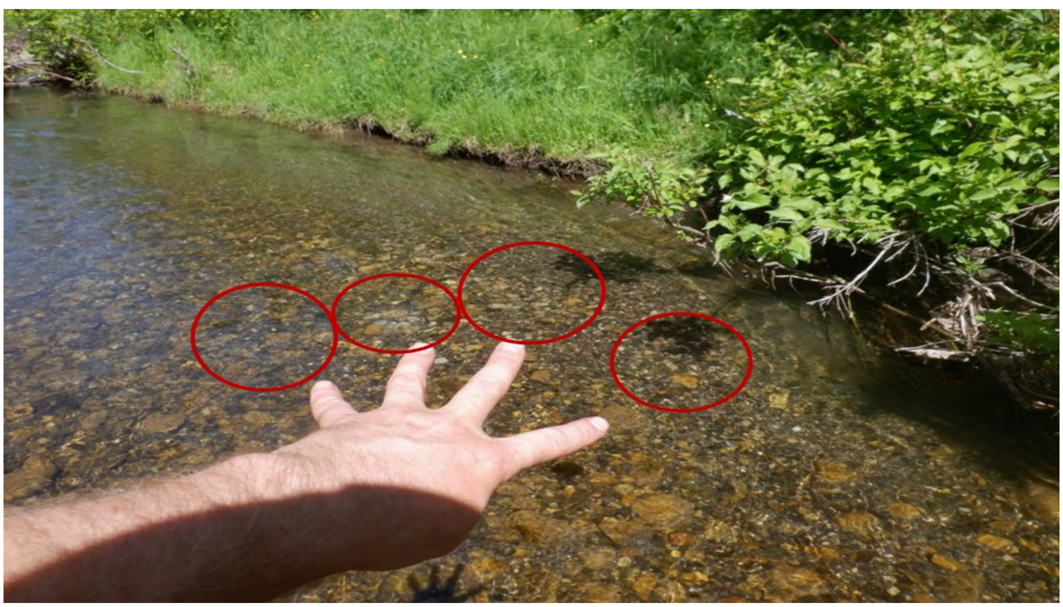

Photo 97. Two Westslope Cutthroat Trout redds observed in Lizard Creek (150-151/196), June 18, 2019.

Photo 98. Westslope Cutthroat Trout redd observed in Lizard Creek (152/196), June 18, 2019.

Photo 99. Three Westslope Cutthroat Trout redds observed in Lizard Creek (153-155/196), June 18, 2019.

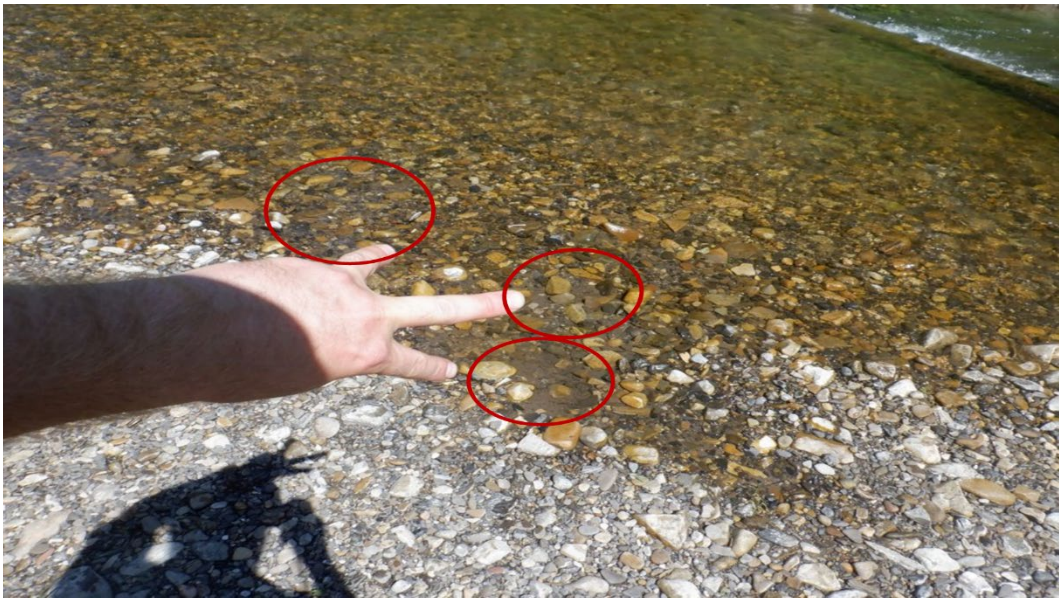

Photo 100. Westslope Cutthroat Trout redd observed in Lizard Creek (156/196), June 18, 2019.

Photo 101. Westslope Cutthroat Trout redd observed in Lizard Creek (157/196), June 18, 2019.

Photo 102. Westslope Cutthroat Trout redd observed in Lizard Creek (158/196), June 18, 2019.

Photo 103. Three Westslope Cutthroat Trout redds observed in Lizard Creek (159-161/196), June 18, 2019.

Photo 104. Seven Westslope Cutthroat Trout redds observed in Lizard Creek (162-168/196), June 18, 2019.

Photo 105. Two Westslope Cutthroat Trout redds observed in Lizard Creek (169-170/196), June 18, 2019.

Photo 106. Westslope Cutthroat Trout redd observed in Lizard Creek (171/196), June 18, 2019.

Photo 107. Four Westslope Cutthroat Trout redds observed in Lizard Creek (172-175/196), June 18, 2019.

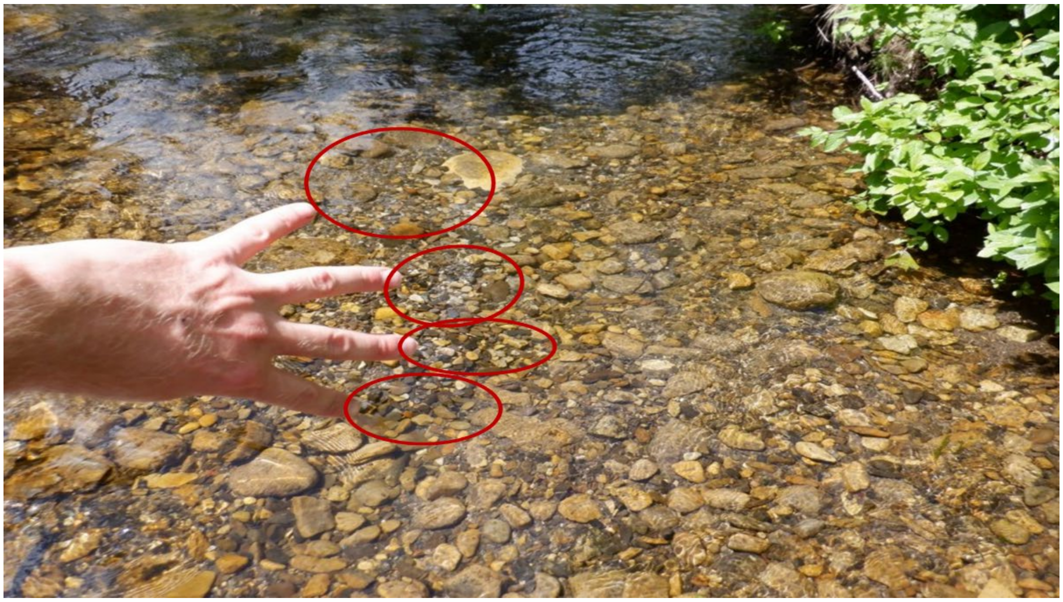

Photo 108. Two Westslope Cutthroat Trout redds observed in Lizard Creek (176-177/196), June 18, 2019.

Photo 109. Three Westslope Cutthroat Trout redds observed in Lizard Creek (178-180/196), June 18, 2019.

Photo 110. Three Westslope Cutthroat Trout redds observed in Lizard Creek (181-183/196), June 18, 2019.

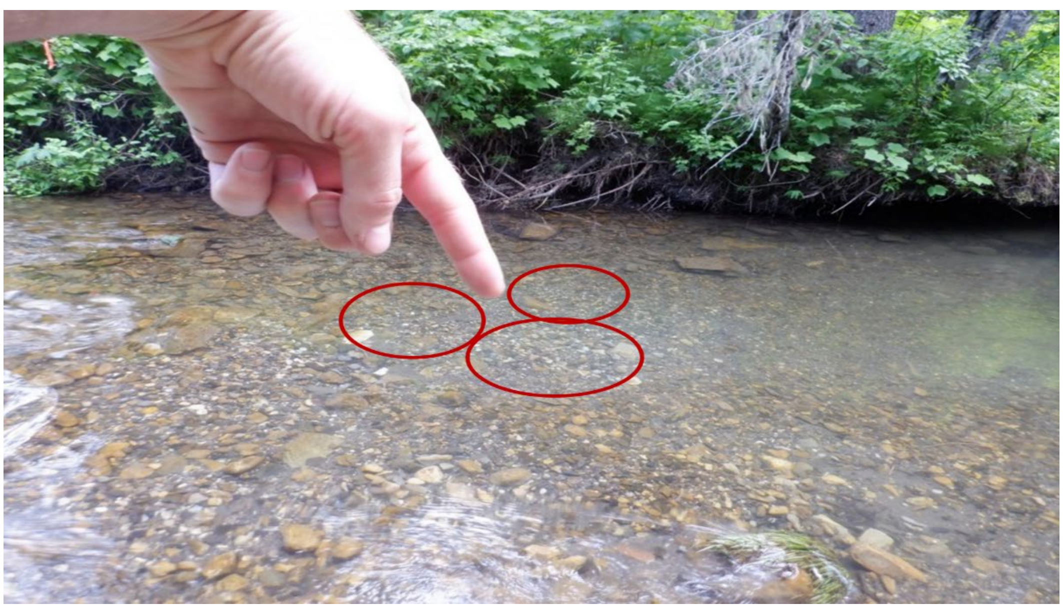

Photo 111. Two Westslope Cutthroat Trout redds observed in Lizard Creek (184-185/196), June 18, 2019.

Photo 112. Westslope Cutthroat Trout redd observed in Lizard Creek (186/196), June 18, 2019.

Photo 113. Two Westslope Cutthroat Trout redds observed in Lizard Creek (187-188/196), June 18, 2019.

Photo 114. Westslope Cutthroat Trout redd observed in Lizard Creek (189/196), June 18, 2019.

Photo 115. Three Westslope Cutthroat Trout redds observed in Lizard Creek (190-92/196), June 18, 2019.

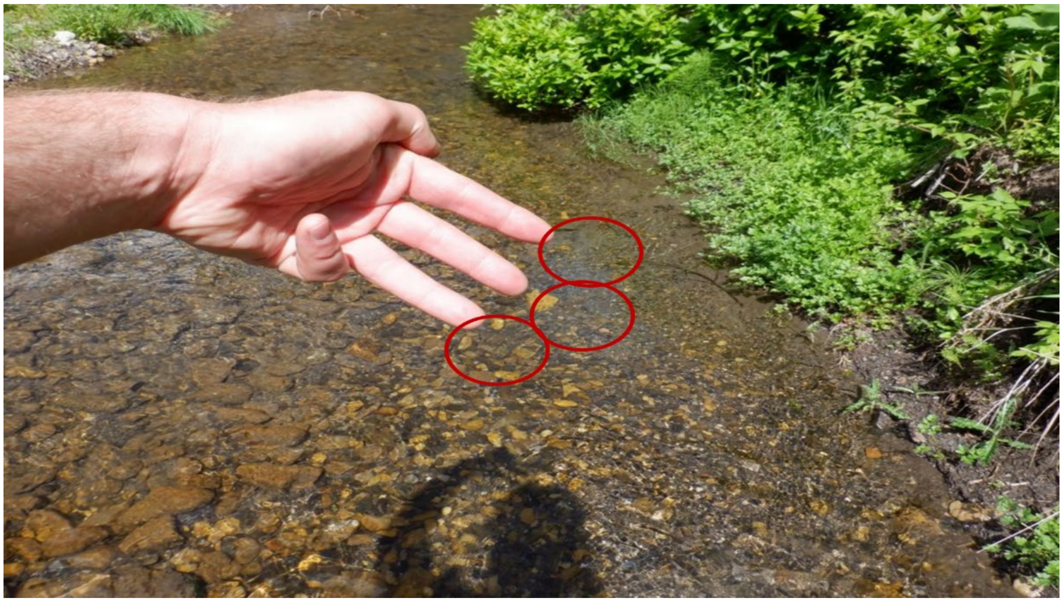

Photo 116. Two Westslope Cutthroat Trout redds observed in Lizard Creek (193-94/196), June 18, 2019.

Photo 117. **Two Westslope Cutthroat Trout redds observed in Lizard Creek (195-196/196), June 18, 2019.**

6. MCCOOL CREEK

Photo 118. **Three Westslope Cutthroat Trout redds observed in McCool Creek (1-3/21), June 20, 2019.**

Photo 119. Westslope Cutthroat Trout redd observed in McCool Creek (4/21), June 20, 2019.

Photo 120. Westslope Cutthroat Trout redd observed in McCool Creek (5/21), June 20, 2019.

Photo 121. Westslope Cutthroat Trout redd observed in McCool Creek (6/21), June 20, 2019.

Photo 122. Westslope Cutthroat Trout redd observed in McCool Creek (7/21), June 20, 2019.

Photo 123. Two Westslope Cutthroat Trout redds observed in McCool Creek (8-9/21), June 20, 2019.

Photo 124. Westslope Cutthroat Trout redd observed in McCool Creek (10/21), June 20, 2019.

Photo 125. Westslope Cutthroat Trout redd observed in McCool Creek (11/21), June 20, 2019.

Photo 126. Westslope Cutthroat Trout redd observed in McCool Creek (12/21), June 20, 2019.

Photo 127. **Westslope Cutthroat Trout redd observed in McCool Creek (13/21), June 20, 2019.**

Photo 128. **Westslope Cutthroat Trout redd observed in McCool Creek (14/21), June 20, 2019.**

Photo 129. Two Westslope Cutthroat Trout redds observed in McCool Creek (15-16/21), June 20, 2019.

Photo 130. Westslope Cutthroat Trout redd observed in McCool Creek (17/21), June 20, 2019.

Photo 131. Westslope Cutthroat Trout redd observed in McCool Creek (18/21), June 20, 2019.

Photo 132. Westslope Cutthroat Trout redd observed in McCool Creek (19/21), July 5, 2019.

Photo 133. Westslope Cutthroat Trout redd observed in McCool Creek (20/21), July 5, 2019.

Photo 134. Westslope Cutthroat Trout redd observed in McCool Creek (21/21), July 5, 2019.

7. MICHEL CREEK

Photo 135. Westslope Cutthroat Trout redd observed in Michel Creek (1/41), July 12, 2019

Photo 136. Westslope Cutthroat Trout redd observed in Michel Creek (2/41), July 12, 2019.

Photo 137. Westslope Cutthroat Trout redd observed in Michel Creek (3/41), July 12, 2019.

Photo 138. Westslope Cutthroat Trout redd observed in Michel Creek (4/41), July 12, 2019.

Photo 139. Westslope Cutthroat Trout redd observed in Michel Creek (5/41), July 12, 2019.

Photo 140. Westslope Cutthroat Trout redd observed in Michel Creek (6/41), July 12, 2019.

Photo 141. Three Westslope Cutthroat Trout redds observed in Michel Creek (7-9/41), July 12, 2019.

Photo 142. Four Westslope Cutthroat Trout redds observed in Michel Creek (10-13/41), July 12, 2019.

Photo 143. Westslope Cutthroat Trout redd observed in Michel Creek (14/41), July 12, 2019.

Photo 144. Westslope Cutthroat Trout redd observed in Michel Creek (15/41), July 12, 2019.

Photo 145. Westslope Cutthroat Trout redd observed in Michel Creek (16/41), July 12, 2019.

Photo 146. Westslope Cutthroat Trout redd observed in Michel Creek (17/41), July 12, 2019.

Photo 147. **Two Westslope Cutthroat Trout redds observed in Michel Creek (18-19/41), July 12, 2019.**

Photo 148. **Two Westslope Cutthroat Trout redds observed in Michel Creek (20-21/41), July 12, 2019.**

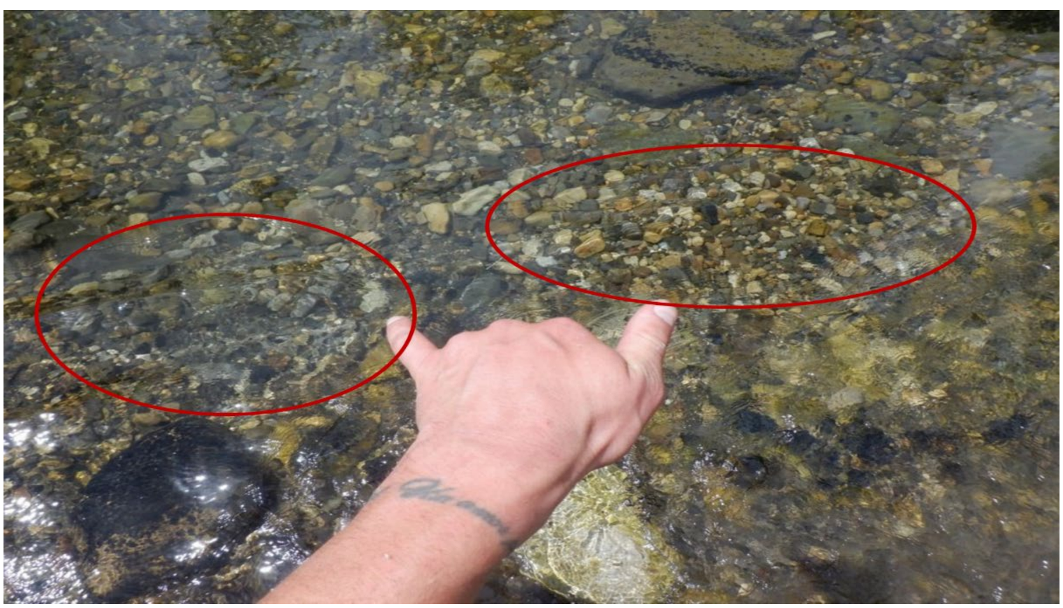

Photo 149. Westslope Cutthroat Trout redd observed in Michel Creek (22/41), June 20, 2019.

Photo 150. Westslope Cutthroat Trout redd observed in Michel Creek (23/41), June 20, 2019.

Photo 151. **Westslope Cutthroat Trout redd observed in Michel Creek (24/41), June 20, 2019.**

Photo 152. **Westslope Cutthroat Trout redd observed in Michel Creek (25/41), June 20, 2019.**

Photo 153. Westslope Cutthroat Trout redd observed in Michel Creek (26/41), June 20, 2019.

Photo 154. Three Westslope Cutthroat Trout redds observed in Michel Creek (27-29/41), June 20, 2019.

Photo 155. Four Westslope Cutthroat Trout redds observed in Michel Creek (30-33/41), June 20, 2019.

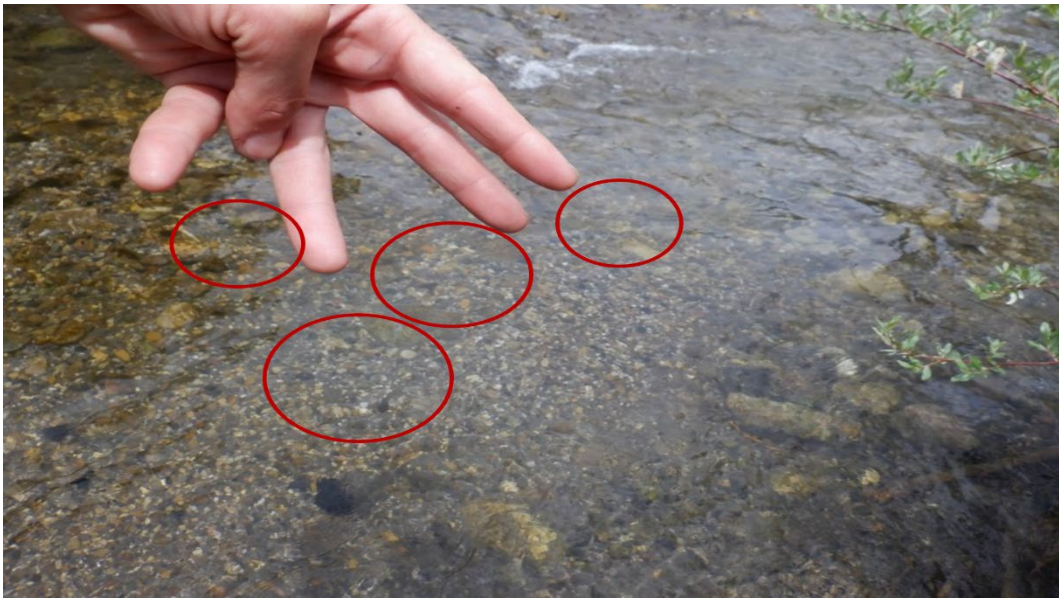

Photo 156. Two Westslope Cutthroat Trout redds observed in Michel Creek (34-35/41), June 20, 2019.

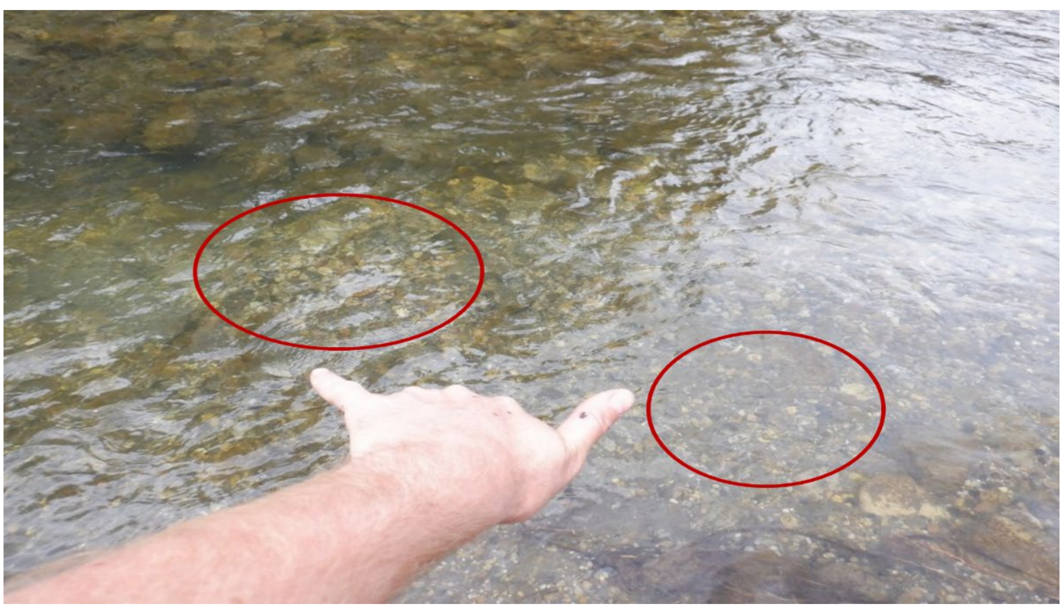

Photo 157. Two Westslope Cutthroat Trout redds observed in Michel Creek (36-37/41), June 20, 2019.

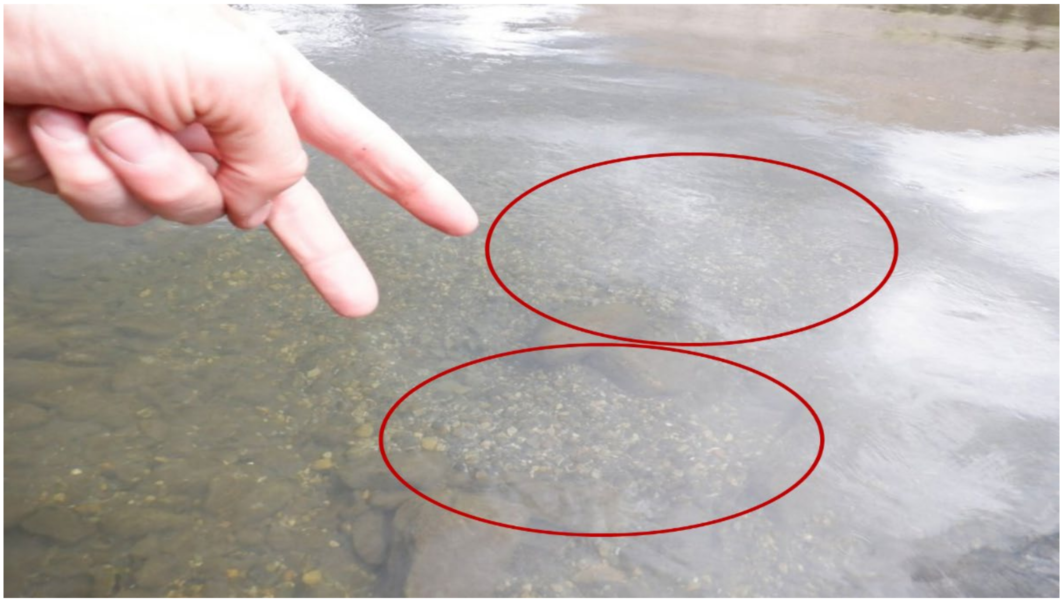

Photo 158. Westslope Cutthroat Trout redd observed in Michel Creek (38/41), June 20, 2019.

Photo 159. Westslope Cutthroat Trout redd observed in Michel Creek (39/41), June 20, 2019.

Photo 160. Westslope Cutthroat Trout redd observed in Michel Creek (40/41), June 20, 2019.

Photo 161. Westslope Cutthroat Trout redd observed in Michel Creek (41/41), June 20, 2019.

8. THOMPSON CREEK

Photo 162. Two Westslope Cutthroat Trout redds observed in Thompson Creek (2/2), May 30, 2019.