Alena Creek Fish Habitat Enhancement Project

Year 3 Monitoring Report

Prepared for:

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EXECUTIVE SUMMARY

This report provides results of Year 3 (2019) of the long-term monitoring program to evaluate the effectiveness of the Fish Habitat Enhancement Project (FHEP) constructed on Alena Creek (also known as Leanna Creek) as per the *Fisheries Act* Authorization issued for the Upper Lillooet Hydro Project (the Project). Ecofish Research Limited (Ecofish) was retained by the Upper Lillooet River Power Limited Partnership (ULRPLP) to conduct monitoring of the FHEP constructed on Alena Creek. The FHEP was designed to offset the footprint and operational habitat losses incurred by the Project. Alena Creek is a tributary to the Upper Lillooet River located approximately 4.1 km downstream of the confluence of Boulder Creek with the Upper Lillooet River.

Historical fish and fish habitat data from Alena Creek and long-term monitoring requirements for the FHEP were originally described in the Alena Creek Long-Term Monitoring Program (Harwood *et al.* 2013). Long-term monitoring requirements were subsequently revised and integrated into Project's Operational Environmental Monitoring Plan (OEMP) (Harwood *et al.* 2017). Baseline data were collected for Alena Creek in 2013 and 2014. Post-construction (i.e., post-enhancement) monitoring started in fall of 2016 and has continued through 2017 (Year 1), 2018 (Year 2) and 2019 (Year 3).

Fish Habitat

A stability assessment was conducted to monitor the stability and functionality of each of the FHEP features and ensure that any remedial action required to maintain the effectiveness of habitat features is identified so that it can be promptly undertaken. To assist in the stability assessments, photo-points were established during the as-built survey in 2016 at a total of eight survey transects and repeated in each subsequent year. At each of the transects, a panorama of photographs was taken to evaluate changes in habitat conditions over time. Qualitative observations were also made along the entire FHEP enhanced reaches.

Excessive erosion that reduces the quality of the constructed habitat has not occurred to date. The channel adjustments that occurred after the November 2016 peak flow event were modest and have largely stabilized since then due to vegetation establishment and natural sorting of sediment. However, three locations were identified where remediation is required to limit potential loss of habitat quality. First and foremost is the beaver dam complex located immediately upstream of Reach 3. This beaver dam has begun to cause flows to partially bypass Reach 3 and deliver fine sediment that is eroded from newly cut channels. Maintaining a lower beaver dam height at the dam that is blocking flow to the mainstem is recommended to keep flows in the channel and limit fine sediment loading. At the downstream extent of Reach 3, the last riffle has incised, which could cause progressive head-cutting and associated incision upstream. Rebuilding this riffle is recommended, which can likely be done without the need for excavators. Lastly, a log jam just upstream of ALE-XS1 has formed in Reach 1 where a channel-spanning log collapsed. This jam should be monitored to ensure it does not grow. If the jam grows and begins to cause backwatering of upstream riffles and associated fine sediment deposition, then it should be removed. Continued monitoring and the repairs to Reach 3 are recommended to occur during summer 2020.

Fish Community

The adult fish community in Alena Creek was assessed by bank walk spawner surveys focusing on Coho Salmon, the dominant species within Alena Creek, completed over three surveys between November and December 2019. The peak count of adult spawning Coho Salmon (*Oncorhynchus kisutch*) was 153 in 2019, which was slightly higher than the baseline years (127 and 111) and 2017 (132) but less than the first post-enhancement monitoring survey in fall 2016 (192). A comparison of the results across years highlights the variability in run timing between years, with the peak live count recorded on November 14 in 2016, December 5 in 2017, and November 5 in 2010 and 2018, and December 9 in 2019. The peak counts provide a general indication of use and demonstrate that Alena Creek supports equivalent or potentially greater use by Coho Salmon spawners compared to pre-enhancement.

Minnow trapping surveys were conducted at eight sites in Alena Creek on September 23, 2019. The objective of minnow trapping was to measure catch-per-unit-effort (CPUE) by species and life history stage to continue monitoring juvenile fish abundance and compare to CPUE prior to enhancement. Of the eight sites, five are in the enhanced reaches of Alena Creek.

The average Cutthroat Trout (*Oncorhynchus clarkii*) CPUE across sites in 2019 (1.1 fish per 100 trap hours) was most similar to 2017 (0.8 fish per 100 trap hours) and less than 2013 and 2018 (1.8 and 1.6 fish per 100 trap hours respectively), while CPUE in 2014 is not comparable due to sampling bias. In all sampling years, the most abundant age class of Cutthroat Trout captured was 1+ parr, with low numbers of fry. The low numbers of Cutthroat Trout fry captured during sampling is likely a result of the timing of emergence of fry in late September and early October when sampling occurs.

The average Coho Salmon CPUE across sites in 2018 and 2019 (83.8 and 33.3 fish per 100 trap hours respectively) was higher than values observed in 2013 and 2017. Similar high CPUE was found in 2014 for Coho Salmon as described above for Cutthroat Trout. The majority of Coho Salmon captured in all years were 0+ (fry); however, 1+ parr have also been detected in Alena Creek each year.

Relatively high captures in the newly established sites in the FHEP are indicative that the enhanced reach is high quality habitat for both juvenile Cutthroat Trout and Coho Salmon.

Hydrology

Seasonal trends in the Alena Creek hydrograph in 2019 were consistent with a coastal, snow-dominated watershed. Seasonal hydrograph patterns remained broadly consistent with observations from baseline and Year 1 and 2 post-construction monitoring. Stage readings in 2019 remained relatively low throughout the winter (January to mid-March) when precipitation was snow dominated, then increased during snow melt in spring (March and April). Stage remained low during monitoring in late-summer and early fall (August 23 to October) when precipitation was minimal.

The daily maximum stage during 2019 at the FSR bridge was recorded on April 19, 2019 (0.47 m) corresponding with spring snowmelt. This was less than the maximum stage measured since records began in May 2013, which was recorded on November 9, 2016 (0.95 m) during a 1-in-20 year return flood event on the Upper Lillooet River, but was consistent with peak values recorded during baseline monitoring. The minimum daily stage during the winter of 2019 (0.14 m) was slightly lower than stage recorded previously during monitoring from November 2016 to January 2019.

During 2019, the stage trends at the FSR bridge and R1 gauge closely aligned, indicating that backwatering from Upper Lillooet River to the FSR bridge did not occur. We recommend continued stage monitoring at both the FSR bridge and the upstream R1 gauge.

Water Temperature

The objective of water temperature monitoring is to ensure that conditions within the FHEP support functional use for spawning, incubation, and rearing by the fish species in Alena Creek. To achieve this, water temperature will be monitored continuously for the first five years post-construction and compared to the pre-construction data using a before-after-control-impact (BACI) design.

Pre-construction water temperature monitoring occurred from April 17, 2013 to December 31, 2014 at the upstream site (upstream of all FHEP works) and from August 27, 2013 to December 31, 2014 at the downstream site (located within the FHEP) (Map 3); winter season water temperatures at the upstream site were not fully captured pre-construction due to data gaps in the winter/early spring 2014 data set. Therefore, direct comparison of pre- and post-construction monitoring for cooler temperature metrics are limited for the upstream site.

Post-construction monitoring commenced at both sites on November 23, 2016. Year 3 data are available up to September 23, 2019 for the upstream site and to October 23, 2019 for the downstream site. No substantial data gaps were recorded post-construction. Analysis of the data included calculating the following temperature metrics: monthly statistics (average, minimum, and maximum water temperatures for each month of record), differences in water temperature between the upstream and downstream monitoring sites, number of days with extreme mean daily temperature (e.g., >18°C, and <1°C), the length of the growing season, exceedance of Bull Trout temperature thresholds, and mean weekly maximum temperature (MWMxT). These metrics are compared to water temperature BC WQG (Oliver and Fidler 2001, MOE 2019) to assess suitability of the water temperature for aquatic life and specifically, Coho Salmon, Cutthroat Trout, and Bull Trout (*Salvelinus confluentus*).

Alena Creek is classified as a cool stream with no days with mean daily water temperatures >18°C in either pre- or post-construction conditions at both sites, and only a few days at the downstream site when the mean daily temperature was <1°C. Despite the small elevation (11 m) difference and short distance (~1 km) between the two sites, the downstream site exhibits greater variability in water temperature and is generally warmer than the upstream site in the summer and cooler in the winter. The water temperature at the upstream site is moderated by groundwater inflow and there is a tributary that enters Alena Creek between the two sites, which may account for some of the cooler temperature downstream in the winter and warmer temperature downstream in the summer.

Overall, considering inter-annual variably in temperature, no substantial change in monthly temperature statistics has been observed in Year 3 in comparison to previous post-construction and pre-construction data. The range in monthly average temperatures at the upstream site was 5.0°C to 8.1°C pre-construction and 4.0°C to 8.1°C post-construction. No pre-construction data are available for the upstream site from mid-January to mid-March, therefore the monthly minimum of 5.0°C measured in December 2014 may not be representative of the coolest monthly average at this site pre-construction.

At the downstream site monthly average temperatures ranged from 2.2°C to 10.1°C pre-construction, and from 1.2°C to 11.7°C post-construction. Minimum monthly temperatures in each year occurred in December or February. In 2019 monthly average temperatures were the highest (11.7°C) and lowest (1.2°C) on record to date, occurring at the downstream site, however, similar instantaneous temperature ranges were observed in the pre- (0.0°C to 14°C) and post-construction (0.0°C to 14.5°C) periods.

Water temperatures at the monitoring sites were generally sub-optimally cool for Cutthroat Trout and Coho Salmon during pre- and post-construction periods, although some sub-optimally warm temperatures were recorded for Bull Trout and Cutthroat Trout incubation and spawning at the downstream site.

In general, it appears the upstream site is more suitable than the downstream site for spawning and incubation of Bull Trout across the stated periodicity for this species. Fewer cool temperature exceedances of the BC WQG occurred upstream during the winter months and overall fewer exceedances of the warm temperature BC WQG in the summer months. Warm surface waters at the upstream site, during incubation stages may be partially mitigated by the groundwater upwelling, such that temperature within the redds may be lower than that measured at the temperature logger.

Results to date indicate that the FHEP provides water temperatures typical of the area, with beneficial moderating effects due to groundwater inflow upstream of the habitat. Overall, temperatures are more suitable for Bull Trout than Coho Salmon and Cutthroat Trout due to the generally cooler optimum temperature ranges for Bull Trout.

Overall, no substantial differences were observed in the pre- and post-construction temperature regimes. We recommend that the monitoring program continue for 5 years post-construction based on the methodologies and schedule prescribed in the Project OEMP (Harwood *et al.* 2017).

Riparian Habitat

The Alena Creek FHEP detailed specific restoration and enhancement prescriptions for the Alena Creek riparian FHEP area to increase the density of conifers and ensure planting success to improve riparian habitat function for fish (Hemmera 2015). The objective of the riparian restoration effectiveness monitoring program is to qualify and quantify revegetation and planting success, including confirming that a diversity of native tree and shrub species, including a component of coniferous trees, become established.

Vegetation in the Alena Creek FHEP area is establishing well and this component of the program is meeting the intended objectives of the FHEP and OEMP (Hemmera 2015, Harwood *et al.* 2013, Harwood *et al.* 2017). In 2019, the density of woody vegetation was 79,900 ± 48,103 stems/ha, far surpassing the overall minimum target of 2,309 stems/ha. Similarly, the density of trees in the FHEP area in 2019 was 50,350 ± 45,222 stems/ha, surpassing the target for mature trees of 1,200 stems/ha, and the overall density of shrubs in the FHEP area was 20,550 ± 11,491 stems/ha, surpassing the shrub specific target of 2,000 stems/ ha. In addition, the cover of vegetation was estimated at 86%, surpassing the target of 80%. In 2019 conifer species accounted for 29% of all trees with a density of 1,700 stems/ha, as compared to the 50 stems/ha, accounting for 0.1% of all trees, in plots prior to restoration (Harwood *et al.* 2016). No mortality of planted or naturally regenerating western redcedar was observed, and overall survival of the species, as well as all coniferous species is assumed to be 100%. The success of conifer regeneration, as well as the observed diversity of tree and shrub species, demonstrates the success of the habitat in progressing towards a mixed coniferous/ deciduous forest from a deciduous forest and in providing a diverse riparian habitat.

The observed high stem densities and vegetation cover within the FHEP area are indicators of a stable site, and no signs of erosion were noted during 2019 field sampling. Thus, no erosion control or soil conditioning appears to be necessary at this time. Similarly, no additional planting or remediation measures are recommended at this time. However, additional thinning of black cottonwood (*Populus trichocarpa)* and red alder (*Alnus rubra*) may be necessary in the long-term if they appear to be suppressing the growth of target conifer species. Monitoring for the presence of invasive species should continue during revegetation surveys, and the thistle species noted in ALE-PR03 should be identified to determine management requirements. If the species is deemed a noxious weed, treatment prescriptions should be developed and implemented. The next revegetation monitoring visit is planned for Year 5 (Harwood *et al.* 2017) and should be conducted in late August or early September before vegetation dies off for the season.

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1. INTRODUCTION

This report provides results of Year 3 (2019) of the long-term monitoring program to evaluate the effectiveness of the Fish Habitat Enhancement Project (FHEP) constructed on Alena Creek (also known as Leanna Creek) as per the *Fisheries Act* Authorization issued for the Upper Lillooet Hydro Project (the Project). Ecofish Research Limited (Ecofish) was retained by the Upper Lillooet River Power Limited Partnership (ULRPLP) to monitor the FHEP on Alena Creek northwest of Pemberton, BC. The FHEP was designed by Hemmera Envirochem Inc. (Hemmera 2015) and Ecofish (Appendix A) to offset the habitat losses incurred due to the footprint and operation of the Project. The Project is composed of two hydroelectric facilities (HEFs) on the Upper Lillooet River and Boulder Creek, and a 72-km-long 230 kV transmission line. Alena Creek is a tributary to the Upper Lillooet River located approximately 4.1 km downstream of the confluence of Boulder Creek with the Upper Lillooet River, and is therefore downstream of the two HEFs (Map 1).

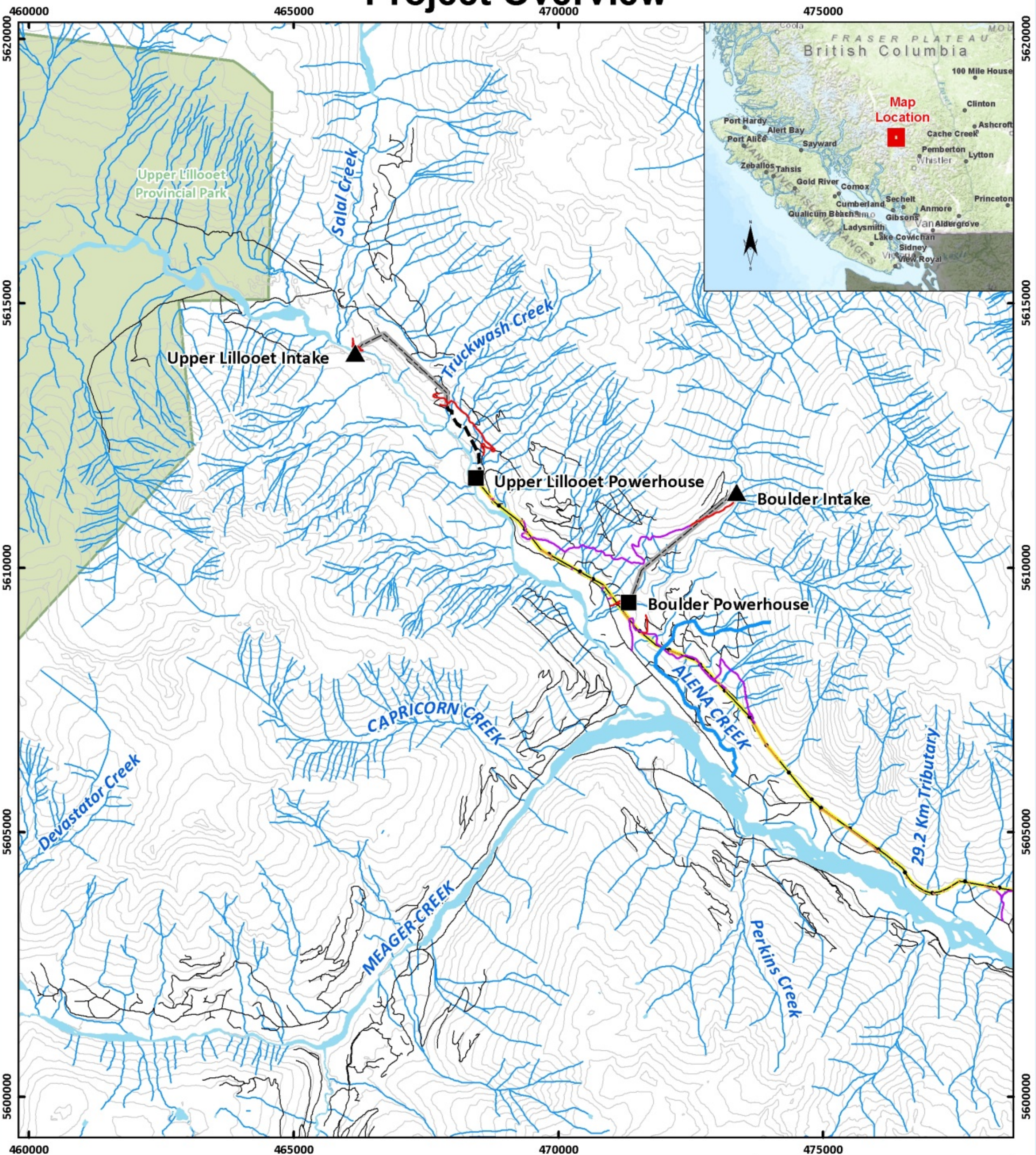
Details of the predicted habitat losses incurred by Project construction and operation are provided in the aquatic and riparian footprint reports for the HEFs and the transmission line (Buchanan *et al.* 2013a, b). These habitat losses were authorized by Fisheries and Oceans Canada (DFO) through the issuance of a *Fisheries Act* Authorization (09-HPAC-PA2-00303) on September 26, 2013. The Authorization was amended on June 17, 2014. The amended Authorization requires the enhancement of 2,310 m^2 of instream habitat to offset the permanent loss of 1,935 m^2 of fish habitat associated with the construction of the Upper Lillooet HEF intake. Under the amended Authorization, there were no offset requirements associated with construction and operation of the Boulder Creek HEF, or with impacts to riparian habitat.

The offsetting plan involved fish habitat enhancement in Alena Creek, which was heavily impacted by the Capricorn/Meager Creek slide (hereafter referred to as the Meager Creek slide): a natural, catastrophic event that occurred on August 6, 2010 and deposited a large amount of woody debris and a thick slurry of sediment in and around Alena Creek. In addition to heavily impacting aquatic habitat, the slide affected riparian habitat either by uprooting trees or by smothering root systems with a thick layer of sediment. The FHEP constructed in the summer of 2016, created a new section of channel and enhanced both the aquatic and riparian habitat of Alena Creek and will therefore benefit Coho Salmon (*Oncorhynchus kisutch*), Cutthroat Trout (*O. clarkii*) and Bull Trout (*Salvelinus confluentus*). The FHEP consists of a downstream (Reach 1) and upstream reach (Reach 3) separated by a naturally recovering low gradient reach (Reach 2) (Map 2). The actual location and geometry of constructed design features was summarized in the as-built drawings (West *et al.* 2017).

Historical fish and fish habitat data from Alena Creek, and long-term monitoring requirements for the FHEP, were originally described in the Alena Creek Long-Term Monitoring Program (Harwood *et al.* 2013). Long-term monitoring requirements were subsequently revised and integrated into Project's Operational Environmental Monitoring Plan (OEMP) (Harwood *et al.* 2017). Results of Years 1 and 2 of Alena Creek pre-construction monitoring are documented in Harwood *et al.* (2016).

Results of Year 1 and 2 (2017, 2018) of post-construction monitoring are presented in Harwood *et al.* (2019). Results from Year 3 (2019) are summarized below.

Project Overview



Legend

ULHP Infrastructure

- ▲ Intake
- ■ Powerhouse
- Proposed Facility Road (New)
- Proposed Tower Road (New)
- Upgrade Required to Existing Road
- Penstock
- Tunnel
- First Nation Reserve
- Parks and Protected Areas
- Roads
- Contours (100 m)

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 1 2 3 4 km

Scale: 1:100,000

NO.	DATE	REVISION	BY
1	07/04/2015	1095_ULP_Overview_AlenaCreek_2015Apr07_ADN	EF
2			
3			
4			
5			

Date Saved: 07/04/2015
Coordinate System: NAD 1983 UTM Zone 10N

ECOFISH RESEARCH

Map 1

Path: M:\Projects-Active\1095_UPPERLILLOOETPROJECT_NEW\MXD\Compensation\1095_ULP_Overview_AlenaCreek_2015Apr07_ADN.mxd

2. OBJECTIVES AND BACKGROUND

2.1. Fish Community

The goal of enhancing aquatic and riparian habitat in Alena Creek was to provide spawning and rearing habitat for Coho Salmon and Cutthroat Trout, and to support equivalent or greater fish use (based on fish abundance) in Alena Creek relative to pre-project conditions. Fish habitat use in Alena Creek was assessed by comparing adult Bull Trout and Coho Salmon spawner abundance and juvenile Cutthroat Trout and Coho Salmon abundance under baseline and post-enhancement conditions. The adults were sampled by counting fish during bank walks during the Coho Salmon spawning season in early November to early December. The juveniles were sampled using minnow traps deployed at eight sites in Alena Creek. The catch per unit effort (CPUE) for minnow trapping can be compared among years to assess changes in fish abundance over time.

2.2. Fish Habitat

In 2016, thirteen riffles and more than 120 pieces of large wood were installed in Reach 1 with total creation of 1,387 m^2 of enhanced fish habitat. A total of 668 m^2 of new instream habitat and 1,139 m^2 of floodplain was created in Reach 3 in 2016. Twelve cobble riffles and over 100 pieces of large woody debris were installed in this reach as part of the FHEP. A stability assessment has been conducted annually to monitor the establishment and functionality of each of the FHEP habitat features to promptly identify whether any remedial action is required to maintain the effectiveness of habitat features.

2.3. Hydrology

Water level data provide useful information on inter-seasonal variation in flow and assist in interpreting changes in the other monitoring components (e.g., water temperature and fish abundance). The hydrological monitoring program in Alena Creek was undertaken by Knight Piésold Ltd (KPL).

2.4. Water Quality

Sampling at two sites during pre-construction monitoring and Year 1 showed that water quality in Alena Creek has generally improved since pre-construction sampling began in 2013 (Harwood *et al.* 2019). Further, monitoring data in Year 1 showed that water quality in the FHEP is generally suitable for aquatic life, including salmonids. Considering these observations, and that instream habitat enhancement is not expected to result in adverse effects on water quality, water quality sampling was discontinued after Year 1 based on a recommendation in the Year 1 annual report (Harwood *et al.* 2018).

2.5. Water Temperature

Small incremental changes in water temperature can potentially affect stream biota, including fish. Fish are vulnerable to both small increases and decreases in water temperature, with tolerance levels varying between species and life-history stages and dependent on existing conditions. The objective of water temperature monitoring is to ensure that conditions within the Alena Creek FHEP support functional use for migration, spawning, incubation, and rearing by the fish species present. Collection of continuous water temperature data will allow for a comparison of pre- and post-construction temperature data to track changes within the FHEP over time. Water temperature may be influenced by the instream enhancement features and maturation of the riparian vegetation planted during the habitat restoration.

Water temperature is monitored continuously at two sites (Map 3) for the first five years post-construction. One site is located upstream of the restoration works and the other is in the downstream end of the FHEP. Alena Creek is classified as a cool stream with no days with mean daily water temperatures >18°C in either pre- or post-construction conditions at both sites. Despite the small elevation (11 m) difference and short distance (~1 km) between the two sites, the downstream site exhibits greater variability in water temperature and is generally warmer than the upstream site in the summer and cooler in the winter (Map 3). The water temperature at the upstream site is moderated by groundwater inflow and there is a tributary that enters Alena Creek between the two sites which may account for some of the cooler temperature downstream in the winter and warmer temperature downstream in the summer.

This Year 3 (2019) annual monitoring data report provides a summary of pre-construction (2013-2014), and post construction (2016-2019), water temperature monitoring results. This report is intended to be primarily a data summary report; any changes in water temperature related to the construction of the FHEP will be evaluated with a BACI analysis following 5 years of post-construction water temperature data collection.

2.6. Riparian Habitat

Riparian areas contribute to fish habitat quality through thermal regulation, minimizing sedimentation by stabilizing stream banks and intercepting run-off, and by providing nutrients, channel-stabilizing large woody debris (LWD), and cover (Gregory *et al.* 1991, Naiman and Decamps 1997, Naiman *et al.* 2000, Richardson 2004). To provide these benefits, a goal of the Alena Creek FHEP is to expedite succession of the riparian area from an early-successional deciduous stand towards a mixed coniferous/deciduous forest. As such, the FHEP included specific restoration and enhancement prescriptions for the riparian area (defined as the terrestrial area within 30 m of the high-water mark of each bank of the stream) to increase the density of conifers and ensure planting success (Hemmera 2015).

The objective of the riparian restoration effectiveness monitoring program, as per the OEMP, is to qualitatively and quantitatively describe the natural regeneration and planting success in the riparian area, and to confirm that a diversity of well-established native tree and shrub species with low observed mortality rates are present within the Alena Creek FHEP area (Harwood *et al.* 2016; Harwood *et al.* 2017). Successful revegetation is defined by several targets: 1) survival of at least 80% of vegetation between monitoring years overall (considered to be 2,309 stems/ ha and 80% cover), and of the planted western redcedar (*Thuja plicata*) stock specifically (DFO and MELP 1998; Harwood *et al*. 2013, Harwood *et al*. 2017); 2) target densities equal to or more than 1,200 tree stems/ ha and 2,000 shrub stems/ha (Harwood *et al*. 2017); and 3) a diversity of healthy vegetation including a transition to a mixed conifer/ deciduous stand from a deciduous stand (Harwood *et al*. 2017, Hemmera 2015).

To evaluate regeneration and planting success, results from the third year of monitoring are compared with three benchmarks: 1) as-built surveys conducted immediately following restoration work in 2016 (Harwood *et al*. 2016) and Year 1 monitoring in 2017 (Harwood *et al*. 2019), 2) data collected four years after the slide prior to restoration work (Harwood *et al*. 2016), and 3) data collected prior to the Meager Creek slide (as estimated from typical characteristics of floodplain sites in the same biogeoclimatic zone; Green and Klinka 1994).

3. METHODS

3.1. Fish Habitat

Reach 1 and 3 of Alena Creek were enhanced as a part of the FHEP. To assess the stability of the enhancements, initial photos were taken at photo-points established during the as-built survey (completed shortly following the construction in 2016). A total of eight transects were surveyed at that time. At each transect, a panorama of photographs was taken to support evaluation of changes in habitat conditions over time. Photographs were taken looking downstream, upstream, from river left to river right, and from river right to river left. The photograph aspects were oriented to provide a full view of the bankfull channel and floodplain, with the transect tape included in the photo to provide a visual reference to aid with analysis of the topographic transect surveys. The transect photos have been repeated during each year since construction (Harwood *et al*. 2016; 2017; 2018; 2019) to allow for detection of changes in channel conditions. Additional photos were also taken throughout Reach 1 and 3 at key points.

3.2. Fish Community

3.2.1. Adult Spawner Abundance

Coho Salmon, Bull Trout, and Cutthroat Trout were captured in Alena Creek during the monitoring studies. Spawner surveys in Alena Creek focused on Coho Salmon and Bull Trout. Spawner surveys for Bull Trout consisted of bank walks conducted approximately every two weeks between September 17 and October 22, 2019 (a total of three surveys). In addition, Coho spawner surveys were conducted every two weeks between November 13 and December 9, 2019 (a total of three surveys). Consistent with previous years, bank walks to count both live fish and carcasses occurred from the downstream confluence with the Upper Lillooet River to the upstream end of Alena Creek at the groundwater spring at the Lillooet River FSR crossing at kilometer 36.5. Due to the meandering nature of the Upper Lillooet River, the downstream confluence with Alena Creek has varied over the survey years by up to ~1 km.

It is important to note that the carcasses counted in Alena Creek are quickly consumed by wildlife in the area, as evidenced by the fact that they are not often whole and show signs of being eaten by wildlife. Often only the pyloric caeca, which animals prefer not to eat, is left behind.

3.2.2. Juvenile Abundance

3.2.2.1. Minnow Trapping

Minnow trapping surveys were conducted in Alena Creek commencing in Year 3 on September 23, 2019. The objective of minnow trapping was to monitor the change among years in the relative abundance of juvenile fish, based on catch-per-unit-effort (CPUE) for individual species and life stages.

A total of eight sites were selected in 2019, the same as 2018 but compared to six in previous years. Four to 10 traps were installed at each site. At ALE-MT06 site, 10 traps were set because it was a large pool that required a higher level of sampling effort. Sampling was conducted in five of the six sites sampled in previous years (ALE-MT01, ALE-MT02, ALE-MT03, ALE-MT05 and ALE-MT06); however, due to beaver activity in previous years, sampling at ALE-MT04 was discontinued in 2018 and 2019 as recommended in the Year 1 report (Harwood *et al.* 2019). Additionally, three new sites established in 2018 in FHEP habitat were sampled, specifically one site in Reach 1 (ALE-MT07) and two sites in Reach 3 (ALE-MT08 and ALE-09; Map 4). The Year 1 report had recommended that one of the additional sites be located just upstream of Reach 1 at the gravel augmentation pile installed as part of the enhancement works; however, due to beaver dam and stability issues at this location, the site was located just downstream of the gravel augmentation pile and in the Reach 1 FHEP area (ALE-MT07).

The minnow traps were baited using salmon roe and left overnight. When the traps were retrieved, captured fish were identified and measured (discussed below).

3.2.2.2. Biological Information

All captured fish were enumerated and identified to species using standard field keys. The fork length of each captured fish was determined using a measuring board (±1.0 mm) and then each fish was weighed using a field scale (±0.1 g).

Aging samples were taken from a sub-sample of captured fish and these were aged at the Ecofish laboratory in Campbell River. Scale samples collected in the field were examined under a dissecting microscope for aging purposes: three representative scales were photographed, and apparent annuli noted on a digital image. Fish age was determined by a biologist and QA'd by a senior biologist. Where discrepancies were identified, they were discussed, and final age determination was based on the professional judgement of the senior biologist.

3.2.2.3. Data Analysis

Individual Fish Data

Biological data from the captured fish were analyzed to define the age structure, size structure, length-weight relationship, length at age, and condition factor by species. Discrete age classes were based on size bins established using length-frequency histograms and age data from the scale analysis. Discrete classes were defined for fry (0+), parr (1+), parr (2+) and adults (3+). These discrete classes allowed all fish to be assigned an age class based on fork length. Based on a review of the aging data and length-frequency histograms, discrete fork length ranges were defined for each age class.

The condition of fish, which is an indication of overall health, can be calculated in a variety of ways, such as Fulton K or relative weight (W_r) (Blackwell *et al.* 2000). A potential problem with the use of Fulton K is an assumption of isometric growth (Blackwell *et al.* 2000); however, in this instance, the condition of fish was calculated separately for each age classes, so violations of this assumption were not expected. The condition of fish was consequently assessed by calculating Fulton's condition factor (*K*) and creating plots of species-specific length-weight relationships. Fulton's condition factor (*K*) was calculated for each fish captured by species and year using the following equation:

$$K = \left(\frac{W}{L^3}\right)100{,}000$$

where W is the weight in g, L is the length in mm, and $100{,}000$ is a scaling constant (Blackwell *et al.* 2000).

Relative Abundance

Relative abundance was evaluated using CPUE for minnow trap data, which was calculated as the number of fish captured per 100 trap hours.

3.3. Hydrology

KPL began monitoring water level at Alena Creek in April 2013. Two water level loggers were originally installed in Alena Creek; one at the Lillooet River FSR crossing (Alena Bridge) and another at the upstream end of the project area (Alena Upstream) (Map 3). For post-construction monitoring, water level data were collected at the Alena Bridge site in 2016, 2017 and 2018. A second gauge (R1) was installed based on recommendation by Harwood *et al.* (2018) on August 23, 2018 at approximately 125 m upstream from the Alena Bridge gauge. The purpose of the second gauge is to examine for potential backwater effects that may be caused by the Upper Lillooet River side channel when flows were high, and to ensure the stage data collected are representative of Alena Creek water levels.

3.4. Water Temperature

3.4.1. Study Design

Pre-construction monitoring occurred from April 17, 2013 to December 31, 2014 at the upstream site and from August 27, 2013 to December 31, 2014 at the downstream site. Post-construction monitoring commenced at both sites on November 23, 2016. Year 3 data are available up to September 23, 2019 for the upstream site and to October 23, 2019 for the downstream site (Table 1).

During the post-construction period, water temperature data were recorded at 15-minute intervals, using self-contained Tidbit v2 loggers made by Onset (details provided in Section 3.4.3) at two monitoring sites: ALE-USWQ1, located upstream of the enhancement works, and ALE-BDGWQ, located at the downstream end of the works, within the enhanced area and just upstream of the FSR bridge (Table 1, Map 3, Appendix B).

During the pre-construction monitoring period, there were gaps in the datasets from mid January 2014 to mid March 2014 at the upstream site, and from the end of March through early April 2014 at the downstream site due to the suspected build-up of ice (McCarthy, pers. comm. 2014) (Table 1). At the upstream site, less than three weeks of water temperature data were available for January, February and March 2014. Therefore, not all summary statistics and temperature metrics (see Section 3.4.4) could be calculated for these months, limiting the available winter season pre-construction data (Table 1). At the downstream site, less than three weeks of data were available for March 2014, limiting the available spring season pre-construction data (Table 1). No data gaps were observed post-construction (i.e., data set is 100 % complete, Table 1).

Table 1. Summary of water temperature site names, logging details and period of data record in Alena Creek pre-construction (2013, 2014) and post-construction (November 2016 through 2019).

Type	Site	UTM Coordinates (10U)		Elevation (masl)[1]	Project Phase	Periods of Record		Number of Data Records	Logging Interval (min.)	No. of Days with Valid Data	% Complete[2]
		Easting	Northing			Start Date	End Date				
Upstream	ALE-USWQ1	472,976	5,606,870	391	Pre-construction	17-Apr-13	31-Dec-14	54,395	60	561	91.0
					Post-construction	23-Nov-16	23-Sep-19	99,236	15	1,035	100
Downstream	ALE-BDGWQ	473,336	5,606,095	382	Pre-construction	27-Aug-13	31-Dec-14	44,075	60	453	93.6
					Post-construction	23-Nov-16	23-Oct-19	102,158	15	1,062	100

[1] Estimated from Google Earth.

Pre-construction (2013-2014) water temperature was monitored via hydrometric gauges maintained by KPL. Post-construction Tidbit temperature loggers were installed.

[2] The pre-construction data gap at the upstream site occurred between mid January and mid March 2014 due to icing concerns, therefore a complete month of data (i.e., more than three weeks) for February 2014 are not available during this phase.

The pre-construction data gap at the downstream site occurred at the end of March through early April 2014, therefore a complete month of data (i.e., more than three weeks) for March are not available during this phase.

3.4.2. Fish Species Distribution

The fish community in Alena Creek consists of Coho Salmon, Cutthroat Trout and Bull Trout (Table 2, Table 3). The BC WQG for water temperature specify optimum temperature ranges for rearing, spawning, incubation, and migration as applicable for these fish species (Table 2). The timing of life history stages in Alena Creek (Harwood *et al.* 2016) is used to define the start and end dates for each of the applicable life stages for Coho Salmon, Cutthroat Trout, and Bull Trout (Table 3).

Table 2. Optimum water temperature ranges for Coho Salmon, Cutthroat Trout, and Bull Trout during spawning, incubation, rearing and migration (MOE 2019).

Species	Optimum Water Temperature Range (°C)			
	Spawning	Incubation	Rearing	Migration
Coho Salmon	4.4 - 12.8	4.0 - 13.0	9.0 - 16.0	7.2 - 15.6
Cutthroat Trout	9.0 - 12.0	9.0 - 12.0	7.0 - 16.0	-
Bull Trout	5.0 - 9.0	2.0 - 6.0	6.0 - 14.0	-

The BC WQG for water temperature is ± 1°C outside the optimum temperature range for each life stage.

Table 3. Fish species periodicity.

Coho Salmon	Cutthroat Trout	Bull Trout
Spawning (Oct. 15 to Jan. 01)	Spawning (Apr. 01 to Jul. 01)	Spawning (Aug. 01 to Dec. 08)
Incubation (Oct. 15 to Apr. 01)	Incubation (May. 01 to Sep. 01)	Incubation (Aug. 01 to Mar. 01)
Rearing (Jan. 01 to Dec. 31)	Rearing (Jan. 01 to Dec. 31)	Rearing (Jan. 01 to Dec. 31)
Migration (Sep. 01 to Dec. 31)	-	-

3.4.3. Quality Assurance / Quality Control

Pre-construction temperature data were recorded at 60-minute intervals using hydrometric gauges maintained by Knight Piésold Ltd. (KPL). The temperature sensors incorporated into the gauges were installed in aluminum standpipes and had an accuracy of ±0.3°C, a resolution of ±0.001°C. Post-construction temperature data were recorded at 15-minute intervals, using self-contained Tidbit v2 loggers made by Onset. The loggers have a range of -20°C to +70°C, are accurate to ±0.2°C, and have a resolution of 0.02°C. Water temperature at ALE-BDGWQ was concurrently logged by two Onset Tidbit loggers installed on separate anchors; this redundancy ensured availability of data in case one of the loggers malfunctioned or was lost. A second Tidbit logger was installed at ALE-USWQ1 in 2019.

Temperature data were carefully inspected and QA'd to ensure that any suspect or unreliable data were excluded from data analysis and presentation. Excluded data included instances where the water temperature sensor was suspected of being out-of-water/dry, affected by snow/ice or buried in sediment. Only data that were definitively ice-affected were removed prior to analysis, and this only occurred pre-construction in 2014 (Table 1).

3.4.4. Data Analysis and Collection

Processing of water temperature data was conducted by first identifying and removing outliers and then compiling data into a time series for all sites. Identification and removal of outliers was conducted as part of a thorough Quality Assurance/Quality Control (QA/QC) process which ensured that any suspect or unreliable data were excluded from analysis and presentation Excluded data included, for example, data where the sensor was suspected of being out of the water, affected by snow or ice, or buried in sediment.

After identifying and removing outliers, the records from duplicate loggers were averaged and records from different download dates were combined into a single time-series for each monitoring site. The time series for all sites were then interpolated to a regular interval of 15 minutes (where data were not already logged on a 15-minute interval), starting at the full hour.

Data are presented in plots that were generated from temperature data collected at, or interpolated to, 15-minute intervals. Analysis of the data involved computing the following summary statistics: monthly statistics (mean, minimum, and maximum water temperatures for each month of record, as well as differences in water temperature among sites), days with extreme mean daily temperature (e.g., >18°C and <1°C), days with exceedances of the minimum and maximum Bull Trout temperature thresholds, the length of the growing season, and the accumulated thermal units in the growing season (i.e., degree days), hourly rates of temperature change, and mean weekly maximum temperature (MWMxT). Table 4 defines these statistics and describes how they were calculated.

The calculation of the end date of the length of the growing season (as defined in Table 4) was modified from 4°C (as per Coleman and Fausch 2007) to 5°C, because the MWMxTs at the upstream site were >4°C in the winter data set for the first year of pre-construction monitoring.

3.4.4.1. Applicable Guidelines

The water temperature BC Water Quality Guidelines (BC WQG) for the protection of aquatic life (as per Oliver and Fidler 2001, MOE 2019) are discussed below.

Hourly Rates of Water Temperature Change

Rapid changes in heating or cooling of water temperature can affect fish growth and survival (Oliver and Fidler 2001). Hourly rates of change in water temperature were compared to the BC WQG, which specifies that the hourly rate of water temperature change should not exceed ±1.0°C/hr (MOE 2019).

Daily Temperature Extremes

Extreme cold or warm temperatures are monitored as part of the water temperature component. The number of days when the daily mean temperature was <1°C was calculated, along with the number of days when the daily mean temperature >18°C and >20°C. Alena Creek is a cool stream where maximum temperatures recorded to date did not exceed 15°C, therefore the number of day >18°C and >20°C are not required. The maximum optimum temperature for the fish species present in the Project area is 16°C (Coho Salmon and Cutthroat Trout rearing life stage, Table 2).

Mean Weekly Maximum Temperature (MWMxT)

The MWMxT is an important indicator of prolonged periods of cold and warm water temperatures that fish are exposed to. The water temperature BC WQG for the protection of aquatic life states "Where fish distribution information is available, then mean weekly maximum water temperatures should only vary by ±1.0°C beyond the optimum temperature range of each life history phase (incubation, rearing, migration and spawning) for the most sensitive salmonid species present" (Oliver and Fidler 2001, MOE 2019). Accordingly, MWMxT values were compared to the optimum temperature ranges for the fish species present based on the life history and periodicity (Table 2, Table 3).

Within each life history period, the completeness of the temperature data record (% complete) is calculated and results are only included if at least 50% of the data for the period is available. The minimum and maximum MWMxT values, % data within the optimum range and % exceedance of ±1.0°C of the optimal temperature range is calculated for each life history period to evaluate the suitability of the temperature regime for each fish species, at each monitoring site, pre- and post-construction.

Bull Trout Temperature Guidelines

Additional BC WQG (MOE 2018) water temperature guidelines are specified for streams with Bull Trout and Dolly Varden (Oliver and Fidler 2001; Table 1 in Appendix C). When either of these fish species are present, the guidelines state that:

- maximum daily water temperature is 15°C;
- maximum daily incubation temperature is 10°C;
- minimum daily incubation temperature is 2°C; and
- maximum daily spawning temperature is 10°C.

The number of days where these thresholds are exceeded are calculated using the appropriate daily maximum or minimum temperature values for each site where Bull Trout are present (Table 4).

Table 4. Water temperature metrics and method of calculation.

Metric	Description	Method of Calculation
Water temperature	Hourly or 15 minute data	Data (interpolated to 15 minute intervals where necessary) presented in graphical form.
Monthly statistics	Mean, minimum, and maximum on a monthly basis	Calculated from 15 minute data (interpolated where necessary) and presented in tabular format.
Rate of water temperature change	Hourly rate of change	Calculated from 15 minute data (interpolated where necessary); presented in summary tables and graphical form.
Degree days in growing season[1]	The beginning of the growing season is defined as the beginning of the first week that mean stream temperatures exceed and remain above 5°C; the end of the growing season was defined as the last day of the first week that mean stream temperature dropped below 4°C (as per Coleman and Fausch 2007).	Daily mean water temperatures were summed over this period (i.e., from the first day of the first week when weekly mean temperatures reached and remained above 5°C until the last day of the first week when weekly mean temperature dropped below 4°C).
Number of Days of Extreme Daily Mean Temperature	Daily average temperature extremes for all streams	Total number of days with daily mean water temperature >18°C , >20°C , and <1°C.
Number of Days of Exceedance	Daily maximum and minimum temperature thresholds for streams with Bull Trout / Dolly Varden	# days maximum daily temperature is >15°C; # days maximum incubation temperature is >10°C; # days minimum incubation temperature is <2°C; # days maximum spawning temperature is >10°C.
MWMxT (Mean Weekly Maximum Temperature)	Mean, minimum, and maximum on a running weekly (7 day) basis	Mean of the warmest daily maximum water temperature based on hourly data for 7 consecutive days; e.g., if MWMxT = 15°C on August 1, 2008, this is the mean of the daily maximum water temperatures from July 29 to August 4, 2008; this is calculated for every day of the year.

[1] The end of the growing season was defined as the last day of the first week than mean stream temperatures dropped below 5°C for Alena Creek.

3.5. Riparian Habitat

Three types of data were evaluated to monitor the success of the riparian restoration works and the overall function of the riparian habitat; these were: (1) vegetation density estimates from permanent revegetation monitoring plots; (2) vegetation ground cover estimates from randomly placed quadrats; and (3) photographs taken over multiple years at permanent photopoint monitoring locations. Methods are discussed in more detail below. Any regionally or provincially designated noxious invasive species were also documented when observed.

3.5.1. Permanent Revegetation Monitoring Plots

Woody vegetation is the primary focus of riparian revegetation monitoring due to its long-term contribution to the maintenance and enhancement of riparian habitat function. Consequently, the density (stems per hectare) of woody vegetation is an important metric and indicator of restored riparian habitat quality. Permanent revegetation monitoring plots are used to sample the density of perennial woody vegetation within 50 m^2 circular plots, as per the BC Silviculture Stocking Survey Procedures (MOF 2009) and vegetation tally procedures employed by the Forest and Range Evaluation Program's Stand Development Monitoring Protocol (MOF 2011).

Four permanent revegetation monitoring plots were established in 2014, prior to construction of the FHEP; however, only one of these four plots (ALE-PRM03) ended up within the restored area. As such, three additional plots were established in 2016, following construction of the FHEP, so that a total of four plots were assessed in 2016 (as-built), 2017 (Year 1) and 2019 (Year 3). These four permanent revegetation monitoring plots will be assessed for the duration of the monitoring program (Map 4).

Perennial woody vegetation includes long-lived species such as trees and shrubs, but excludes forbs, grasses, and mosses. The surveyors counted the number of stems of all native perennial woody plants and conducted health and mortality checks. Plants showing signs of abiotic stress, insect damage, fungal blights, or other afflictions were all counted as living, but incidences of the afflictions and the host plant species were noted. Stems were defined as those stems of a plant that were individually distinct at ground level. Tree or shrub seedlings with secondary leaves that were the size of a quarter or larger were counted. No minimum height requirements were applied.

The DFO and MELP effective revegetation criteria provided a spacing target of 2.0 m for planting (DFO and MELP 1998). When 80% survival is considered, this equates to an overall target of 2,309 stems/ha, as written in the original proposed long-term monitoring program for Alena Creek (Harwood *et al.* 2013). The current OEMP set minimum targets of 1,200 stem/ha for trees and 2,000 stems/ha for shrubs for revegetated areas associated with temporary riparian habitat loss created during project construction, however the performance measure set for the success of riparian revegetation within the FHEP area is 80% survival with no differentiation between tree or shrub densities (Harwood *et al.* 2017). These target densities for tree and shrub species, as well as overall densities, were considered when assessing whether an adequate density of woody vegetation is growing within the FHEP area. The variability in the stem density estimates was assessed using a two-tailed students t-test and a 90% confidence interval (*t* value = 2.35). In addition, the presence and relative number of stems of each species were considered to assess if a diverse assemblage of native tree and shrub species is becoming established within the Alena Creek FHEP area, and if the species composition is indicative of expedited succession to a mixed coniferous/ deciduous forest. The overall survival rate of vegetation, as well as the survival of western red cedar (*Thuja plicata*) specifically, was calculated by dividing the total number of live plants by the total number of live and dead plants combined, as observed in any given year.

3.5.2. Percent Vegetation Cover Estimates

Vegetated ground cover, including herbaceous and small woody species, is an indicator of substrate stabilization and suitable growing conditions early in the revegetation process. A target of 80% cover has been adopted for the monitoring program (DFO and MELP 1998; Harwood *et al.* 2013, Harwood *et al.* 2017. Quadrat sampling was employed to determine the percent ground cover of all herbaceous and woody vegetation, excluding lichens, fungi and mosses. Quadrat sampling provides a method for accounting for regeneration of the forb and grass layer, which is not captured by counting perennial woody vegetation within the permanent monitoring plots. This method is most informative during the early vegetation re-establishment period when all vegetation is low to the ground. The quadrat method consists of counting the number of 10 × 10 cm quadrat squares that contain vegetation within the 0.25 m^2 quadrat. Ten quadrat replicates were randomly located within the vicinity of the permanent revegetation monitoring plots and results from the ten replicates were averaged to provide an average percent cover for the site. Photos of each quadrat replicate were taken and are available upon request.

3.5.3. Photopoint Comparison

Photopoint monitoring, employed by taking repeat photographs over time, provides insight into how the riparian condition and associated functions change over time. Photographs were taken facing 0° (north), 90° (east), 180° (south) and 270° (west) from 1.3 m above each permanent monitoring plot centre to qualitatively document change over time. The north facing photographs are appended to this report, whereas additional photographs are available upon request. Additional descriptive photographs were also taken of the monitoring sites.

4. RESULTS

4.1. Fish Habitat

4.1.1. Overview

Photos were taken at established photo-point locations in the enhanced reaches (Reach 1 and Reach 3) of Alena Creek on November 13, 2019. A comparison of all photos is available in Appendix D. Overall, the riparian vegetation has increased since 2016 and the channel has remained stable over this time. Grasses and herbaceous vegetation continue to establish well throughout the reaches and protect the bank from excessive erosion, while also providing cover for small salmonids. No substantial changes to the stream channel were noted that were not anticipated based on the dynamic stability criteria of the design. Historical beaver activity has created significant damming upstream of both Reach 1 and Reach 3, which has been managed in accordance with best management practices for dam removal provided by a licensed trapper from EBB Environmental Consulting Inc. Fortunately, beaver dams have not been constructed within Reach 1 or Reach 3 since channel works were completed. A description of channel condition and geomorphic processes is provided for the two reaches in the following section.

4.1.2. Reach 1

Reach 1 is the most downstream reach of Alena Creek and extends up from the Lillooet River Forest Service Road (FSR, Map 4) bridge. A summary of observations at each cross section is provided below.

- **ALE-XS1** - Channel had previously avulsed onto river left floodplain and created a side-channel less than 10 m long. This channel appears to have been less active in 2019 compared to 2018 but this could be a result of difference in flow between surveys. The riffle is still composed of gravel and is relatively free of fines but has some algae growth. No concerns for long term stability (Figure 1 to Figure 4).
- **ALE-XS2** - Channel may be more backwatered in this location due to a collapse of one of the channel-spanning logs downstream (Figure 5). Some undercutting has occurred on river left under a longitudinally aligned log, which appears to be stable and has created good cover habitat. Root wads on river right continue to provide good cover habitat. A downstream collapsed log should be monitored closely in future years to ensure the jam is not causing excessive fines deposition or full channel avulsion.
- **ALE-XS3** - Channel hydraulic diversity remains as designed, and the riffle has low fines content; no concerns for long term stability.
- **ALE-XS4** - Pool depth has remained as designed with minimal aggradation of fines. Root wads continue to provide good cover conditions. No concerns for long term stability.

Figure 1. Looking from river left to river right at ALE-XS1 on September 19, 2016.

Figure 2. Looking from river left to river right at ALE-XS1 on November 10, 2017.

Figure 3. Looking from river left to river right at ALE-XS1 on November 5, 2018.

Figure 4. Looking from river left to river right at ALE-XS1 on November 13, 2019.

Figure 5. Log that has collapsed between ALE-XS1 and ALE-XS2 (left) causing moderate side-channel formation (right and shown in Figure 1 to Figure 4) and partial backwatering of a riffle. Photos taken on June 20, 2019.

4.1.3. Reach 3

The channel is still recovering from a peak flow event that occurred shortly after construction on November 9, 2016. Following this flow event, a mid-channel bar formed just upstream of the ALE-XS6 site as the result of erosion along the right bank (Figure 6). The channel widening at this location caused a moderate reduction in gravel quality at the adjacent riffle, but minimal reduction in salmonid habitat quality overall. Bank erosion has also caused channel widening and down-cutting in section at the riffle-crest downstream of ALE-XS5 (Figure 7). Repairs are recommended in this reach, as described in Section 5.1.

Beaver damming activity has been increasing upstream of Reach 3. The dams may restrict fish migration to the upstream spawning reach, impede gravel supply to Reach 3, and cause diversion of flow around the Reach 3 constructed channel. Furthermore, a sudden dam breach could cause a pulse of fine sediment to be delivered to, and deposited in, Reach 3. Two new channels have already formed on the west side of Reach 3 due to a large beaver pond approximately 30–50 m upstream of Reach 3. These channels are cutting into fine sediment and delivering it to Reach 3. One channel enters Reach 3 approximately 40 m downstream from the head of Reach 3 (Figure 8) and the other enters where the construction access road came in midway through the reach (Figure 9).

A summary of observations at each cross section is provided below.

- **ALE-XS5** - Channel hydraulic diversity remains as designed, and the riffle has low fines content despite moderate bank erosion upstream. One channel-spanning log has collapsed but is only subtly affecting hydraulics. Root wads upstream of the riffle continue to provide good cover conditions; there are no concerns for long term stability.

- **ALE-XS6** - Some sand deposition has occurred on riffle material, likely originating partially from upstream supply and from bank erosion that largely occurred during the November 2016 high flow event. Grass and herbaceous bank vegetation have established that should prevent excessive erosion in the future. No concerns for long term stability.
- **ALE-XS7** - Pool has aggregated with sand to some extent and may now be at an equilibrium depth with the upstream sand supply. Rootwads continue to provide cover habitat, and riffles are generally free of fines; there are no concerns for long term stability.
- **ALE-XS8** – The riffle is still relatively free of fines and excessive erosion has not occurred. Fines deposition has occurred on the glide that is unavoidable given upstream sediment supply; there are no concerns for long term stability.

Figure 6. Mid-channel bar just upstream of ALE-XS6. Photo taken on June 20, 2019.

Figure 7. Bank erosion and channel down-cutting at ALE-XS5 requiring repair. Photo taken on June 20, 2019.

Figure 8. Entry point of upper new channel formed near upstream extent of Reach 3. Photo taken on November 13, 2019.

Figure 9. Entry point of lower new channel formed near upstream extent of Reach 3. Photo taken on June 20, 2019.

4.2. Fish Community

4.2.1. Adult Spawner Abundance

The peak count of Coho Salmon spawners observed in 2019 was 153 live fish and 20 carcasses on December 9, 2019 (Table 5). The peak count of adult spawning Coho Salmon was 153 in 2019, which was slightly higher than the baseline years (127 and 111) and 2017 (132) but less than 2016 (192) (Table 6). A comparison of observations among years also highlights the variability in run timing, with the annual peak live count recorded on November 5 in 2010 and 2018, November 14 in 2016, December 5 in 2017, and December 9 in 2019. The peak counts provide a general indication of use and demonstrate that Alena Creek supports equivalent or potentially greater use by Coho Salmon spawners compared to pre-enhancement, although among-year variability in spawner abundance is strongly affected by other factors such as marine survival. An example photograph of spawning Coho Salmon observed December 9, 2019 is provided in Figure 10. A single Bull Trout was observed on October 1, 2019 (Table 5).

Table 5. Summary of adult fish observed during fall spawner surveys in 2019.

Stream	Date	Survey Time	Survey Distance	# of Live Adults Observed[1]			# of Adult Carcasses Observed[1]		
				BT	CT	CO	BT	CT	CO
Alena Creek	17-Sep-19	1.5	1,750	0	0	0	0	0	0
	1-Oct-19	1.9	2,300	1	0	0	0	0	0
	22-Oct-19	2.0	2,300	0	0	0	0	0	0
	13-Nov-19	4.7	2,300	0	0	21	0	0	2
	24-Nov-19	1.9	2,300	0	0	91	0	0	19
	9-Dec-19	2.5	2,300	0	0	153	0	0	20
Alena Creek Total:		**14.5**	**13,250**	**1**	**0**	**265**	**0**	**0**	**41**

[1] BT = Bull Trout, CT = Cutthroat Trout, CO = Coho Salmon

Table 6. Peak Coho Salmon spawner counts during baseline (2010, 2011) and post-construction monitoring (2016, 2017, 2018 and 2019).

	2010 Peak Count (05-Nov-10)		2011 Peak Count (02-Dec-11)		2016 Peak Count (27-Nov-16)		2017 Peak Count (05-Dec-17)		2018 Peak Count 5-Nov-18		2019 Peak Count (09-Dec-19)	
	Live	**Dead**	**Live**	**Dead**	**Live**	**Dead**	**Live**	**Dead**	**Live**	**Dead**	**Live**	**Dead**
	127	0	110	1	174	18	110	22	**126**	**0**	153	20
Total	**127**		**111**		**192**		**132**		**126**		**173**	

Figure 10. Spawning Coho Salmon observed on December 9, 2019.

4.2.2. Juvenile Abundance

4.2.2.1. Overview

On September 23, 2019, 44 minnow traps were set overnight in riffle, pool, and glide habitats ranging in depth from 0.2 to 1.2 m (Table 7). A total of 436 fish were captured during minnow trap sampling consisting of 423 Coho Salmon and 13 Cutthroat Trout (Table 7). No juvenile Bull Trout were captured in 2019. Raw data tables and representative photographs of minnow trapping sites are presented in Appendix E.

Table 7. Summary of minnow trapping habitat characteristics and fish captures in Alena Creek on September 24, 2019.

Site	Date	Enhancement Status	# of Traps	Total Soak Time (hrs)	Mesh Size (mm)	Habitat Type	Trap Depth Range (m)	Total Captures		
								BT	CO	CT
ALE-MT01	24-Sep-19	Enhanced	5	116.4	3	Glide, Riffle	0.3 - 0.4	0	7	2
ALE-MT02	23-Sep-19	Enhanced	5	117.1	3-6	Pool, Riffle	0.3 - 0.5	0	15	0
ALE-MT07	23-Sep-19	Enhanced	5	120.7	3-6	Pool	0.4 - 0.8	0	25	2
ALE-MT03	23-Sep-19	Unenhanced	4	100.1	3-6	Pool, Glide	0.2 - 0.6	0	68	4
ALE-MT06	23-Sep-19	Unenhanced	10	261.7	3-6	Pool	0.3 - 1.2	0	138	3
ALE-MT08	23-Sep-19	Enhanced	5	141.1	3-6	Pool, Riffle	0.3 - 0.7	0	54	0
ALE-MT09	23-Sep-19	Enhanced	5	140.9	3-6	Pool, Riffle	0.2 - 0.3	0	26	1
ALE-MT05	23-Sep-19	Unenhanced	5	142.1	6	Pool	0.3 - 0.4	0	90	1
Grand Total:			**44**	**1,139.9**				**0**	**423**	**13**
Grand Average:			**5.5**	**142.5**				**0**	**53**	**2**

4.2.2.2. Cutthroat Trout

A total of 13 Cutthroat Trout, ranging in length from 46 to 121 mm, were captured during the 2019 sampling program (Table 10). Based on a review of the length-frequency histogram (Figure 11) and aging data from scale analysis (Figure 13), discrete fork length ranges were defined for each age class (Table 10). Summary statistics of fish length, weight, and condition factor are presented for each age class in Table 11. Catch per unit effort (CPUE) ranged from 0 fish per 100 trap hours at ALE-MT08 to 4.0 fish per 100 trap hours in ALE-MT03 (Table 12). The average CPUE was 1.2 fish per 100 trap hours and the standard deviation was 1.3 fish per 100 trap hours.

Cutthroat Trout Fry (0+)

A total of three Cutthroat Trout fry (0+) were captured in 2019. A single fry was captured at ALE-MT01 (enhanced), ALE-MT07 (enhanced), and ALE-MT03 (unenhanced).

Cutthroat Trout Parr (1+)

Cutthroat Trout parr (1+) were distributed throughout Alena Creek and were captured at all sites except for ALE-MT02 and ALE-MT08 (enhanced) and ALE-MT05 (unenhanced) (Table 20). A total of 9 Cutthroat Trout 1+ parr were captured, with the largest number of fish captured in ALE-MT03 and ALE-MT06.

Cutthroat Trout Parr (2+)

A single Cutthroat Trout 2+ parr was captured in 2019 in ALE-MT05 (unenhanced reach).

Figure 11. Fork length frequency for juvenile Cutthroat Trout captured (minnow trapping) in Alena Creek in 2019.

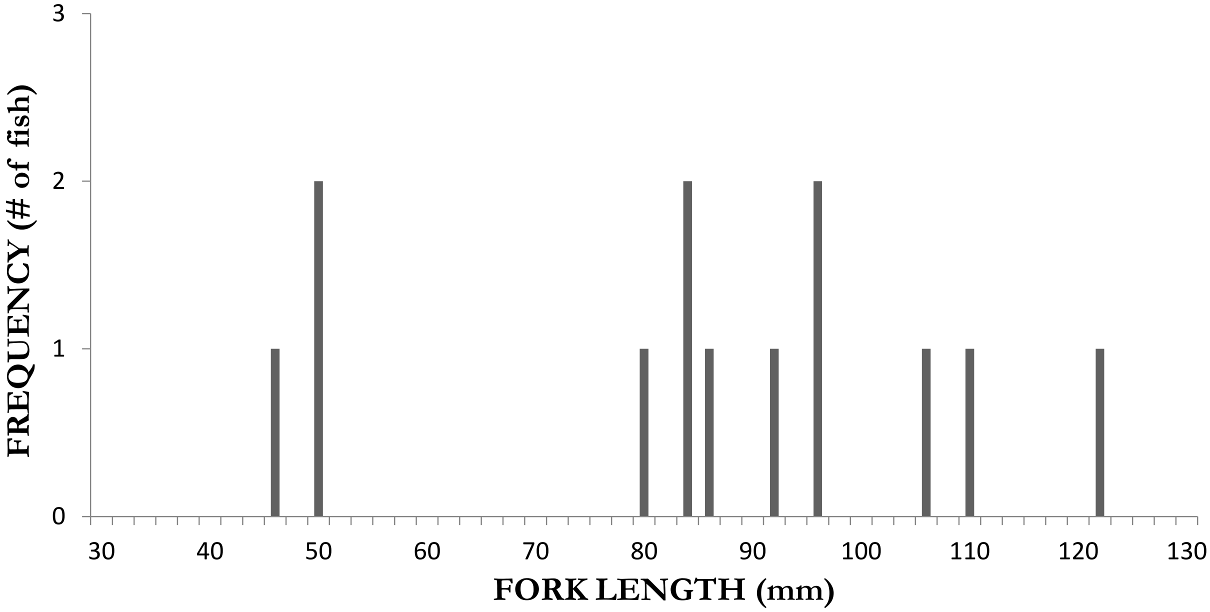


Figure 12. Fork length versus age for juvenile Cutthroat Trout captured in Alena Creek in 2019.

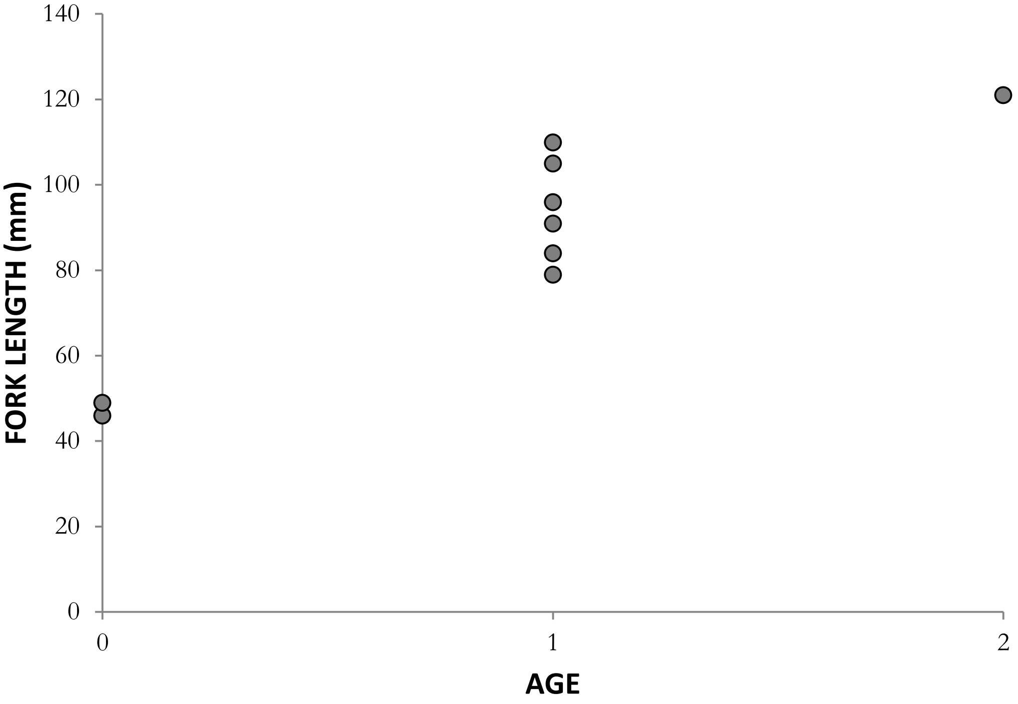


Table 8. Age size bins for juvenile Cutthroat Trout captured in Alena Creek in 2019.

Age Class	Fork Length Range (mm)
Fry (0+)	46-49
Parr (1+)	79-110
Parr (2+)	121+

Table 9. Summary of fork length, weight and condition for juvenile Cutthroat Trout captured in Alena Creek in 2019.

Age Class	Fork Length (mm)				Weight (g)				Condition Factor (K)			
	n	Average	Min	Max	n	Average	Min	Max	n	Average	Min	Max
Fry (0+)	3	48	46	49	3	1.0	1.0	1.0	3	0.91	0.85	1.03
Parr (1+)	9	92	79	110	6	9.0	5.0	13.0	9	0.97	0.84	1.13
Parr (2+)	1	121	121	121	0	0.0	0.0	0.0	0	-	-	-
All	**13**	**84**	**46**	**121**	**9**	**6.3**	**1.0**	**13.0**	**13**	**0.95**	**0.84**	**1.13**

Table 10. **Catch and CPUE for Cutthroat Trout captured by minnow trapping in Alena Creek in 2019.**

Site	Date	Enhancement Status	# of Traps	Total Soak Time (hrs)	Minnow Trap Catch (# of Fish)				Minnow Trap CPUE (# of Fish/100 Trap hrs)			
					0+	1+	2+	All	0+	1+	2+	All
ALE-MT01	24-Sep-19	Enhanced	5	116.4	1	1	0	**2**	0.9	0.9	0.0	**1.7**
ALE-MT02	23-Sep-19	Enhanced	5	117.1	0	0	0	**0**	0.0	0.0	0.0	**0.0**
ALE-MT07	23-Sep-19	Enhanced	5	120.7	1	1	0	**2**	0.8	0.8	0.0	**1.7**
ALE-MT03	23-Sep-19	Unenhanced	4	100.1	1	3	0	**4**	1.0	3.0	0.0	**4.0**
ALE-MT05	23-Sep-19	Unenhanced	5	142.1	0	0	1	**1**	0.0	0.0	0.7	**0.7**
ALE-MT06	23-Sep-19	Unenhanced	10	261.7	0	3	0	**3**	0.0	1.1	0.0	**1.1**
ALE-MT08	23-Sep-19	Enhanced	5	141.1	0	0	0	**0**	0.0	0.0	0.0	**0.0**
ALE-MT09	23-Sep-19	Enhanced	5	140.9	0	1	0	**1**	0.0	0.7	0.0	**0.7**
Grand Total:			**44**	**1,139.9**	**3**	**9**	**1**	**13**	**2.7**	**6.5**	**0.7**	**9.9**
Grand Average:			**5.5**	**142.5**	**0**	**1**	**0**	**2**	**0.3**	**0.8**	**0.1**	**1.2**
Grand Standard Deviation:				**50.4**	**1**	**1**	**0**	**1**	**0.5**	**1.0**	**0.2**	**1.3**

4.2.2.3. Coho Salmon

A total of 423 juvenile Coho Salmon were captured during minnow trap sampling in Alena Creek on September 24, 2019. Based on a review of the length-frequency histogram (Figure 13) and aging data from scale analysis (Table 11), discrete fork length ranges were defined for each age class (Table 12). Summary statistics of fish length, weight, and condition factor are presented for each age class in Table 12. CPUE ranged from 6.0 fish per 100 trap hours at ALE-MT01 (enhanced reach) to 68.3 fish per 100 trap hours in ALE-MT05 (unenhanced) (Table 13). The total average CPUE was 35.0 fish per 100 trap hours and the standard deviation was 24.0 fish per 100 trap hours (Table 13).

Coho Salmon Fry (0+)

Coho Salmon fry (0+) were captured at all sampling sites in 2019 and are distributed throughout the sampled reaches of Alena Creek (Table 13). Coho Salmon fry were most abundant at ALE-MT03 and ALE-MT06 in the unenhanced reach (Reach 2) and ALE-MT08 in the enhanced reach (Reach 3).

Coho Salmon Parr (1+)

Coho Salmon 1+ parr were captured at most sites in 2019 except for ALE-MT02 and ALE-MT09 (Table 13). They were most abundant in ALE-MT05, in the unenhanced reach (Reach 4).

Figure 13. **Fork length frequency for juvenile Coho Salmon captured (minnow trapping) in Alena Creek in 2019.**

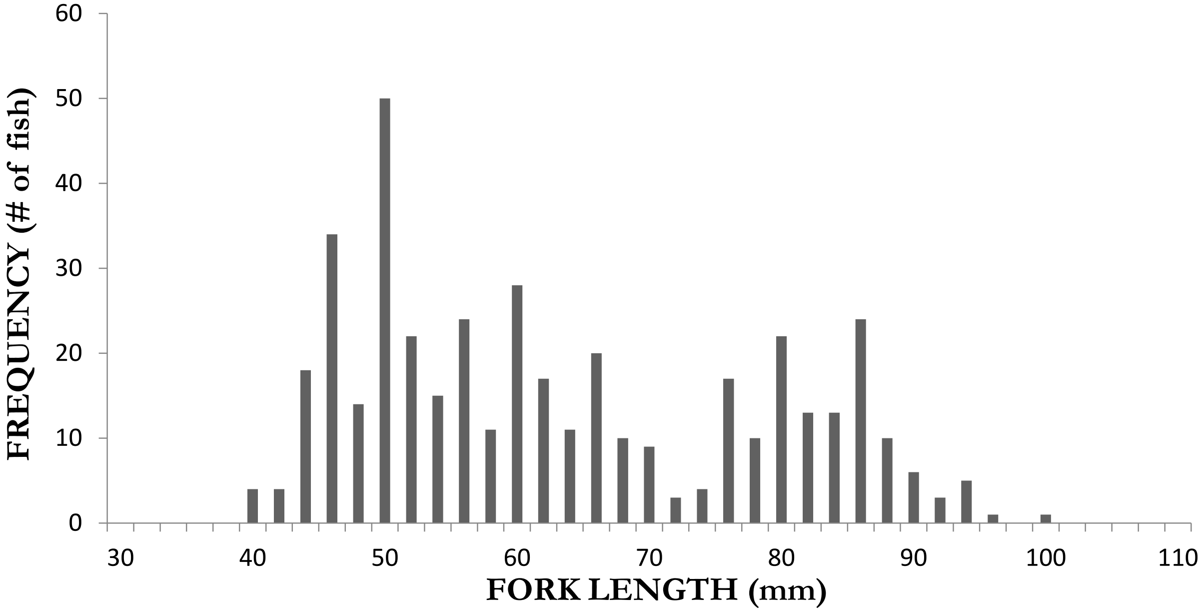


Figure 14. **Fork length versus age for Coho Salmon captured in Alena Creek in 2019.**

Table 11. Age size bins for Coho Salmon captured in Alena Creek in 2019.

Age Class	Fork Length Range (mm)
Fry (0+)	40-73
Parr (1+)	74-100

Table 12. Summary of fork length, weight and condition for Coho Salmon captured in Alena Creek in 2019.

Age Class	Fork Length (mm)				Weight (g)				Condition Factor (K)			
	n	Average	Min	Max	n	Average	Min	Max	n	Average	Min	Max
Fry (0+)	297	54	40	73	220	2.0	0.4	6.0	297	1.27	0.47	2.85
Parr (1+)	126	83	74	100	63	6.8	5.0	12.0	126	1.21	0.76	1.56
All	**423**	**63**	**40**	**100**	**283**	**3.1**	**0.4**	**12.0**	**423**	**1.26**	**0.47**	**2.85**

Table 13. Catch and CPUE for Coho Salmon captured in Alena Creek in 2019.

Site	Date	Enhancement Status	# of Traps	Total Soak Time (hrs)	Minnow Trap Catch (# of Fish)				Minnow Trap CPUE (# of Fish/100 Trap hrs)			
					0+	1+	2+	All	0+	1+	2+	All
ALE-MT01	24-Sep-19	Enhanced	5	116.4	6	1	0	**7**	5.2	0.9	0.0	**6.0**
ALE-MT02	23-Sep-19	Enhanced	5	117.1	15	0	0	**15**	12.8	0.0	0.0	**12.8**
ALE-MT07	23-Sep-19	Enhanced	5	120.7	20	5	0	**25**	16.6	4.1	0.0	**20.7**
ALE-MT03	23-Sep-19	Unenhanced	4	100.1	52	16	0	**68**	52.0	16.0	0.0	**68.0**
ALE-MT06	23-Sep-19	Unenhanced	10	261.7	93	45	0	**138**	35.5	17.2	0.0	**52.7**
ALE-MT08	23-Sep-19	Enhanced	5	141.1	50	4	0	**54**	35.4	2.8	0.0	**38.3**
ALE-MT09	23-Sep-19	Enhanced	5	140.9	26	0	0	**26**	18.5	0.0	0.0	**18.5**
ALE-MT05	23-Sep-19	Unenhanced	5	142.1	35	55	0	**90**	24.6	38.7	0.0	**63.3**
Grand Total:			**44**	**1,139.9**	**297**	**126**	**0**	**423**	**200.6**	**79.7**	**0.0**	**280.3**
Grand Average:			**5.5**	**142.5**	**37**	**16**	**0**	**53**	**25.1**	**10.0**	**0.0**	**35.0**
Grand Standard Deviation:				**50.4**	**28**	**22**	**0**	**45**	**15.1**	**13.5**	**0.0**	**24.0**

4.2.2.4. Bull Trout

No Bull Trout were captured in Alena Creek minnow traps in 2019.

4.2.2.5. Comparison Among Years

Cutthroat Trout

The average CPUE across sites in 2019 (1.1 fish per 100 trap hours) was most similar to 2017 (0.8 fish per 100 trap hours) and less than 2013 and 2018 (1.8 and 1.6 fish per 100 trap hours respectively) (Figure 15). The average CPUE in 2014 (7.2 fish per 100 trap hours) was higher than other years; however, the 2014 CPUE results are biased high by the short daytime sets and the likelihood that catchability is not constant throughout the trap soak time, with a high initial catch rate that diminishes over time (Harwood *et al.* 2016). There were more sites sampled in 2018 and 2019 (eight sites versus six sites in previous years)

In 2019, Cutthroat Trout were relatively evenly distributed in low numbers throughout Alena Creek; this is similar to previous years although the standard deviation was slightly higher in 2019 (Figure 16). Specifically, the standard deviation of CPUE among sites was 1.0 fish per 100 trap hours compared to 0.8 fish per 100 trap hours in 2018 and 0.7 fish per 100 trap hours in 2017 and 2013.

In all sampling years, the most abundant age class of Cutthroat Trout captured was 1+ parr. Three fry were captured in 2019 compared to zero captured in 2017 and 2018. Similar to 2019, three fry were also captured during two sampling events in September 2013 and one fry was captured in October 2014. The low abundance of Cutthroat Trout fry captured during sampling is likely a result of the timing of emergence of fry in late September / early October.

Figure 15. **Comparison of minnow trap CPUE for Cutthroat Trout during baseline (2013 and 2014) and post-construction (2017, 2018, and 2019). Error bars represent standard error. Note that 2014 CPUE may be an overestimation due to shorter soak time at some sites due to bear activity.**

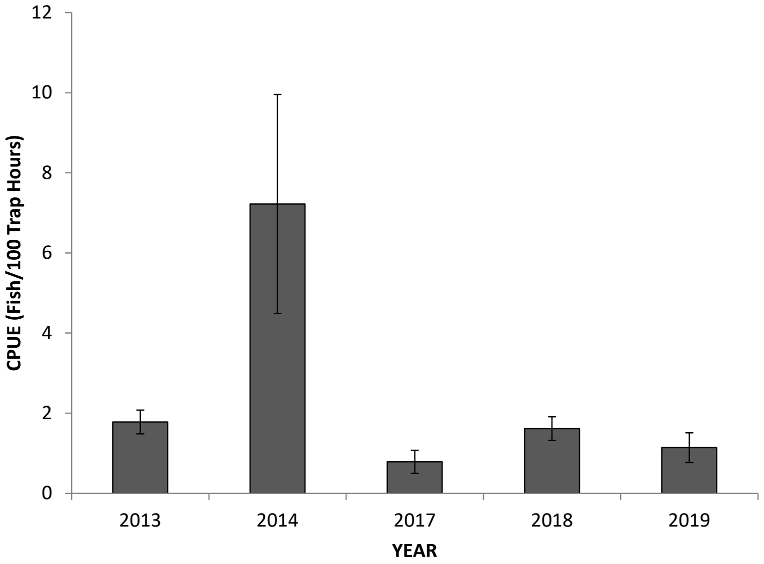
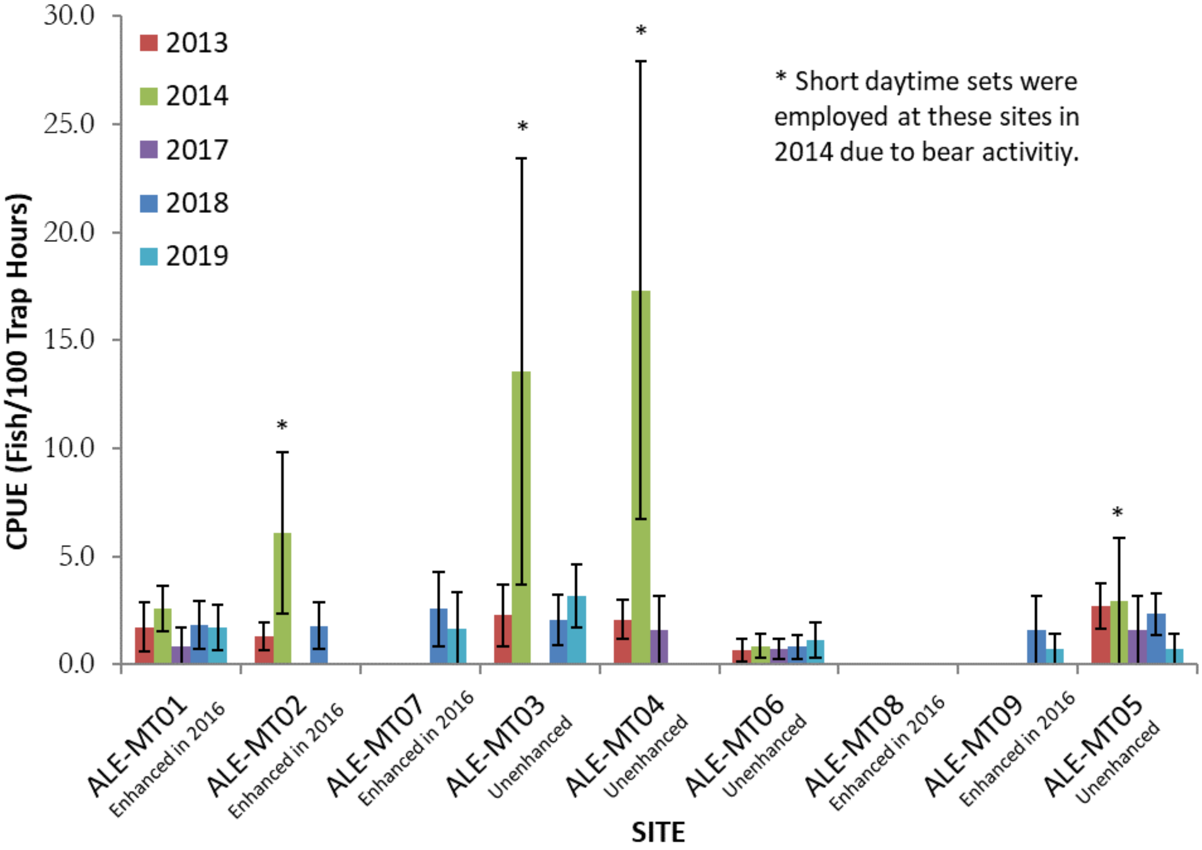


Figure 16. **Comparison of minnow trap CPUE for Cutthroat Trout at each site during baseline (2013 and 2014) and post-construction (2017, 2018, and 2019). Error bars represent standard error.**



Coho Salmon

The average CPUE across sites in 2018 and 2019 (83.8 and 33.3 fish per 100 trap hours respectively) was higher than values observed in 2013 and 2017 (Figure 17). There were more sites sampled in 2018 and 2019 (eight sites versus six sites in previous years), although this should not directly affect CPUE as it is a standardized metric.

In 2019, Coho Salmon fry were captured at all sites, with parr present at most sites similar to previous years (Figure 18). The standard deviation of CPUE among sites in 2019 was within range of previous years.

Figure 17. Comparison of minnow trap CPUE for Coho Salmon during baseline (2013 and 2014) and post-construction (2017, 2018, and 2019) monitoring periods. Error bars represent standard error. Note that 2014 CPUE may be an overestimation due to shorter soak time at some sites due to bear activity.

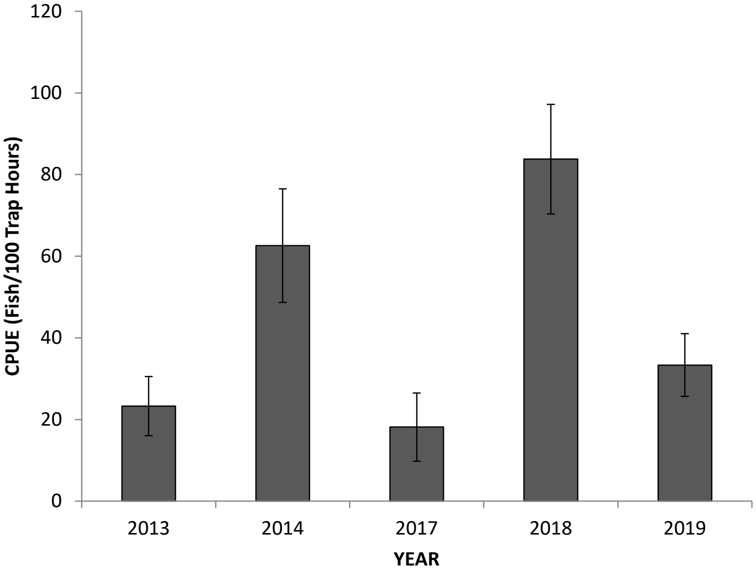
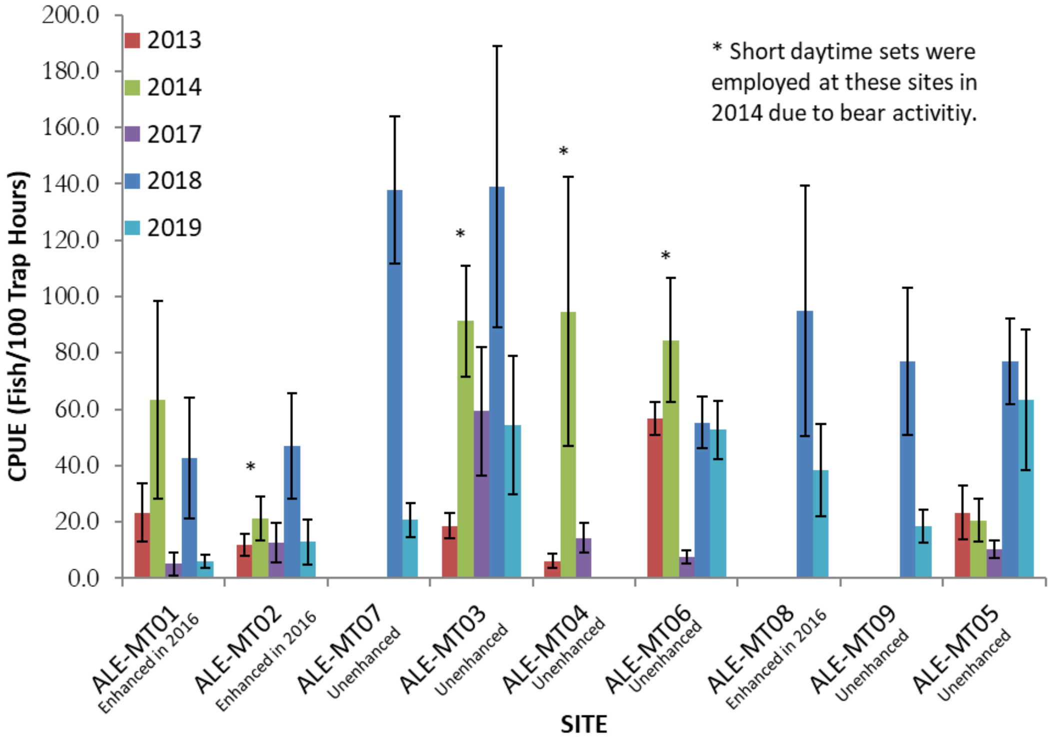


Figure 18. Comparison of minnow trap CPUE for Coho Salmon at each site during baseline (2013 and 2014) and post-construction (2017, 2018, and 2019). Error bars represent standard error.



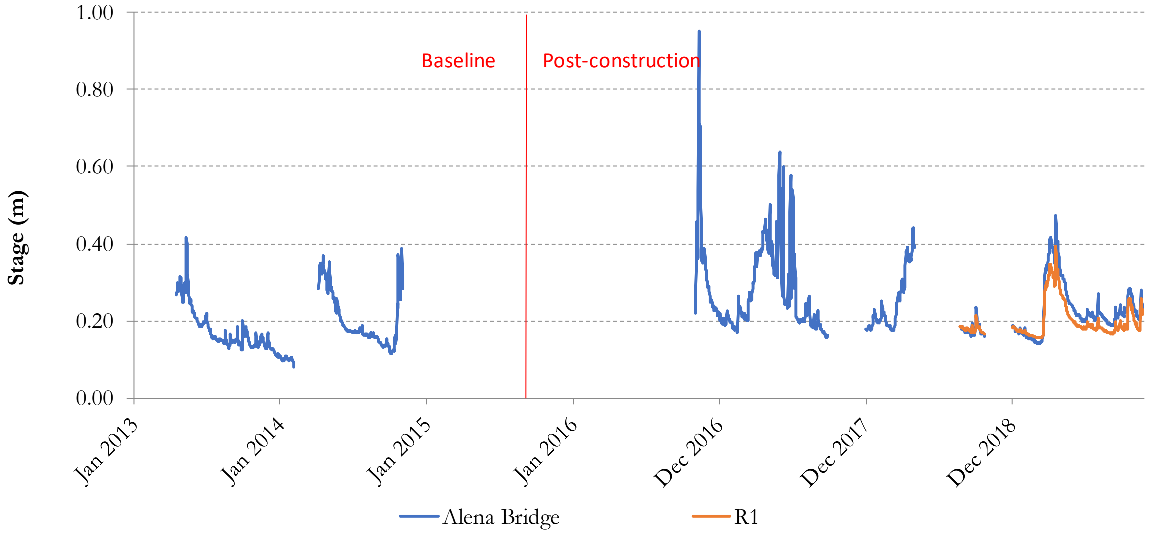
4.3. Hydrology

Seasonal trends in the Alena Creek hydrograph in 2019 were consistent with a coastal, snow-dominated watershed. Seasonal hydrograph patterns remained broadly consistent with observations from baseline and Year 1 and 2 post-construction monitoring. Stage readings in 2019 remained relatively low throughout the winter (January to mid-March) when precipitation was snow dominated, then increased during snow melt in spring (March and April). Stage remained low during monitoring in late-summer and early fall (August 23 to October) when precipitation was minimal (Figure 19).

The daily maximum stage during 2019 at the FSR bridge was recorded on April 19, 2019 (0.47 m) corresponding with spring snowmelt. This was less than the maximum stage measured since records began in May 2013, which was recorded on November 9, 2016 (0.95 m) during a 1-in-20 year return flood event on the Upper Lillooet River (McCoy, pers. comm. 2016), but was consistent with peak values recorded during baseline monitoring (Figure 19). Several higher stage values were also recorded in 2017 between mid-May to early-July (Figure 19). Overall mean daily stage at the FSR bridge measured from January to November of 2019 was 0.23 ± 0.07 m, and dropped below 0.16 m for 36 days from February 9, 2019 to March 16, 2019 with a minimum of 0.14 m. This minimum value is slightly lower than stage recorded previously during monitoring from November 2016 to January 2019.

During 2017, high stage readings were recorded at the FSR bridge that were suspected to be a result of backwatering from Upper Lillooet River (Harwood *et al.* 2018). A second gauge (R1) was installed on August 23, 2018 approximately 125 m upstream of the Alena Bridge gauge for comparison to assess backwater effects. During 2019, the stage trends at the FSR bridge and R1 gauge closely aligned (Figure 19), indicating that backwatering from Upper Lillooet River to the FSR bridge was no longer occurring.

Figure 19. **Stage in Alena Creek at the Lillooet River FSR bridge during baseline (April 2013 to November 2014), and Year 1 to Year 3 of post-construction monitoring (November 2016 to November 2019).**



4.4. Water Temperature

4.4.1. Overview

The results of the pre-construction and post construction water temperature metrics, including Year 3 (2019) data, are summarized in the following sections. Water temperature site photographs are presented in Appendix B and annual water temperature figures and BC WQG for water temperature are presented in Appendix C. This report is intended to be primarily a data summary report; any changes in water temperature related to the construction of the FHEP will be evaluated with a BACI analysis following 5 years of post-construction water temperature data collection.

Years 1, 2, and 3 (2017, 2018, 2019) complete nearly three full years of post-construction water temperature data collection at the upstream (control; ALE-USWQ) and downstream site (impact; ALE-BDGWQ). The period of record is from November 23, 2016 to September 23, 2019 (Table 1, Map 3). Data availability is based on the most recent download of water temperature loggers. There are no data gaps in the post-construction data set to date (Table 1). Data gaps occurred pre-construction due to icing issues and out of water events in the winter of 2014. These data gaps resulted in a loss of winter season data at the upstream site, therefore temperature minima may not have been fully captured upstream of the FHEP works pre-construction.

The temperature regime is presented using a) daily average temperature data, b) daily maximum temperature data and c) daily minimum temperature data (Figure 20). The pattern of differences in water temperature between the two sites during the winter and summer seasons is largely the same pre- and post-construction, as depicted in the cumulative frequency distribution between the sites (Figure 21). Despite the small difference in elevation (11 m) and short distance (~1 km) between the sites, the downstream site is generally warmer than the upstream site in the summer and cooler in the winter (Figure 20, Figure 21). In addition to the influence of groundwater upstream, there is a tributary that enters Alena Creek between the two sites, which may account for some of the cooler temperatures downstream in the winter and warmer temperatures downstream in the summer (Figure 20, Figure 21, Map 3).

In general, water temperature upstream (ALE-USWQ1) varied over a narrower range than observed downstream (ALE-BDGWQ) (Figure 20). The moderation of the water temperature regime upstream is likely due to the presence of groundwater inflow at this site. The daily average temperatures recorded at both sites were higher post-construction than pre-construction in the warmer months and the increase is more pronounced at the downstream site, likely due to the moderating effect of the groundwater inflow at the upstream site (Figure 20). Trends in the data attributable to the FHEP will be evaluated following five years of data collection through a BACI analysis.

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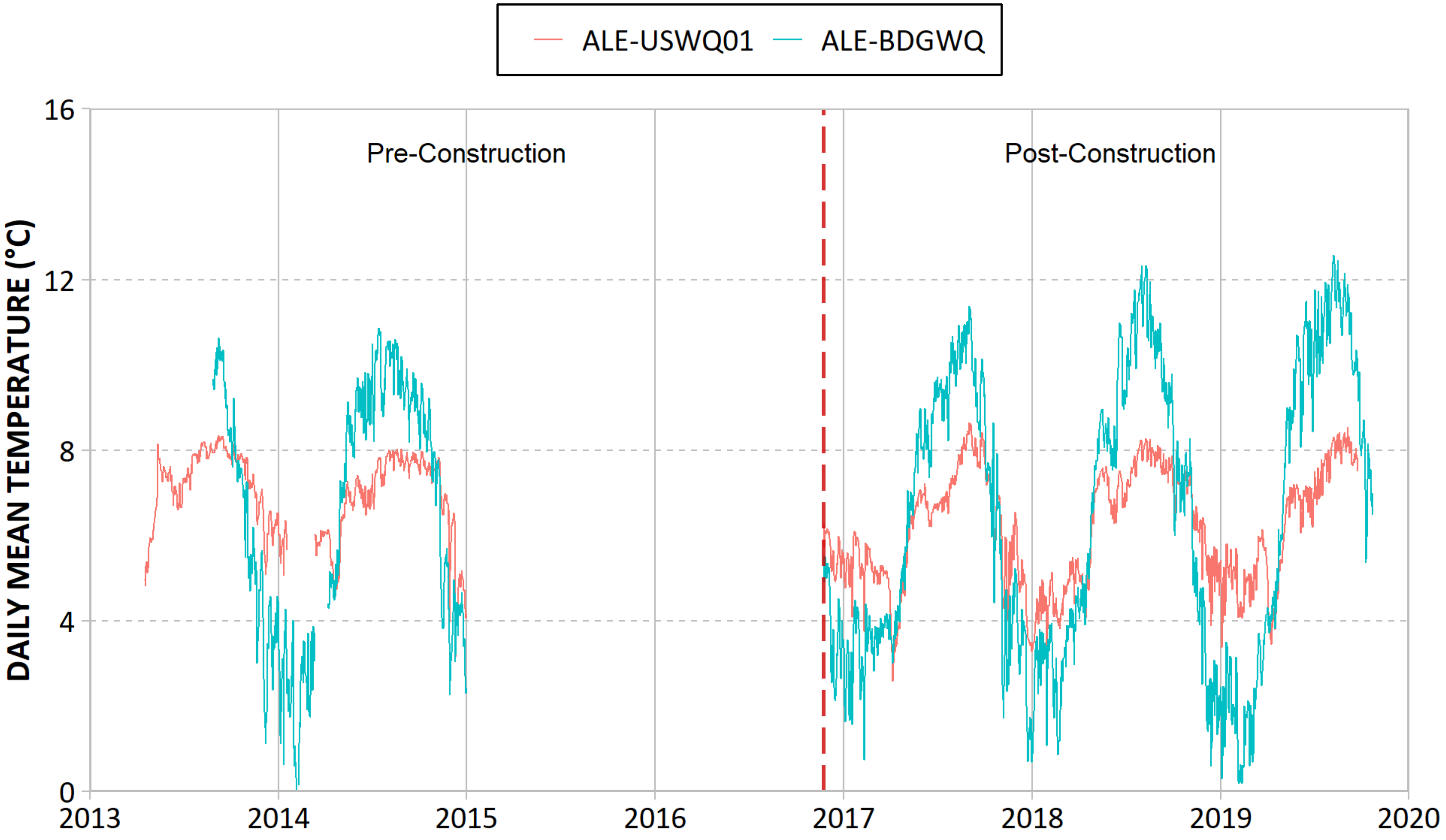
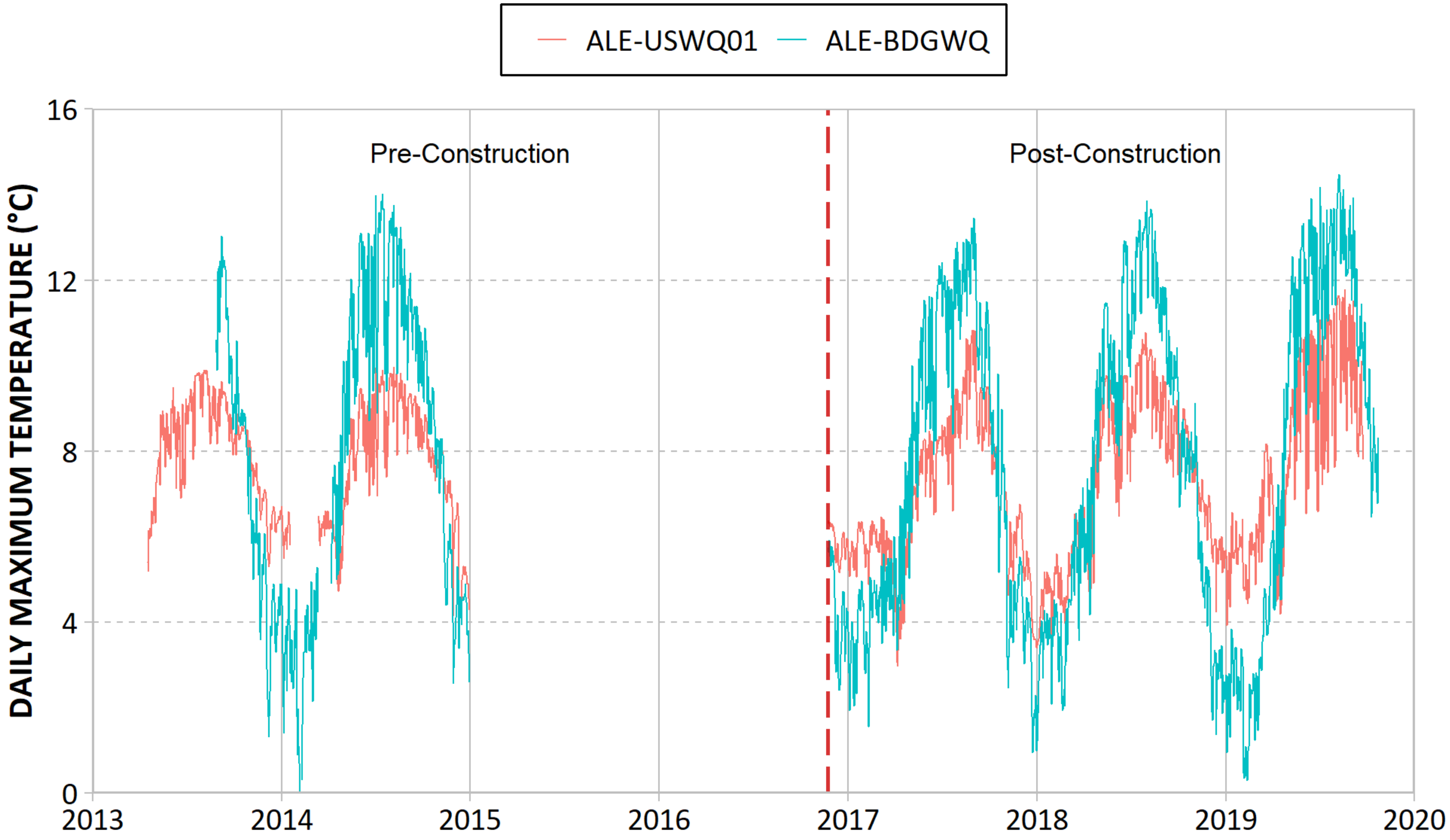
Figure 20. Overall average, maximum and minimum temperature regime in Alena Creek pre-construction (2014 to 2015) and post-construction (2017 to 2019).

(a) Daily Average



(b) Daily Maximum



(c) Daily Minimum

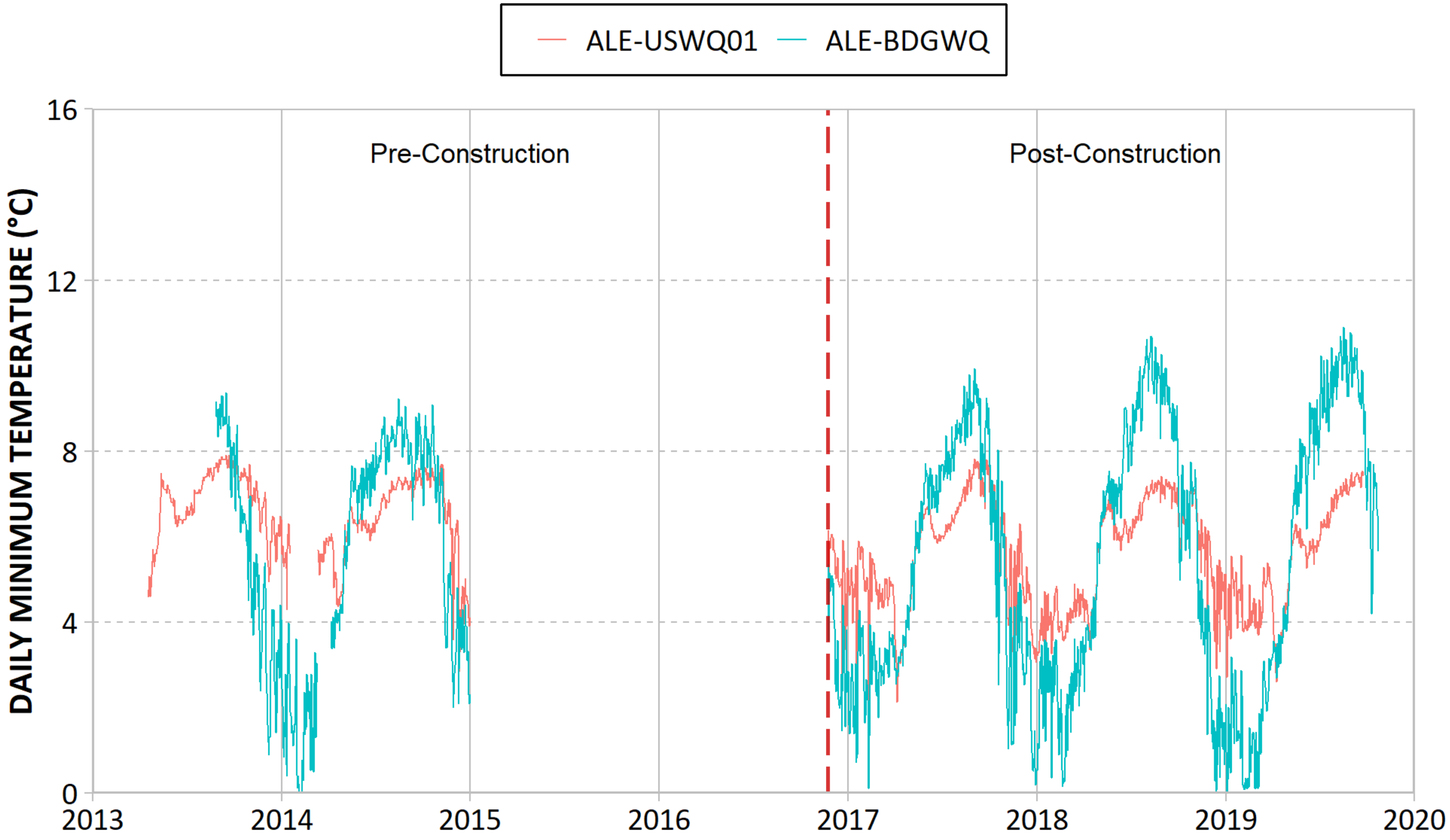
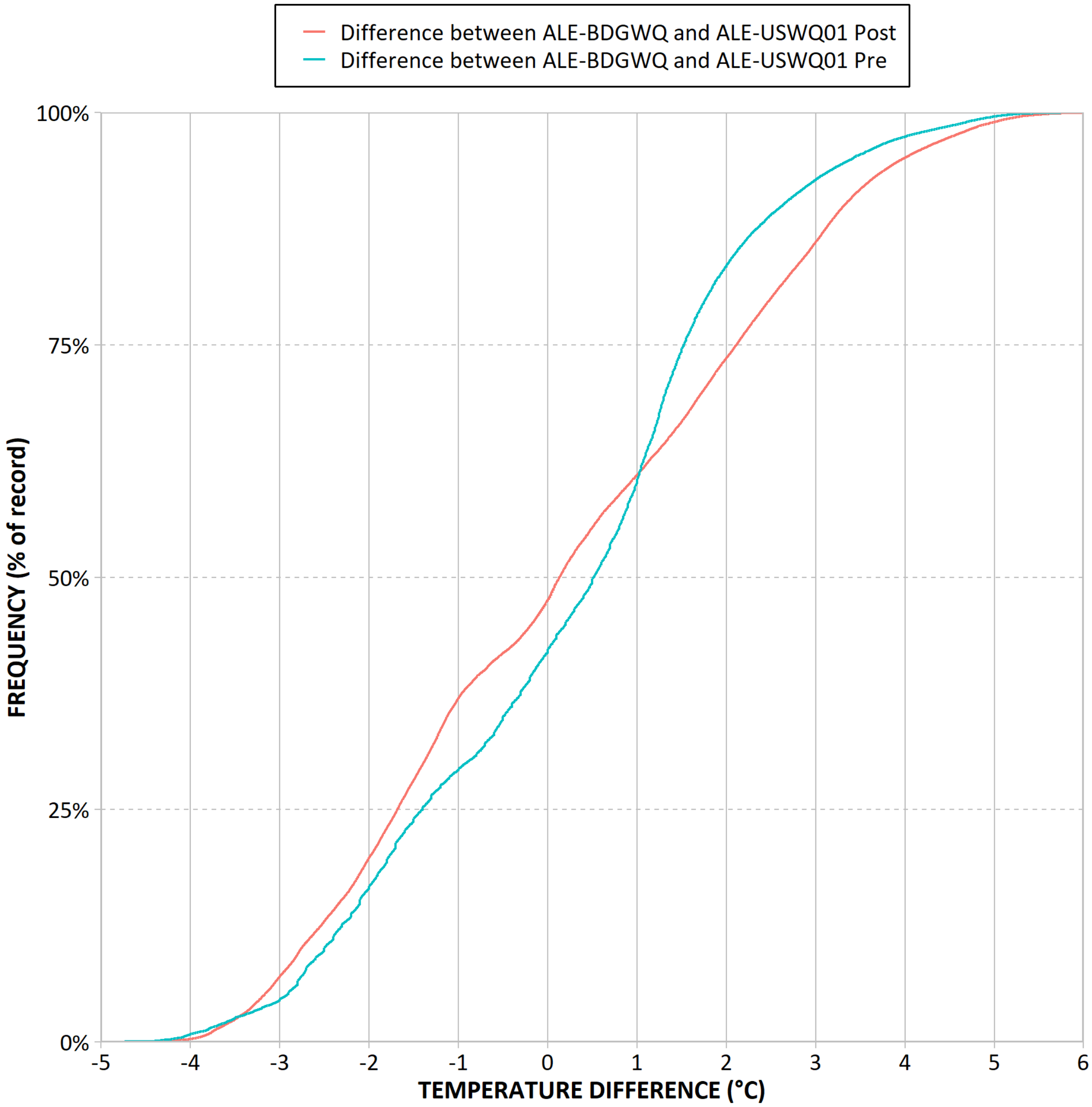


Figure 21. **Cumulative frequency distribution of differences in pre-construction (2013-2014) and post-construction (2016-2019) instantaneous water temperature between the downstream site (ALE-BDGWQ) and the upstream site (ALE-USWQ1) (positive values indicate warmer temperatures at ALE-BDGWQ).**



4.4.2. Monthly Summary Statistics

The mean, instantaneous minimum, instantaneous maximum, and standard deviation for water temperature for each month of the record are summarized for the pre-construction period in Table 14 and for the post-construction period in Table 15. Overall, no substantial change in monthly temperature statistics has been observed in Year 3 in comparison to Year 1 at the upstream sites where the range in monthly average temperatures at the was 5.0°C to 8.1°C pre-construction and 4.0°C to

8.1°C post-construction. No data are available for February or March pre-construction at the upstream site, therefore the monthly average minimum of 5.0°C measured in December 2014 may not be representative of the coolest monthly average pre-construction.

At the downstream site monthly average temperatures ranged from 2.2°C to 10.1°C pre-construction (Table 14), and from 1.2°C (February 2019) to 11.7°C (August 2019) post-construction (Table 15). To date 2019 exhibits the highest and lowest average monthly temperatures at the downstream sites.

Pre-construction minimum and maximum instantaneous temperatures ranged from 2.8°C (December 2014) to 10.0°C (July and August 2014) at the upstream site and 0.0°C (February 2014) to 14.0°C (July 2014) at the downstream site. Post-construction, instantaneous minimum and maximum temperatures ranged from 0.8°C (February 2017) to 11.8°C (August 2019) at the upstream site and 0.0°C (January 2019) to 14.5°C (August 2019) at the downstream site.

Table 14. Alena Creek monthly water temperature summary statistics measured pre-construction (May 2013 to December 2014).

Year	Month	Water Temperature (°C)							
		ALE-USWQ1				ALE-BDGWQ			
		Avg	Min	Max	SD	Avg	Min	Max	SD
2013	May	7.2	5.4	9.0	0.8	-	-	-	-
	Jun	7.0	6.2	9.5	0.6	-	-	-	-
	Jul	7.6	6.5	9.9	0.9	-	-	-	-
	Aug	8.0	7.3	9.9	0.6	-	-	-	-
	Sep	8.1	7.3	9.6	0.4	9.6	6.9	13.0	1.2
	Oct	7.8	6.9	8.9	0.3	7.5	4.5	10.6	1.0
	Nov	7.0	6.1	8.1	0.4	5.2	2.4	7.6	1.0
	Dec	6.1	5.0	7.1	0.5	3.4	0.9	5.5	1.1
2014	Jan	-	-	-	-	2.7	0.4	4.9	1.1
	Feb	-	-	-	-	2.2	0.0	5.0	1.2
	Mar	-	-	-	-	-	-	-	-
	Apr	5.4	4.4	6.4	0.6	5.0	3.4	9.6	1.1
	May	6.7	5.3	8.9	0.6	7.9	5.3	12.0	1.4
	Jun	7.0	5.9	9.5	0.8	9.1	6.4	13.1	1.6
	Jul	7.4	6.3	10.0	0.9	9.9	7.4	14.0	1.7
	Aug	7.9	7.1	10.0	0.7	10.1	7.9	13.8	1.4
	Sep	7.7	6.6	9.4	0.5	9.2	6.4	12.2	1.1
	Oct	7.6	6.9	8.9	0.3	8.4	6.7	10.9	0.8
	Nov	6.9	3.6	8.0	0.9	5.4	2.0	8.3	1.6
	Dec	5.0	2.8	6.8	0.9	3.9	2.1	5.3	0.7

Monthly statistics were not generated for months with less than three weeks of data.

Instantaneous maximum (red shading) and instantaneous minimum (blue shading) are highlighted for the monitoring period.

Table 15. **Alena Creek monthly water temperature summary statistics measured post-construction (December 2016 to September 2019).**

Year	Month	Water Temperature (°C)							
		ALE-USWQ1				ALE-BDGWQ			
		Avg	Min	Max	SD	Avg	Min	Max	SD
2016	Dec	5.5	2.5	6.3	0.4	3.5	1.5	5.7	0.9
2017	Jan	5.4	2.0	6.4	0.5	3.2	0.7	5.0	1.0
	Feb	5.3	0.8	6.4	0.5	3.2	0.1	5.1	0.9
	Mar	5.1	4.3	6.5	0.3	3.8	2.5	6.0	0.6
	Apr	4.0	2.1	6.4	0.9	4.3	2.5	8.3	1.1
	May	6.4	4.5	8.3	0.7	7.3	4.3	11.5	1.4
	Jun	6.7	5.8	8.5	0.6	8.5	6.5	12.3	1.4
	Jul	6.9	5.9	9.5	0.8	9.5	7.3	12.9	1.4
	Aug	7.9	6.6	10.8	0.9	10.4	8.1	13.2	1.3
	Sep	8.1	6.7	10.8	0.7	9.7	6.8	13.5	1.1
	Oct	6.9	3.8	8.8	0.8	6.9	2.5	9.8	1.2
	Nov	5.4	3.3	7.1	0.8	3.8	1.0	6.6	1.2
	Dec	4.6	3.1	6.6	0.9	2.8	0.2	5.3	1.3
2018	Jan	4.2	3.2	5.2	0.5	2.9	0.4	4.3	0.9
	Feb	4.3	3.6	5.6	0.4	2.5	0.1	4.5	1.1
	Mar	5.0	3.8	6.8	0.6	3.8	1.0	7.1	1.0
	Apr	5.1	3.4	8.5	1.0	5.2	2.4	9.9	1.4
	May	7.3	5.5	9.8	0.8	8.3	5.4	11.5	1.3
	Jun	6.9	5.7	9.8	0.8	9.0	6.4	12.9	1.5
	Jul	7.6	5.9	10.8	1.1	10.8	7.7	13.6	1.4
	Aug	8.0	6.8	10.4	0.8	11.1	8.3	13.9	1.1
	Sep	7.6	6.7	9.8	0.6	9.7	7.4	11.9	0.8
	Oct	7.2	5.6	9.0	0.6	7.2	5.0	8.8	0.8
	Nov	6.4	3.9	8.4	0.6	5.2	1.4	9.1	1.4
	Dec	5.2	2.9	6.8	0.6	2.1	0.1	4.8	0.9
2019	Jan	5.1	2.7	6.6	0.6	2.2	0.0	3.8	0.8
	Feb	4.6	3.8	6.4	0.6	1.2	0.1	3.2	0.8
	Mar	5.4	3.7	8.2	0.9	2.8	0.1	5.9	1.1
	Apr	4.5	2.6	7.7	0.9	4.8	2.7	9.6	1.4
	May	6.7	4.8	10.7	1.2	8.8	4.4	13.3	2.0
	Jun	6.8	5.3	10.8	1.2	10.0	6.2	13.9	1.6
	Jul	7.4	5.9	11.3	1.2	10.9	8.4	14.2	1.3
	Aug	8.1	6.7	11.8	1.2	11.7	9.2	14.5	1.2
	Sep	-	-	-	-	10.2	6.6	13.9	1.2

Monthly statistics were not generated for months with less than three weeks of data.

Instantaneous maximum (red shading) and instantaneous minimum (blue shading) are highlighted for the monitoring period.

Post construction water temperature monitoring commenced on November 23, 2016.

4.4.3. Growing Season Degree Days

The fall and early winter (October to December 31) weekly and maximum average temperatures upstream of the FHEP area are relatively mild, remaining above 4°C during the pre- and post-construction monitoring periods. Therefore, the growing season end date was calculated based on weekly average temperatures reaching 5°C rather than 4°C (see Section 3.4.4).

The start of the growing season based on the water temperature record at each site is consistently observed at the middle to end of April both pre- and post-construction (Table 16). The growing season end dates were more variable upstream ranging from late December pre-construction to early November to mid December post-construction. At the downstream site, the growing season end dates were in late November pre-construction and early to mid November post-construction.

Considering both sites which define the downstream and upstream extent of the FHEP, the growing season varied from 1,740 to 1,897-degree days pre-construction to 1,345 to 1,872 degree days post-construction. The shortest growing season occurred upstream in 2017 (1,345 days, Table 16).

Table 16. Growing season length and degree days upstream and downstream of the FHEP in Alena Creek pre- and post-construction.

Site	Project Phase	Year	No. of days with valid data	Growing Season Data Summary				
				Start Date	End Date	Length (day)	Data Gap (day)	Degree Days
Upstream (ALE-USWQ1)	Pre-construction	2013	256	20-Apr	28-Dec	253	2	1,836
		2014	306	24-Apr	31-Dec	252	3	1,740
	Post-construction	2017	364	28-Apr	4-Nov	191	1	1,345
		2018	365	20-Apr	10-Dec	235	0	1,670
		2019	264	22-Apr	-	-	-	-
Downstream (ALE-BDGWQ)	Pre-construction[1]	2013	125	-	22-Nov	-	-	-
		2014	329	20-Apr	30-Nov	225	1	1,897
	Post-construction	2017	364	23-Apr	1-Nov	193	1	1,645
		2018	365	17-Apr	11-Nov	209	0	1,872
		2019	295	20-Apr	-	-	-	-

[1] Temperature monitoring at ALE-BDGWQ began in August 2013, therefore the start date and accumulated thermal units for the 2013 growing season could not be calculated.

4.4.4. Hourly Rates of Water Temperature Change

Rapid temperature changes in temperature (greater than ±1.0°C/hr) can affect fish growth and survival (Oliver and Fidler 2001). Hourly rates of change in water temperature were compared to the BC WQG, which specify that the hourly rate of water temperature change should not exceed ±1.0°C/hr (Table 17, Figure 22).

Based on Ecofish's experience collecting pre-construction data on several other streams in British Columbia (file data), it is normal for a small percentage of data points to have hourly rates of water temperature change that exceed ±1.0°C/hr.

During pre- and post-construction of the FHEP, the percentage of record where exceedances were observed was low (<1.00%). Exceedances occurred less often post-construction at the downstream site, however more exceedances (0.83%) were observed at the upstream site post-construction in comparison to pre-construction (0.17%) (Table 17).

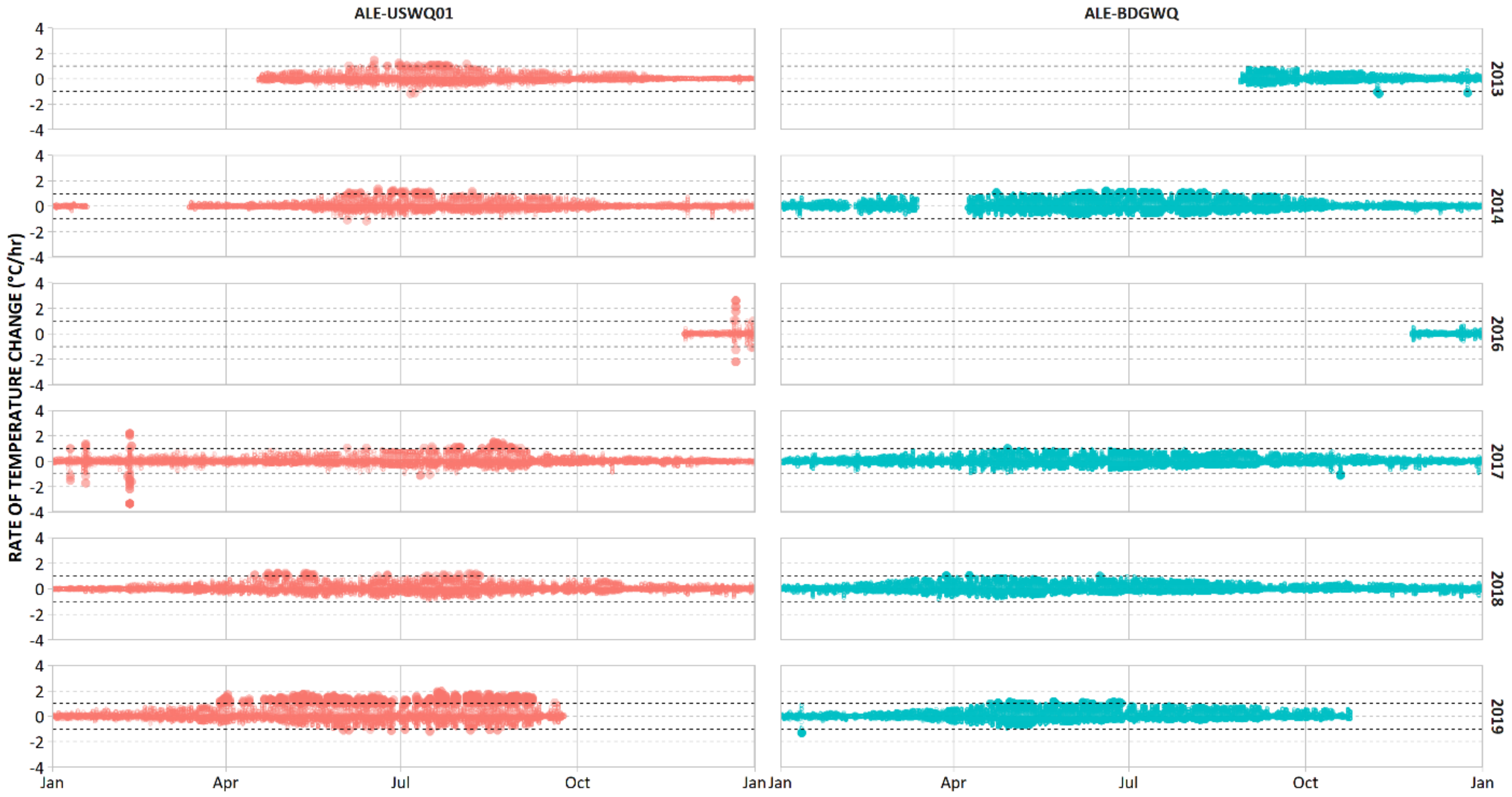
The magnitude of the water temperature increase/decrease was highest during the summer months at the upstream site post-construction, which is likely to be a consequence of groundwater inflow at this location.

Table 17. Hourly rate of change (°C/hr) summary statistics and occurrence of rate of change in exceedance of ± 1.0°C/hr.

Site	Project Phase	Period of Record		n	Occurrence		Max -ve	Percentile				Max +ve
		Start Date	End Date		No.	% of Record		1st	5th	95th	99th	
ALE-USWQ1	Pre-Construction	17-Apr-13	30-Dec-14	54,395	94	0.17	-1.15	-0.44	-0.25	0.32	0.77	1.45
	Post-Construction	23-Nov-16	23-Sep-19	99,191	821	0.83	-3.32	-0.59	-0.30	0.42	0.91	2.63
ALE-BDGWQ	Pre-Construction	27-Aug-13	30-Dec-14	44,075	102	0.23	-1.15	-0.61	-0.40	0.55	0.88	1.23
	Post-Construction	23-Nov-16	23-Oct-19	102,158	60	0.06	-1.28	-0.53	-0.34	0.52	0.79	1.17

n = number of datapoints.

Figure 22. Summary of the hourly rate of change (°C/hr) for each year pre-construction (2013 and 2014) and post- construction (2016, 2017, 2018 and 2019).



4.4.5. Daily Temperature Extremes

Alena Creek is classified as a cool stream with no days with average water temperatures >18°C observed in either pre- or post-construction conditions (Table 18). Considering all sites and dates, the maximum monthly water temperature was 14.0°C pre-construction (July 2014) and 14.5°C post-construction (August 2019), both of which occurred at the downstream site (Table 14, Table 15).

At the upstream site, there were no days when the daily average temperature was <1°C pre- or post-construction. In contrast, at the downstream site, one day was observed during pre-construction (2014) and three to 19 days per year were observed post-construction (2019) with daily average temperatures <1°C. The coolest temperatures measured to date at the downstream site were observed in 2019.

Table 18. Summary of daily average water temperature extremes (number of days >18°C and <1°C) at ALE-USWQ1 and ALE-BDGWQ.

Site	Project Phase	Year[1]	n (days)	Days T_{water} > 18°C	Days T_{water} < 1°C
ALE-USWQ01	Pre-construction	2013	256	0	0
		2014	306	0	0
	Post-construction	2016	38	-	-
		2017	364	0	0
		2018	365	0	0
		2019	264	0	0
ALE-BDGWQ	Pre-construction	2013	125	0	0
		2014	328	0	1
	Post-construction	2016	38	-	-
		2017	364	0	3
		2018	365	0	5
		2019	295	0	19

n is the number of days that have observations for at least 23 hours.

4.4.1. Bull Trout Temperature Guidelines

Bull Trout specific water temperate guidelines (see Section 3.4.4.1) were applied to the pre- and post-construction water temperature records by calculating the number of days of exceedance of the minimum and maximum temperature thresholds (Table 19). In BC, Bull Trout are considered to have the highest thermal sensitivity of the native salmonids evaluated in Oliver and Fiddler (2001), therefore more restrictive guidelines are applied to streams with this species.

During both pre- and post-construction monitoring periods, the highest maximum daily temperatures did not exceed the prescribed thresholds for rearing (15°C) at either site (Table 19).

The number of days where daily maximum water temperatures were outside the Bull Trout thresholds for spawning and incubation (i.e., >10°C) were higher overall at the downstream site (ALE-BDGWQ) in comparison to the upstream site (ALE-USWQ1), due to warmer temperatures in August and September at the downstream site (Table 19, Figure 20). In general, water temperatures at the downstream site do not cool below 10°C until late September/October (Table 14 and Table 15, Appendix C). Warmer temperatures (i.e., more days with exceedances of the 10°C limit) post-construction in comparison to pre-construction were observed at both the upstream and downstream sites suggesting this is due to natural inter-annual variability.

The number of days where the minimum temperature was less than the incubation threshold (i.e., <2°C) was also higher at the downstream site due to cooler temperatures at this site during the winter months; while the upstream site has a warmer temperature regime in the winter due to the groundwater input (Figure 20). These results suggest that temperature regime may be more suitable for Bull Trout at the upper end of the FHEP during spawning and incubation where there are fewer days with temperatures >10°C and <2°C. (Table 19).

Table 19. Summary of the number of days where the daily minimum or maximum water temperature (°C) exceeds the Bull Trout thresholds BC WQG (MOE 2019).

Site	**Project Phase**	**Year**	**n (days)[1]**	**Temperature Thresholds**			
				Rearing (Year Round)	**Spawning (Aug.1 - Dec. 8)**	**Incubation (Aug. 1 - Mar. 1)**	
				T_{water} > 15°C	**T_{water} > 10°C**	**T_{water} < 2°C**	**T_{water} > 10°C**
ALE-USWQ1	Pre-construction	2013	256	0	0	0	0
		2014[2]	328	0	0	0	0
	Post-construction	2017	364	0	14	2	14
		2018	365	0	5	0	10
		2019	295	0	23	0	28
ALE-BDGWQ	Pre-construction	2013	125	0	28	9	28
		2014	329	0	51	34	58
	Post-construction	2017	364	0	46	39	53
		2018	365	0	10	0	47
		2019	295	0	48	49	55

[1] n is the number of days that have observations for at least 23 hours.

[2] Pre-construction data collected at the upstream site excludes February 2014 data based on suspected ice/frozen temperature loggers.

4.4.2. Mean Weekly Maximum Temperatures (MWMxT)

MWMxT is an important indicator of prolonged periods of warm water temperatures that fish are exposed to. The guideline for the protection of aquatic life (Oliver and Fidler 2001) states "Where fish distribution information is available, then mean weekly maximum water temperatures should only vary + or – 1 degrees C beyond the optimum temperature range of each life history phase (migration, incubation, rearing, and spawning) for the most sensitive salmonid species present"(Table 2).

A comparison of MWMxT temperature data to optimum temperature ranges for Coho Salmon, Cutthroat Trout, and Bull Trout was completed for each species using pre- and post-construction data collected at the upstream site (Table 20, Table 21) and the downstream site (Table 22, Table 23).

Each of the tables provides the percent complete of the data record for each life stage along with the minimum and maximum MWMxT range in each period. The percentage of data within each optimum temperature range is provided to evaluate the overall suitability of the temperate range for each fish species life stage. Exceedance of the BC WQG range (greater than ±1°C outside the optimum ranges) are highlighted in each summary table (blue indicates MWMxTs are cooler than the lower guideline and red indicates temperatures are higher than the upper guidelines). The year-round range in MWMxT temperature corresponds to the rearing life stage for all the fish species. At the upstream site, post-construction, MWMxT ranged from 3.5°C to 11.5°C to date, while pre-construction MWMxTs ranged from 4.4°C to 9.9°C (Table 20, Table 21). During February 2014 data were not included due to icing concerns, therefore the minimum MWMxT value may not be representative of the pre-construction period. In 2019, the highest MWMxT value of 11.5°C was recorded.

At the downstream site, post-construction, MWMxT ranged from 0.6°C to 14.0°C to date, while pre-construction MWMxTs ranged from 1.7°C to 13.7°C (Table 22, Table 23). In 2019, both the lowest and the highest MWMxT values were recorded (0.6°C to 14.0°C).

MWMxT values in relation to species-specific optimal temperature ranges differed by species and location. Bull Trout prefer cooler temperatures overall in comparison to Cutthroat Trout and Coho Salmon (Table 2), therefore fewer exceedances of the cooler temperature limits are observed for this species. In general, the exceedances of the cooler temperature limits were more prevalent at the downstream site (ALE-BDGWQ). The upstream location (ALE-USWQ) was warmer during the winter months, likely due to the influence of groundwater at this location. General trends for each species are discussed below.

4.4.2.1. Coho Salmon:

During pre- and post-construction periods, at the upstream site, MWMxT values for Coho Salmon were largely within optimal temperature ranges during spawning and incubation but were sub-optimally cool on occasion during migration and rearing (blue shading in summary tables; Table 20, Table 21). During pre- and post-construction periods at the downstream site, exceedances of the cooler temperature limits (blue shading) were observed during all life stages, while no exceedances of the upper temperature limits were observed (Table 22, Table 23).

4.4.2.2. Cutthroat Trout:

During pre- and post-construction periods, at the upstream site, MWMxT values for Cutthroat Trout were sub-optimally cool on occasion during spawning, incubation and rearing (blue shading; Table 20, Table 21). During pre- and post-construction periods at the downstream site, exceedances of the cooler temperature limits were observed during all life stages; however, exceedances were generally observed less often during incubation and occasional exceedances of the higher temperature limits (red shading) were observed during incubation and spawning (post-construction only; Table 22, Table 23).

4.4.2.3. Bull Trout:

During pre- and post-construction periods, at the upstream site, MWMxT values were largely within optimal ranges with exceedances of the upper limit during incubation and occasionally during spawning (post-construction only). Occasionally, exceedances of the lower limits were observed during rearing (Table 20, Table 21). During pre- and post-construction periods at the downstream site, exceedances of the cooler temperature limits were observed during all life stages; however, exceedances were observed less often during incubation and exceedances of the higher temperature limits (red shading) were observed during incubation and spawning (Table 22, Table 23).

Warmer surface waters during Bull Trout incubation at the upstream site may be partially mitigated by groundwater upwelling, which would result in lower temperature within the redds during the warmer months (Table 20, Table 21).

Cooler and warmer MWMxTs occurred in 2019 than in previous years. Evaluation of any increased heating or cooling attributable to the FHEP will be completed following five years of data collection. Overall, no substantial change in the range of MWMxTs were observed between pre- and post-construction phases considering natural inter-annual variability in water temperature and considering that there were data gaps during the cooler months in the pre-construction data set.

Table 20. Pre-construction MWMxTs during Coho Salmon, Cutthroat Trout and Bull Trout life stages at ALE-USWQ1.

Species	Life Stage Data			Year	% Complete[1]	MWMxT		% of MWMxT		
	Periodicity	Optimum Temperature Range (°C)	Duration (days)			Min. (°C)	Max. (°C)	Below Lower Bound by >1°C	Within Optimum Range	Above Upper Bound by >1°C
Coho Salmon	Migration (Sep. 01 to Dec. 31)	7.2-15.6	122	2013	100	5.6	9.4	6.6	63.1	0.0
				2014	95.1	4.4	9.3	21.6	62.9	0.0
	Spawning (Oct. 15 to Jan. 01)	4.4-12.8	79	2013	100	5.6	8.5	0.0	100.0	0.0
				2014	91.1	4.4	7.9	0.0	98.6	0.0
	Incubation (Oct. 15 to Apr. 01)	4.0-13.0	169	2013	67.5	5.6	8.5	0.0	100.0	0.0
				2014	42.6	-	-	-	-	-
	Rearing (Jan. 01 to Dec. 31)	9.0-16.0	365	2013	70.1	5.6	9.9	35.9	23.4	0.0
				2014	83.0	4.4	9.7	53.5	18.5	0.0
Cutthroat Trout	Spawning (Apr. 01 to Jul. 01)	9.0-12.0	92	2013	79.3	5.9	8.9	42.5	0.0	0.0
				2014	98.9	5.0	9.3	58.2	6.6	0.0
	Incubation (May. 01 to Sep. 01)	9.0-12.0	124	2013	100	6.9	9.9	16.1	35.5	0.0
				2014	99.2	6.3	9.7	18.7	37.4	0.0
	Rearing (Jan. 01 to Dec. 31)	7.0-16.0	365	2013	70.1	5.6	9.9	3.1	78.1	0.0
				2014	83.0	4.4	9.7	13.9	66.0	0.0
Bull Trout	Spawning (Aug. 01 to Dec. 08)	5.0-9.0	130	2013	100	5.6	9.9	0.0	73.8	0.0
				2014	98.5	5.8	9.7	0.0	71.1	0.0
	Incubation (Aug. 01 to Mar. 01)	2.0-6.0	213	2013	79.3	5.6	9.9	0.0	5.9	64.5
				2014	69.0	4.4	9.7	0.0	14.3	78.2
	Rearing (Jan. 01 to Dec. 31)	6.0-14.0	365	2013	70.1	5.6	9.9	0.0	96.9	0.0
				2014	83.0	4.4	9.7	3.0	86.1	0.0

Blue shading indicates exceedance of the lower bound of the BC WQG optimum temperature range by more than 1°C (Oliver and Fidler 2001).

Red shading indicates exceedance of the upper bound of the BC WQG optimum temperature range by more than 1°C (Oliver and Fidler 2001).

[1] If less than 50 % of the data are available for the life stage period, the statistics are not calculated and data are not included in the summary table.

Table 21. Post-construction MWMxT for Coho Salmon, Cutthroat Trout and Bull Trout life stages at ALE-USWQ1.

Species	Life Stage Data			Year	% Complete[1]	MWMxT		% of MWMxT		
	Periodicity	Optimum Temperature Range (°C)	Duration (days)			Min. (°C)	Max. (°C)	Below Lower Bound by >1°C	Within Optimum Range	Above Upper Bound by >1°C
Coho Salmon	Migration (Sep. 01 to Dec. 31)	7.2-15.6	122	2016	28.7	-	-	-	-	-
				2017	100	3.5	10.5	43.4	44.3	0.0
				2018	100	5.3	9.3	23.8	55.7	0.0
				2019	16.4	-	-	-	-	-
	Spawning (Oct. 15 to Jan. 01)	4.4-12.8	79	2016	45.6	-	-	-	-	-
				2017	100	3.5	7.8	0.0	84.8	0.0
				2018	100	5.2	8.6	0.0	100.0	0.0
				2019	0	-	-	-	-	-
	Incubation (Oct. 15 to Apr. 01)	4.0-13.0	169	2016	74.6	4.6	6.3	0.0	100.0	0.0
				2017	100	3.5	7.8	0.0	91.1	0.0
				2018	99.4	4.8	8.6	0.0	100.0	0.0
				2019	0.0	-	-	-	-	-
	Rearing (Jan. 01 to Dec. 31)	9.0-16.0	365	2016	9.6	-	-	-	-	-
				2017	99.7	3.5	10.6	70.3	11.3	0.0
				2018	100	3.5	10.4	56.7	20.8	0.0
				2019	71.8	4.7	11.5	46.6	38.5	0.0
Cutthroat Trout	Spawning (Apr. 01 to Jul. 01)	9.0-12.0	92	2016	0	-	-	-	-	-
				2017	98.9	3.5	8.4	87.9	0.0	0.0
				2018	100.0	5.3	9.7	44.6	26.1	0.0
				2019	100.0	4.7	10.4	35.9	35.9	0.0
	Incubation (May. 01 to Sep. 01)	9.0-12.0	124	2016	0	-	-	-	-	-
				2017	99.2	6.2	10.6	40.7	22.8	0.0
				2018	100.0	7.3	10.4	10.5	58.9	0.0
				2019	100.0	7.6	11.5	2.4	73.4	0.0
	Rearing (Jan. 01 to Dec. 31)	7.0-16.0	365	2016	0	-	-	-	-	-
				2017	99.7	3.5	10.6	40.4	46.7	0.0
				2018	100.0	3.5	10.4	33.7	55.1	0.0
				2019	71.8	4.7	11.5	30.2	62.6	0.0

Blue shading indicates provincial guideline exceedance of the lower bound of the optimum temperature range by more than 1°C (Oliver and Fidler 2001).

Red shading indicates provincial guideline exceedance of the upper bound of the optimum temperature range by more than 1°C (Oliver and Fidler 2001).

[1] If less than 50 % of the data are available for the life stage period, the statistics are not calculated and data are not included in the summary table.

Table 21. Continued.

Species	Life Stage Data			Year	% Complete[1]	MWMxT		% of MWMxT		
	Periodicity	Optimum Temperature Range (°C)	Duration (days)			Min. (°C)	Max. (°C)	Below Lower Bound by >1°C	Within Optimum Range	Above Upper Bound by >1°C
Bull Trout	Spawning (Aug. 01 to Dec. 08)	5.0-9.0	130	2016	9.2	-	-	-	-	-
				2017	100	5.2	10.6	0.0	71.5	9.2
				2018	100	5.7	10.3	0.0	76.9	1.5
				2019	39.2	-	-	-	-	-
	Incubation (Aug. 01 to Mar. 01)	2.0-6.0	213	2016	44.6	5.4	6.3	0.0	70.5	0.0
				2017	100	3.5	10.6	0.0	50.7	41.3
				2018	99.5	4.8	10.3	0.0	41.0	47.6
				2019	23.8	-	-	-	-	-
	Rearing (Jan. 01 to Dec. 31)	6.0-14.0	365	2016	9.6	-	-	-	-	-
				2017	99.7	3.5	10.6	9.9	59.6	0.0
				2018	100	3.5	10.4	15.1	66.3	0.0
				2019	71.8	4.7	11.5	5.3	69.8	0.0

Blue shading indicates provincial guideline exceedance of the lower bound of the optimum temperature range by more than 1°C (Oliver and Fidler 2001).

Red shading indicates provincial guideline exceedance of the upper bound of the optimum temperature range by more than 1°C (Oliver and Fidler 2001).

[1] If less than 50 % of the data are available for the life stage period, the statistics are not calculated and data are not included in the summary table.

Table 22. Pre-construction MWMxT for Coho Salmon, Cutthroat Trout and Bull Trout stages at ALE-BDGWQ.

Species	Life Stage Data			Year	% Complete[1]	MWMxT		% of MWMxT		
	Periodicity	Optimum Temperature Range (°C)	Duration (days)			Min. (°C)	Max. (°C)	Below Lower Bound by >1°C	Within Optimum Range	Above Upper Bound by >1°C
Coho Salmon	Migration (Sep. 01 to Dec. 31)	7.2-15.6	122	2013	99.2	2.1	12.5	43.0	49.6	0.0
				2014	96.7	3.5	11.7	39.0	59.3	0.0
	Spawning (Oct. 15 to Jan. 01)	4.4-12.8	79	2013	98.7	2.1	8.8	9.0	70.5	0.0
				2014	93.7	3.5	9.1	0.0	75.7	0.0
	Incubation (Oct. 15 to Apr. 01)	4.0-13.0	169	2013	83.4	1.7	8.8	15.6	48.9	0.0
				2014	43.8	-	-	-	-	-
	Rearing (Jan. 01 to Dec. 31)	9.0-16.0	365	2013	33.7	-	-	-	-	-
				2014	89.6	1.7	13.7	44.6	49.8	0.0
Cutthroat Trout	Spawning (Apr. 01 to Jul. 01)	9.0-12.0	92	2013	0.0	-	-	-	-	-
				2014	92.4	5.8	12.7	24.7	60.0	0.0
	Incubation (May. 01 to Sep. 01)	9.0-12.0	124	2013	2	-	-	-	-	-
				2014	99.2	8.5	13.7	0.0	61.0	13.8
	Rearing (Jan. 01 to Dec. 31)	7.0-16.0	365	2013	33.7	-	-	-	-	-
				2014	89.6	1.7	13.7	34.3	59.9	0.0
Bull Trout	Spawning (Aug. 01 to Dec. 08)	5.0-9.0	130	2013	76.9	2.1	12.5	6.0	47.0	25.0
				2014	99.2	3.5	13.3	3.9	29.5	48.1
	Incubation (Aug. 01 to Mar. 01)	2.0-6.0	213	2013	83.1	1.7	12.5	0.0	54.2	36.2
				2014	69.5	3.5	13.3	0.0	31.1	67.6
	Rearing (Jan. 01 to Dec. 31)	6.0-14.0	365	2013	33.7	-	-	-	-	-
				2014	89.6	1.7	13.7	30.0	65.4	0.0

Blue shading indicates exceedance of the lower bound of the BC WQG optimum temperature range by more than 1°C (Oliver and Fidler 2001).

Red shading indicates exceedance of the upper bound of the BC WQG optimum temperature range by more than 1°C (Oliver and Fidler 2001).

[1] If less than 50 % of the data are available for the life stage period, the statistics are not calculated and data are not included in the summary table.

Table 23. Post-construction MWMxT for Bull Trout, Cutthroat Trout, and Coho Salmon life stages at ALE-BDGWQ.

Species	Life Stage Data			Year	% Complete[1]	MWMxT		% of MWMxT		
	Periodicity	Optimum Temperature Range (°C)	Duration (days)			Min. (°C)	Max. (°C)	Below Lower Bound by >1°C	Within Optimum Range	Above Upper Bound by >1°C
Coho Salmon	Migration (Sep. 01 to Dec. 31)	7.2-15.6	122	2016	29.5	-	-	-	-	-
				2017	100	1.6	12.9	50.0	44.3	0.0
				2018	100	2.3	11.5	43.4	54.9	0.0
				2019	41.0	-	-	-	-	-
	Spawning (Oct. 15 to Jan. 01)	4.4-12.8	79	2016	46.8	-	-	-	-	-
				2017	100	1.6	8.1	19.0	45.6	0.0
				2018	100	2.2	8.1	38.0	59.5	0.0
				2019	7.59	-	-	-	-	-
	Incubation (Oct. 15 to Apr. 01)	4.0-13.0	169	2016	75.1	2.8	5.7	1.6	58.3	0.0
				2017	100	1.6	8.1	14.2	53.3	0.0
				2018	100	0.6	8.1	50.9	38.5	0.0
				2019	3.5	-	-	-	-	-
	Rearing (Jan. 01 to Dec. 31)	9.0-16.0	365	2016	9.8	-	-	-	-	-
				2017	99.7	1.6	13.1	56.3	37.6	0.0
				2018	100	1.8	13.4	53.2	41.9	0.0
				2019	80.3	0.6	14.0	42.3	53.6	0.0
Cutthroat Trout	Spawning (Apr. 01 to Jul. 01)	9.0-12.0	92	2016	0	-	-	-	-	-
				2017	98.9	4.4	12.2	38.5	41.8	0.0
				2018	100	5.7	12.6	23.9	60.9	0.0
				2019	100	5.1	13.1	26.1	45.7	4.3
	Incubation (May. 01 to Sep. 01)	9.0-12.0	124	2016	0	-	-	-	-	-
				2017	99.2	7.5	13.1	4.1	58.5	0.8
				2018	100	8.8	13.4	0.0	59.7	12.1
				2019	100	9.8	14.0	0.0	35.5	18.5
	Rearing (Jan. 01 to Dec. 31)	7.0-16.0	365	2016	9.8	-	-	-	-	-
				2017	99.7	1.6	13.1	46.4	50.5	0.0
				2018	100	1.8	13.4	40.0	55.6	0.0
				2019	80.3	0.6	14.0	35.5	62.5	0.0

Blue shading indicates provincial guideline exceedance of the lower bound of the optimum temperature range by more than 1°C (Oliver and Fidler 2001).

Red shading indicates provincial guideline exceedance of the upper bound of the optimum temperature range by more than 1°C (Oliver and Fidler 2001).

[1] If less than 50 % of the data are available for the life stage period, the statistics are not calculated and data are not included in the summary table.

Table 23. Continued.

Species	Life Stage Data			Year	% Complete[1]	MWMxT		% of MWMxT		
	Periodicity	Optimum Temperature Range (°C)	Duration (days)			Min. (°C)	Max. (°C)	Below Lower Bound by >1°C	Within Optimum Range	Above Upper Bound by >1°C
Bull Trout	Spawning (Aug. 01 to Dec. 08)	5.0-9.0	130	2016	10.0	-	-	-	-	-
				2017	100	3.3	13.1	6.2	26.9	43.8
				2018	100	2.4	13.4	5.4	36.9	34.6
				2019	62.3	7.6	14.0	0.0	22.2	69.1
	Incubation (Aug. 01 to Mar. 01)	2.0-6.0	213	2016	45.1	-	-	-	-	-
				2017	100	1.6	13.1	0.0	51.6	40.8
				2018	100	0.6	13.4	3.3	45.5	46.0
				2019	37.9	-	-	-	-	-
	Rearing (Jan. 01 to Dec. 31)	6.0-14.0	365	2016	9.8	-	-	-	-	-
				2017	99.7	1.6	13.1	42.3	53.6	0.0
				2018	100	1.8	13.4	30.7	60.0	0.0
				2019	80.3	0.6	14.0	29.4	63.8	0.0

Blue shading indicates provincial guideline exceedance of the lower bound of the optimum temperature range by more than 1°C (Oliver and Fidler 2001).
Red shading indicates provincial guideline exceedance of the upper bound of the optimum temperature range by more than 1°C (Oliver and Fidler 2001).

[1] If less than 50 % of the data are available for the life stage period, the statistics are not calculated and data are not included in the summary table.

4.5. Riparian Habitat

4.5.1. Permanent Revegetation Density Monitoring Plots

The 2019 revegetation monitoring plot results show that stem densities have recovered to pre-treatment values since the construction and replanting of the FHEP in 2016 (Table 24; Figure 23). Replanting of western redcedar has been successful, and the density of western redcedar continues to increase (e.g., Figure 24). Douglas-fir (*Pseudotsuga mensiesii*) and western hemlock (*Tseuga heterophylla*) stem densities remained the same or increased slightly from 2017 but have decreased overall since planting in 2016. Neither species was present in any of the pre-construction plots in 2014, including ALE-PRM03, demonstrating that the FHEP work is meeting the objective of expediting the transition to a mixed coniferous/deciduous forest. Red alder and black cottonwood stem densities have also increased significantly since 2016 due to natural regeneration. Although the stem density of red alder is now similar to 2014, its relative abundance is lower, again indicating that the FHEP area is meeting the objective of increased conifer abundance. Overall shrub diversity has increased slightly since 2016 (by one species), and the number of species in ALE-PRM03 is the same as it was in 2014.

In October 2019, the mean estimated stem density of woody vegetation for all four monitoring plots was 79,900 ± 48,103 stems/ha, in consideration of a 90% confidence interval, surpassing the minimum target for all vegetation of 2,309 stems/ha (Table 24). Stem densities in individual plots ranged from 24,400 stems/ha to 122,400 stems/ha. The mean stem density in 2019 nearly doubled relative to 2017, when it was 43,200 ± 36,210 stems/ha, while the stem density following treatment in 2016 was only 5,002 ± 5,700 (Table 24). In 2014, the overall density of woody vegetation in the Alena Creek riparian area was estimated as 46,250 ± 32,469 stems/ha (Harwood *et al.* 2016), therefore the mean density of woody vegetation in the FHEP area has greatly increased as compared to prior to construction, however, the confidence intervals of the two surveys overlap, limiting our confidence in the change. The current stem density is appropriate for early establishment but is much higher than expected or desired for a mature stand. The stem density is expected to naturally decrease over time as trees increase in size and competition results in self-thinning. Thus, a future decrease in stem density should not be a cause for alarm *per se*, but rather it should be expected as part of the natural succession of forests post-disturbance. As trees mature and increase in size, they provide deeper roots for ground and bank stabilization, larger canopies for thermoregulation (including shade) and litter drop, and eventually provide larger woody debris contributions to the stream channel (Hemmera 2015).

Overall, the density of trees in the FHEP area in 2019 was 50,350 ± 45,222 stems/ha, far surpassing the target for mature trees of 1,200 stems/ha. Similarly, the overall density of shrubs in the FHEP area was 20,550 ± 11,491 stems/ha, far surpassing the shrub specific target of 2,000 stems/ ha.

In 2019, three conifer species were observed in the permanent monitoring plots: western hemlock, western redcedar, and Douglas-fir, with a combined density of 1,700 stems/ha (Table 25). Conifer tree species accounted for 29% of trees in 2019, whereas they accounted for 19% in 2017, 40% in 2016 immediately after construction, and 0.1% in 2014 prior to restoration (Harwood *et al.* 2016). Overall, a comparison of the density of coniferous trees in 2019 to 2016 shows an increase of 162%.

The decrease in conifers in Year 1 can be attributed to slight declines in western hemlock and Douglas-fir, whereas the rebound observed in Year 3 can largely be attributed to an increase in naturally regenerating western redcedar, as well as survival and growth of existing plants (Figure 24). Western hemlock stem densities remained the same in 2019 as in 2017, at 50 ± 118 stems/ha, a decrease from 150 ± 225 stems/ha in 2016 (i.e.., a single tree was observed in one of the plots in 2019 and 2017, down from three in 2016). A single Douglas-fir was observed in 2019, whereas Douglas-fir was not present at all in 2017. However overall, the Douglas-fir stem density dropped slightly in 2019 from post-treatment planting in 2016, when the stem density was 100 ± 118 (i.e., two stems were found in one plot). In 2019, the density of western redcedar increased from 2016 and 2017 to 1,600 ± 2,078 stems/ha. In 2014, prior to the restoration treatment, no western hemlock or Douglas-fir were observed in any monitoring plots, and only a single western redcedar was observed in each plot (although this was in a different set of plots). No mortalities of any tree species were observed in 2019 (Table 26), as opposed to 2017, when one red alder, one Douglas-fir, and three western redcedar were observed to be dead. Therefore, survival of the single western redcedar between 2018 and 2019 is 100%, exceeding the minimum survival threshold of 80% and indicating that planting can be deemed successful.

The density of deciduous trees is increasing in the FHEP area. The estimated stem density of both black cottonwood and red alder was high in 2019, at 33,700 ± 26,356 and 23,950 ± 25,831 stems/ha, respectively (Table 25; Figure 24). This represents an increase from both 2017 and 2016, when the restoration treatment reduced the stem density of black cottonwood to 250 ± 445 and the stem density of red alder to 1,350 ± 3,177. The stem density of red alder along Alena Creek is now similar to pre-treatment in 2014, when red alder dominated both the overstory in general and the overstory of the previous permanent monitoring plots specifically, including ALE-PRM03, with an average of 33,950 ± 34,582 stems/ha (Harwood *et al.* 2016).

Vegetation data for the Meager Creek slide area and for the Alena Creek FHEP area prior to the landslide are limited, but similar sites within the Coastal Western Hemlock southern dry sub maritime biogeoclimatic zone (CWHds1) provide some information (Green and Klinka 1994). In mid-bench riparian habitats in this zone, early successional stands of red alder and black cottonwood are typically complemented with western redcedar in later stages (Green and Klinka 1994). Monitoring in 2014 indicated that, prior to the Meager Creek slide, ALE-PRM03 was in an area that was dominated by mature red alder (Harwood *et al.* 2016), thus the addition of conifers demonstrates an advancement of successional stage. As the riparian FHEP area was designed to have a low gradient, floodplain conditions will likely continue.

The diversity of shrub species in the FHEP area increased in 2019, as compared to previous monitoring years and is about the same as pre-construction. In 2019, nine shrub species were identified in the monitoring plots, an increase from six in 2017 and seven in 2016 (Table 25), and a slight decrease from 10 detected during baseline pre-construction surveys (Harwood *et al.* 2016). Two new shrub species were observed in 2019: falsebox (*Paxistima myrsinites*) and hardhack (*Spirea douglasii*). Otherwise, shrub species composition remained the same as in 2017, although relative abundances changed. In

2019, the unknown willow species (or multiple species) was the most abundant shrub species, at 14,000 ± 10,657 stems/ha, a significant increase from previous years (e.g., in 2016 it was 150 ± 353 stems/ha). Thimbleberry (*Rubus parviflora*), red-osier dogwood (*Cornus stolonifera*), and devil's club (*Oploplanax horridus*) were the next most abundant shrubs in 2019. These three species were also the most abundant shrub species in 2017, and the latter two were the most abundant, along with Sitka willow (*Salix sitchensis*), in 2016. ALE-PRM03 had the highest shrub diversity of the four plots in 2019, with six identified species and the unidentified willow species. This could possibly be related to the relatively low abundance of competing vegetation, specifically black cottonwood and red alder. This is the same number of species that were found in the plot in 2014, before the restoration treatment (Harwood *et al.* 2016).

In 2019, a potentially invasive thistle species was observed in ALE-PRM03. Year 5 monitoring should aim to identify the thistle to the species level, as management implications will differ depending on the species. Some thistles, such as Canada thistle (*Cirsium arvense*) are considered noxious weeds and are provincially regulated under the *Weed Control Act* (*Weed Control Act*, RSBC 1996, c 487; *Weed Control Regulation* B.C. Reg. 143/2011) and land occupiers are legally required to manage. Other thistle species have management recommendations by regional weed committees but are otherwise unregulated, such as bull thistle (*Cirsium vulgare*). No other provincially or regionally noxious or invasive plant species were detected within the FHEP area, and none have been found in previous years. Although riparian monitoring is focused on the permanent revegetation monitoring plots, Ecofish crews watch for noxious plant species while conducting other fieldwork within the FHEP area, particularly in the vicinity of areas with high susceptibility to invasion such as access roads, construction areas, and riparian areas. The OEMP lays out steps for invasive plant monitoring, including measuring the extent and location of the invasive plants, developing treatment options, and reporting to the owner and IAPP program (Harwood *et al.* 2017).

Table 24. **Summary of riparian habitat data collected for the Alena Creek FHEP in 2019 (Year 3) and 2017 (Year 1) of effectiveness monitoring; in 2016 (baseline), immediately after riparian restoration works; and in 2014, four years after the Meager Creek slide.**

Permanent Revegetation Monitoring Plot	UTM (Zone 10U)		Year[1]	Woody Vegetation Density			Estimated Vegetation Cover (%)	Revegetation Area (Site) Comments
	Easting	Northing		Count of Live Stems/Plot	Count of Dead Stems/Plot	Estimated Live Vegetation Density (stems/ha)		
ALE-PRM03	473335	5606225	2019	122	0	24,400	100	Lots of natural regeneration, some invasive thistle observed in the site. Generally good survival of the planted stock and abundant ground cover. Two planted western redcedar along the stream bank are dead. Leaves have dropped from deciduous trees.
			2017	62	3	12,400	80	Good revegetation with horsetail, grass, and ferns. Most of the planted plugs have survived.
			2016	60	0	12,000	30	-
			2014[2]	305	0	61,000	88	Extensive natural regeneration of red alder under a mostly dead red alder overstory, with a few large living red alder.
ALE-PRM05	473014	5606707	2019	409	0	81,800	97	Lots of natural regeneration. Abundant horsetail ground cover. Planted stock is thriving and growing tall. Leaves have dropped from deciduous trees.
			2017	107	2	21,400	37	Some natural revegetation occurring, especially along and within 10 m of the streambank.
			2016	18	0	3,600	8	-
ALE-PRM06	473348	5606089	2019	612	0	122,400	64	Dense natural regeneration, including abundant grass and other ground cover vegetation. 100% survival for planted conifers and lots of western redcedar regeneration. Leaves have dropped from deciduous trees.
			2017	327	0	65,400	59	Good natural regeneration, high survival of planted vegetation.
			2016	22	0	4,400	16	-
ALE-PRM07	473338	5606166	2019	455	0	91,000	89	Dense natural regeneration. Lots of grass, moss, and fireweed. All planted conifers have survived and are looking very healthy.
			2017	368	0	73,600	66	Good natural regeneration of horsetail, grass, bunchberry, fireweed, ferns, red alder and black cottonwood, especially in concave microtopographies.
			2016	14	0	2,800	39	-
2019 Estimated Density (stems/ha)						**79,900**		
Confidence Interval (±stems/ha)						**48,103**		
2017 Estimated Density (stems/ha)						**43,200**		
Confidence Interval (±stems/ha)						**36,210**		
2016 Estimated Density (stems/ha)						**5,002**		
Confidence Interval (±stems/ha)						**5,700**		

[1] Compensation/ restoration treatments were conducted in 2016, thus 2016 is considered the baseline as-built survey for the restoration works. 2017 was Year 1 of the effectiveness monitoring program for Alena Creek and 2019 was Year 3 of effectiveness monitoring (the second year of revegetation monitoring). In addition a baseline survey was conducted in 2014, prior to restoration works.

[2] ALE-PRM03 was the only plot (of four) established in 2014, prior to restoration works, that fell within the construction area and was thus sampled again in 2016 and 2017.

Table 25. Live species counted within each of the permanent revegetation monitoring plots in 2019 (Year 3). Stem density summaries are included for 2017 (Year 1) and 2016 (baseline).

Year	Permanent Revegetation Monitoring Plot	Trees						Shrubs												*Total*
		western hemlock (*Tsuga heterophylla*)	western redcedar (*Thuja plicata*)	Douglas-fir (*Pseudotsuga menziesii*)	black cottonwood (*Populus balsamifera ssp. trichocarpa*)	red alder (*Alnus rubra*)	*Subtotal*	devil's club (*Oplopanax horridus*)	falsebox (*Paxistima myrsinites*)	hardhack (*Spiraea douglasii*)	red elderberry (*Sambucus racemosa*)	red-osier dogwood (*Cornus stolonifera*)	black raspberry (*Rubus leucodermis*)	thimbleberry (*Rubus parviflorus*)	salmonberry (*Rubus spectabilis*)	Sitka willow (*Salix sitchensis*)	trailing blackberry (*Rubus ursinus*)	willow (unknown species) (*Salix* sp.)	*Subtotal*	
2019	ALE-PRM03	0	2	0	3	37	*42*	20	0	3	1	0	0	24	1	0	17	14	*80*	*122*
	ALE-PRM05	0	3	1	247	18	*269*	0	1	0	0	4	0	10	1	0	0	124	*140*	*409*
	ALE-PRM06	1	21	0	224	243	*489*	0	0	10	0	27	0	0	8	0	0	78	*123*	*612*
	ALE-PRM07	0	6	0	200	181	*387*	0	0	0	0	2	0	1	1	0	0	64	*68*	*455*
	Mean (stems/ plot)	0.25	8.00	0.25	168.50	119.75	*296.75*	5.00	0.25	3.25	0.25	8.25	0.00	8.75	2.75	0.00	4.25	70.00	*102.75*	*399.50*
	Confidence Interval (± stems/plot)	0.59	10.39	0.59	131.78	129.16	*226.11*	11.77	0.59	5.55	0.59	14.83	0.00	13.08	4.12	0.00	10.00	53.29	*40.32*	*240.51*
	Estimated Density (stems/ha)	**50**	**1,600**	**50**	**33,700**	**23,950**	*59,350*	**1,000**	**50**	**650**	**50**	**1,650**	**0**	**1,750**	**550**	**0**	**850**	**14,000**	*20,550*	*79,900*
	Confidence Interval (± stems/ha)	**118**	**2,078**	**118**	**26,356**	**25,831**	*45,222*	**2,353**	**118**	**1,110**	**118**	**2,967**	**0**	**2,616**	**824**	**0**	**2,000**	**10,657**	*8,064*	*48,103*
2017	**Estimated Density (stems/ha)**	**50**	**700**	**0**	**23,100**	**15,800**	*39,650*	**650**	**0**	**0**	**350**	**650**	**0**	**1,100**	**450**	**0**	**250**	**100**	*3,550*	*43,200*
	Confidence Interval (± stems/ha)	**118**	**781**	**0**	**20,115**	**17,600**	-	**1,377**	**0**	**0**	**353**	**703**	**0**	**1,129**	**778**	**0**	**588**	**235**	-	*36,210*
2016	**Estimated Density (stems/ha)**	**150**	**800**	**100**	**250**	**1,350**	*2,650*	**850**	**0**	**0**	**50**	**700**	**200**	**250**	**350**	**500**	**0**	**150**	*3,050*	*5,700*
	Confidence Interval (± stems/ha)	**225**	**508**	**235**	**445**	**3,177**	-	**1,542**	**0**	**0**	**118**	**804**	**471**	**353**	**556**	**891**	**0**	**353**	-	*5,002*

Table 26. Dead tree species counted within each of the permanent revegetation monitoring plots in 2019 (Year 3). Stem density summaries of dead trees are included for 2017 (Year 1) and 2016 (baseline), from which survival estimates can be calculated overall and by species.

Year	Permanent Vegetation Monitoring Plot	western hemlock (*Tsuga heterophylla*)	western redcedar (*Thuja plicata*)	Douglas-fir (*Pseudotsuga menziesii*)	black cottonwood (*Populus balsamifera ssp. trichocarpa*)	red alder (*Alnus rubra*)	*Total*
2019	ALE-PRM03	0	0	0	0	0	*0*
	ALE-PRM05	0	0	0	0	0	*0*
	ALE-PRM06	0	0	0	0	0	*0*
	ALE-PRM07	0	0	0	0	0	*0*
	Mean (stems/ plot)	0.00	0.00	0.00	0.00	0.00	*0.00*
	Confidence Interval (± stems/plot)	0.00	0.00	0.00	0.00	0.00	*0.00*
	Estimated Density (stems/ha)	**0**	**0**	**0**	**0**	**0**	***0***
	Confidence Interval (± stems/ha)	**0**	**0**	**0**	**0**	**0**	***0***
2017	**Estimated Density (stems/ha)**	**0**	**150**	**50**	**0**	**50**	***250***
	Confidence Interval (± stems/ha)	**0**	**225**	**118**	**0**	**118**	***353***
2016	**Estimated Density (stems/ha)**	**0**	**0**	**0**	**0**	**0**	***0***
	Confidence Interval (± stems/ha)	**0**	**0**	**0**	**0**	**0**	***0***

Figure 23. Overview of FHEP channel taken from ALE-PRM05, demonstrating revegetation success of trees and shrubs, on October 29, 2019.

Figure 24. Revegetation success observed at ALE-PRM07. Photo is representative of western redcedar growth and the regeneration of other shrub and herb species, as well as the potential future condition in the background, on October 29, 2019.

4.5.2. Percent Vegetation Cover Estimates

In 2019, the mean percent cover of vegetation among all four plots was 86%, surpassing the target of 80% survival (assuming the natural regeneration potential cover of 100%), and an increase from 61% in 2017 and 23% post-treatment in 2016 (Table 24). This is similar to the pre-treatment mean percent cover of 82% estimated in 2014. In 2019, the percent cover of individual plots ranged from 64% cover at ALE-PRM06, to 100% cover at ALE-PRM03. ALE-PRM03 also had the highest percent cover in 2017, possibly due to the dominance of undisturbed soil. In 2017, ALE-PRM05 had the lowest percent cover (37%) of all sites, which was attributed to its location within the Meager Creek slide path, resulting in substrate with low organic content. However, in the 2019 survey, percent cover at ALE-PRM05 had increased to 97%, due to increases in cover of horsetail (*Equisetum* spp.) (Figure 25). Horsetail is an indicator of disturbed sites and is associated with sandy or silty soils and streambanks, as it can fix its own nitrogen (Klinka *et al.* 1989). The plot with the lowest percent cover in 2019 was ALE-PRM06, at 64%. Leaf litter was abundant in quadrats within ALE-PRM06, and it is possible that the relatively low percent cover observed in this plot was an artefact of sampling late in the season when many leaves had already senesced, and that the high amounts of leaf litter will contribute to future soil enhancements and growth (Figure 26).

Figure 25. High percent vegetation cover of primarily horsetail in a sampling quadrat at ALE-PRM05, located within the Meager Creek slide path, October 29, 2019.

Figure 26. Relatively low percent vegetation cover in sampling quadrat at ALE-PRM06 October 29, 2019 due to abundance of leaf litter.

4.5.3. Photopoint Comparison

Standard photographs taken in 2016, 2017, and 2019 from 1.3 m above the plot centre, facing 0 degrees (north) are presented in Appendix F to compare site and vegetation condition among years at each plot. Representative photos of the general site conditions surrounding each permanent monitoring plot are also provided. Additional photographs taken in the remaining three cardinal directions (east, south, west) from 1.3 m above the plot centre are available upon request. The replicate standard photographs show an increase in vegetation abundance from 2016 to 2017, and further infilling of woody shrubs (possibly red alder or black cottonwood) in 2019 at all sites. Thus, photographic monitoring supports data from the stem density monitoring plots (Section 4.5.1) that demonstrate an increase in stem density in the first three years of the monitoring program, as well as vegetation cover results (Section 4.5.2) that show an increase in ground cover, especially of horsetail.

5. SUMMARY AND RECOMMENDATIONS

The success of the FHEP will be judged according to the criteria in the *Fisheries Act* Authorization, namely that the habitat enhancement is physically stable, maintains suitable flows, has been demonstrated to provide spawning and rearing habitat for Coho Salmon and Cutthroat Trout of not less than 2,310 m^2, and supports equivalent or greater fish usage relative to pre-project densities in Alena Creek. Details of the monitoring to be conducted to evaluate the effectiveness of the FHEP are described in the Project's OEMP (Harwood *et al.* 2017); however, based on the results of Year 3 monitoring we recommend the following adjustments be made.

5.1. Fish Habitat

The overall function and quality of the FHEP remains high despite the flood event that occurred a few months after construction. In the downstream reach, Reach 1, we recommend continued monitoring of the bank erosion at 0+185 m just upstream of ALE-XS1. In Reach 3, we recommend undertaking instream repairs during the least risk timing window in August 2020. We anticipate that all repairs can be completed by hand with a crew of four over 1–2 days including a qualified professional to lead the work. At ALE-XS5, material from the constructed riffle crest that is currently dewatered can be utilized to reconstruct the weir in the wetted width. This will alleviate the risk of head-cutting that could cause incision upstream. The erosion issues upstream of both ALE-XS6 and ALE-XS7 should also be repaired. It may be possible to complete the repairs utilizing materials on site (e.g., cobbles and large wood pieces), or in nearby deposits on the side of the FSR. Establishment of herbaceous plants along the constructed channel banks has been suitable to protect the channel banks. Installing additional live stakes was considered, but is not recommended since it could increase local beaver activity.

Beavers were trapped within the Alena Creek FHEP area and dams were removed in the fall of 2018 and 2019 by a licensed trapper from EBB Environmental Consulting Inc. Beaver damming has been ongoing since this time in the reach upstream of Reach 3, causing disruption of flow and sediment supply to the upper section of Reach 3, and causing fine sediment loading to Reach 3 where the diverted flow re-enters. We recommend ongoing management of the beaver dams upstream of

Reach 3, and in particular, lowering of the dam that is blocking flow to the mainstem in order to prevent flow diversion. Lastly, a log jam just upstream of ALE-XS1 has formed in Reach 1 where a channel-spanning log collapsed. This jam should be monitored to ensure it does not grow. If the jam grows and begins to cause backwatering of upstream riffles and associated fine sediment deposition, then it should be removed.

5.2. Fish Community

The fish community component of the Alena Creek FHEP monitoring was successfully implemented in 2019. We recommend that the monitoring program continue in 2020 following the methods used in 2019.

5.3. Hydrology

Simultaneous monitoring of stage at FSR bridge and R1 upstream locations during spring and summer (April to the end of July) is needed to accurately account for the backwatering of the gauge at the FSR bridge over Alena Creek when flows in the Upper Lillooet River are high, and to ensure the stage data collected are representative of Alena Creek water levels. We recommend continuing hydrometric monitoring at both locations. Future monitoring efforts should also include standard practice of gauge maintenance recommended by RISC (2009) prior to spring snowmelt and throughout monitoring period to avoid future issues with missing data during this critical period.

5.4. Water Temperature

FHEP pre-construction water temperature monitoring occurred from April 17, 2013 to December 31, 2014 at the upstream site (upstream of the FHEP) and from August 27, 2013 to December 31, 2014 at the downstream site (within the FHEP) (Map 3); winter season water temperatures at the upstream site were not fully captured pre-construction due to data gaps in the winter/early spring 2014 data set. Therefore, direct comparison of pre- and post-construction monitoring for the cooler temperature metrics are limited for the upstream site.

Post-construction monitoring commenced at both sites on November 23, 2016. Year 3 data are available up to September 23, 2019 for the upstream site and to October 23, 2019 for the downstream site. No substantial data gaps were recorded.

Monthly average temperatures were the highest (11.7°C) and lowest (1.2°C) on record to date in 2019, occurring at the downstream site, however, no substantial in the instantaneous temperature range were observed in the pre- (0.0°C to 14°C) and post-construction (0.0°C to 14.5°C) periods.

Results to date indicate that the FHEP provides water temperatures typical of the area, with beneficial moderating effects due to groundwater inflow upstream of the habitat. Overall temperatures are more suitable for Bull Trout than Coho Salmon and Cutthroat Trout due to the generally cooler optimum temperature ranges for Bull Trout.

Considering inter-annual variability, no substantial differences were observed in the pre- and post-construction temperature regimes. We recommend that the monitoring program continue for 5 years post-construction based on the methodologies and schedule prescribed in the Project OEMP (Harwood *et al.* 2017).

5.5. Riparian Habitat

The goal of the restoration treatment is on the trajectory of being met, namely to ensure that a diversity of well-established native tree and shrub species with low observed mortality rates are present within the Alena Creek FHEP area, including successfully replanting western redcedar to expedite succession from a deciduous stand to a mixed coniferous/ deciduous stand, to enhance the riparian habitat for fish. Furthermore, results from Year 3 of monitoring indicate that stem densities and vegetation cover within the Alena Creek riparian FHEP area have well surpassed minimum targets and are similar to prior to the revegetation treatment (Harwood *et al.* 2016). Therefore, no additional planting or remediation measures are recommended at this time, but additional thinning of black cottonwood and red alder may be necessary to reach the longer-term goal if these species appear to be suppressing target conifer species.

The high stem densities (Section 4.5.1) and vegetation cover are indicators of good growing conditions and stable substrate, and no signs of erosion were noted during 2019 field sampling. Thus, no erosion control or soil conditioning appears to be necessary at this time.

Monitoring for the presence of invasive species should continue during revegetation surveys, and the thistle species noted in ALE-PR03 should be identified to determine management requirements. If the species is deemed a noxious weed, treatment prescriptions should be developed and implemented. The next revegetation monitoring visit is planned for Year 5 and should be conducted in late August or early September before vegetation dies off for the season.

6. CLOSURE

The OEMP outlines the operational monitoring frequency and duration for each monitoring component. The monitoring objectives for Year 3 were achieved. Based on the results from the first year of monitoring, changes to the WQ monitoring program were recommended. Further detail will be provided in a separate submission for review by regulatory agencies.

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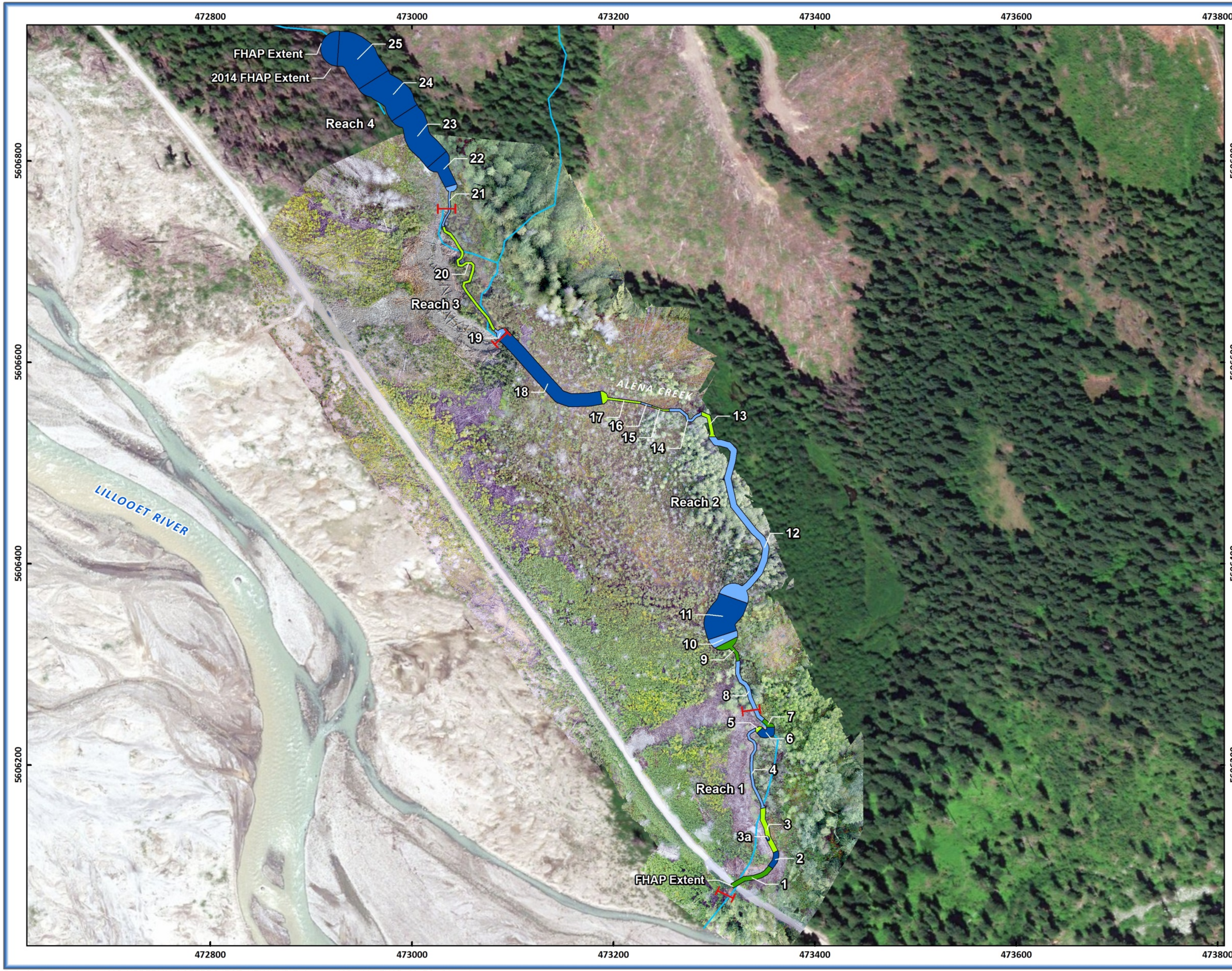
PROJECT MAPS

UPPER LILLOOET HYDRO PROJECT

Alena Creek
Fish Habitat Assessment



Legend

FHAP Type

- Glide
- Pool
- Riffle
- Run
- Reach Break
- I The extent of enhanced habitat is delineated by Reach 1 (downstream) and Reach 3 (upstream)
- Streams

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	17/04/2018	1095_ALN_FHAP_2017Oct24	SPK
2			
3			
4			
5			

Date Saved: 17/04/2018
Coordinate System: NAD 1983 UTM Zone 10N

ECOFISH RESEARCH

Map 2

Path: M:\Projects-Active\1095_UPPERLILLOOETPROJECT_NEW\MXD\Fisheries\1095_ALN_FHAP_2017Oct24.mxd

UPPER LILLOOET HYDRO PROJECT

Alena Creek Water Temperature Monitoring Sites

Legend

- ● Water Temperature Monitoring Site
- I Reach Break — The extent of enhanced habitat is delineated by Reach 1 (downstream) and Reach 3 (upstream)
- Meager Creek Slide Extent
- Enhanced Reaches
- Streams (Hedberg)

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

Scale: 1:4,000

NO.	DATE	REVISION	BY
1	24/04/2019	1095_ALN_WT_MonitoringSites_2019Feb25	SPK
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3			
4			
5			

Date Saved: 24/04/2019
Coordinate System: NAD 1983 UTM Zone 10N

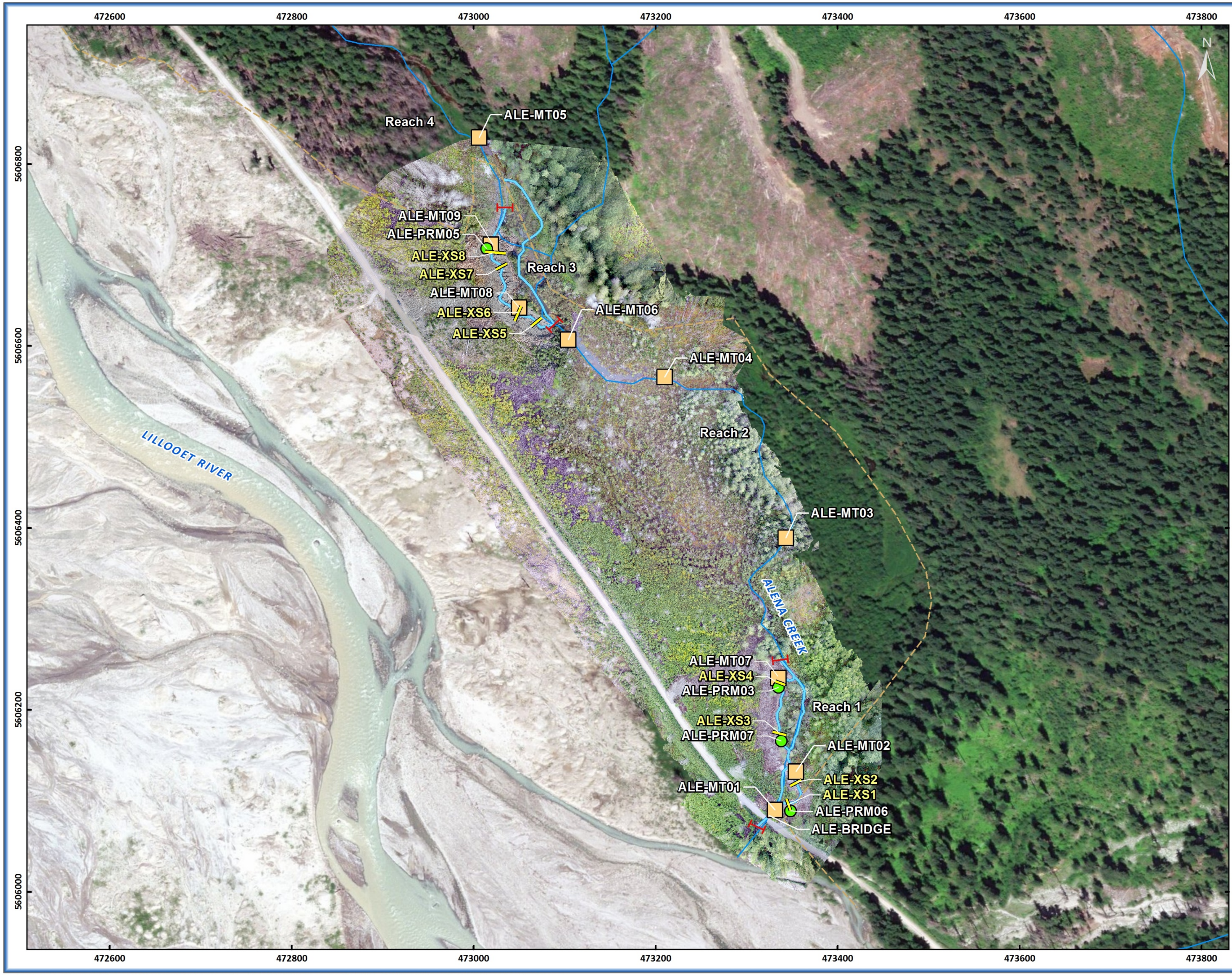
ECOFISH RESEARCH

Map 3

Path: M:\Projects-Active\1095_UPPERLILLOOETPROJECT_NEW\MXD\WaterQuality\1095_ALN_WT_MonitoringSites_2019Feb25.mxd

UPPER LILLOOET HYDRO PROJECT

Alena Creek Fish Abundance Sampling and Riparian Monitoring Sites



Legend

🟧 Minnow Traps

● Permanent Vegetation Monitoring Plots

I Reach Break
The extent of enhanced habitat is delineated by Reach 1 (downstream) and Reach 3 (upstream)

— Transect Sites

- - Meager Creek Slide Extent

— Enhanced Reaches

— Streams (Hedberg)

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 25 50 100 150 200 m

Scale: 1:4,000

NO.	DATE	REVISION	BY
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2			
3			
4			
5			

Date Saved: 24/04/2019
Coordinate System: NAD 1983 UTM Zone 10N

ECOFISH RESEARCH

Map 4

Path: M:\Projects-Active\1095_UPPERLILLOOETPROJECT_NEW\MXD\Fisheries\1095_ALN_FishAbundanceRipMonSites_2019Mar26.mxd

APPENDICES