Alena Creek Fish Habitat Enhancement Project

Year 1 Monitoring Report

Prepared for:

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EXECUTIVE SUMMARY

Hydrology

Post-construction monitoring of water levels in Alena Creek was conducted at the Lillooet River Forest Service Road (FSR) crossing at the downstream end of the Fish Habitat Enhancement Project (FHEP). Seasonal trends in the Alena Creek hydrograph are consistent with a coastal, snow dominated watershed. Stage remained relatively low throughout the winter (January to mid-March) when precipitation was snow dominated, as well as from mid-July through the end of September when precipitation was minimal. Stage also increased through March and April associated with the spring snow melt as was observed during baseline. However, high water levels were observed at the Alena Bridge site in June and July 2017; these were atypical and not associated with precipitation. The high stage readings appear to be the result of backwatering caused by a new side channel of the Upper Lillooet River just downstream of the hydrometric gauge.

The daily peak in stage was recorded on November 9, 2016 (0.95 m) during a flood event that represented a 1-in-20 year flood event on the Upper Lillooet River. Overall, mean daily stage (± SD) in Alena Creek from November 2016 to September 2017 was 0.28 m ± 0.12 m and stage did not drop below 0.16 m. However, these results are skewed by the likely backwatering effect caused by the Upper Lillooet River side channel.

To 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 moving the gauge upstream.

Water Quality

Water Chemistry

The purpose of the long-term monitoring of water chemistry is to ensure the maintenance of suitable water quality for the protection of aquatic life, and monitor any improvements in water quality resulting from the construction of the habitat compensation features. Concerns were raised by DFO over potentially elevated concentrations of metals, particularly iron and arsenic thus these parameters were included in baseline monitoring and the first year of the LTMP (Harwood *et al.* 2013). Water chemistry data are collected at two sites; a control site (ALE-USWQ/ALE-USWQ1), upstream of the enhancement habitat, and at a second site (ALE-BDGWQ) located at the downstream end of the enhancement habitat.

Baseline water chemistry data were collected quarterly for general water quality parameters, nutrients and anions, dissolved oxygen, total metals and dissolved metals in 2013 and 2014. Baseline water quality data met the applicable BC Water Quality Guidelines (BC WQG) for the protection of aquatic life (MOE 2018) for all parameters with the exception of dissolved oxygen (applicable to buried life stages only), total iron (T-Fe) and dissolved iron (D-Fe), which exceeded the BC WQG at both the upstream control site and the downstream bridge site during baseline sampling (Harwood *et* *al*. 2016). Dissolved arsenic was below the applicable BC WQG during baseline sampling and post-construction monitoring.

The most recent OEMP for the Upper Lillooet Hydro Project (Harwood *et al*. 2018) specified quarterly sampling for the first year followed by a cessation of water quality sampling if no concerns are identified.

Water quality in Alena Creek has generally improved since baseline sampling began in 2013. In year 1 monitoring, no exceedances of the minimum BC WQG for dissolved oxygen were observed at the site in the enhancement habitat (ALE-BDGWQ), with data indicating a well aerated condition (dissolved oxygen concentrations ranging from 10.38 mg/L to 10.81 mg/L).

Concentrations of dissolved iron exceeded the short-term maximum BC WQG of 0.35 mg/L at the site in the enhancement habitat during all sampling periods, with the range of concentrations similar between baseline and year 1 monitoring. Total iron exceeded the short-term maximum BC WQG of 1 mg/L at one or both sites on all sampling dates during baseline sampling. However, only one exceedance occurred during year 1 sampling at the site in the enhancement habitat, and concentrations at this site in year 1 sampling were on average lower than observed during baseline sampling.

Considering these observations and that instream enhancement is not expected to result in adverse effects on water quality, it is recommended that water quality monitoring on Alena Creek be ceased.

Water Temperature

The objective of water temperature monitoring is to ensure that conditions within the enhancement habitat support functional use for spawning, incubation, and rearing by the fish species present. This report provides a summary of year 1 post-construction water temperature results, with discussion of results relative to the baseline monitoring period.

Water temperature data were collected at the two water quality sites: ALE-USWQ1, immediately upstream of the instream works, and ALE-BDGWQ, at the downstream end of the works. Pre-construction monitoring occurred from April 17, 2013 to December 31, 2014 and post-construction monitoring to date has occurred from November 23, 2016 to present (data up to November 10, 2017 are included in this report). 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), instantaneous and daily average, minimum and maximum temperature, number of days with extreme mean daily temperature (e.g., >18°C, >20°C, and <1°C), the length of the growing season, and the accumulated thermal units in the growing season (i.e., degree days), and mean weekly maximum temperature (MWMxT). In addition, instantaneous minimum and maximum temperatures within critical periods for Bull Trout were compared to guideline limits for this species.

During the year 1 monitoring period, both monitoring sites had complete data records, but data gaps did occur during pre-construction monitoring. In post-construction year 1, the pattern in daily temperature has been largely similar to pre-construction phase. There has been no substantial change in the pattern of inter-site differences in water temperature compared to the pre-construction phase. Temperatures at site ALE-BDGWQ are cooler in winter and warmer in summer than at site ALE-USWQ1.

The range of monthly average temperatures was similar between the pre- and post-construction phases at both sites. The coolest temperatures were observed between December to April, while the warmest months were July to September. Over the available data record, monthly average temperatures at the upstream site (ALE-USWQ1) ranged from 5.0°C to 8.1°C pre-construction, and from 4.0°C to 8.1°C post-construction. At the downstream site (ALE-BDGWQ) monthly average temperatures ranged from 2.2°C to 10.1°C pre-construction, and from 3.2°C to 10.4°C post-construction.

There has been no apparent change to the growing season start dates (end of April) post-construction compared to pre-construction, but the growing season end dates (early November) during the post-construction phase are earlier than those observed during the pre-construction phase (between mid-November and mid-December) at both monitoring sites. As a result, there has been a decrease in cumulative degree days during the growing season at both sites during post-construction phase in year 1.

With respect to daily extreme temperatures, Alena Creek is classified as a cool stream based on there being no days with mean water temperatures >18°C in either pre or post-construction conditions, at either site and few days when the mean temperature was <1°C. The highest maximum instantaneous temperatures did not exceed the prescribed guideline upper threshold of daily temperature for Bull Trout (18°C) for the entire period of record at any site. The maximum (instantaneous) water temperature recorded within the Project area was 13.75°C, recorded at site ALE-BDGWQ in 2015.

In general, it appears site ALE-USWQ1 is more suitable than site ALE-BDGWQ for spawning and incubation of Bull Trout across the stated periodicity for this species. The highest maximum daily temperatures never exceeded the prescribed guideline upper threshold for spawning and incubation (10°C) at site ALE-USWQ1, but exceedances did occur at site ALE-BDGWQ under both pre and post-construction conditions. This occurred because of warm temperatures in August and September; in general, water temperatures at ALE-BDGWQ do not cool below 10°C until late September/October.

No exceedances of the daily mean temperature threshold occurred at the upstream site (ALE-USWQ1), although some instantaneous records were less than 2°C. Daily mean water temperatures did fall outside the lower threshold range for Bull Trout incubation (2°C) at site ALE-BDGWQ, under both pre- and post-construction conditions: the frequency of occurrence was lower post-construction.

In general, water temperature at the monitoring sites was optimal for the fish species and life stages present under both pre and post-construction periods, although some sub-optimally cool temperatures were recorded within most periods as well. Notable exceptions for both baseline and post-construction periods where MWMxTs were sub-optimally cool for the majority of, or the entire period, include: Coho Salmon rearing and Cutthroat Trout spawning and incubation at site ALE-USWQ1. Temperatures also were cooler than optimal at times for Coho Salmon rearing, Bull Trout spawning at site ALE-BDGWQ.

Sub-optimally warm temperatures were observed in August and September at both sites during Bull Trout spawning and incubation period and for a small proportion of the record at site ALE-BDGWQ during Cutthroat Trout incubation. Warm surface waters during incubation may be partially mitigated by the groundwater upwelling at site ALE-USWQ1, such that temperature within the redds may be lower.

Overall, the minimum and maximum MWMxT was greatest at site ALE-BDGWQ and more moderate at site ALE-USWQ1, perhaps due to a thermal buffering effect of groundwater at the upstream site. No substantial change in the range of MWMxTs was observed at site ALE-BDGWQ between pre and post-construction phases: MWMxT ranged from 2.1°C to 13.7°C pre-construction and from 2.8°C to 13.0°C post-construction. The range of MWMxTs observed at site ALE-USWQ1 was slightly greater post-construction (3.5°C to 10.5°C post vs. 4.4°C to 9.9°C pre) but was small enough to be explained by interannual variability.

Water temperature monitoring will continue in Year 2 of post-construction phase at the established monitoring sites to continue to build on a dataset that will facilitate the identification of any biologically significant differences between pre- and post-construction temperature regimes, and aid in the interpretation of key monitoring parameters, such as changes in fish abundance. The most recent OEMP for the Upper Lillooet Hydro Project (Harwood *et al.* 2018) noted that if no issues were identified with water temperature or the fish community in Alena Creek, annual reporting would be suspended, with final results reported following year 5. Although no issues with water temperature were identified, given the recommended changes to the fish community monitoring program and the lack of a complete water temperature data set for some life-history stages (e.g., spawning and incubation periods for Coho Salmon), we recommend water temperature results be reported on in year 2.

Fish Habitat

Stability Assesssment

A stability assessment was conducted to monitor the structural integrity and functionality of each of the enhancement habitat features and ensure that any remedial action required to maintain the effectiveness of habitat features is taken in a timely manner. To assist in the stability assessments, photo-points were established during the as-built survey at a total of eight survey transects. At each of the transects a panorama of photographs was taken to facilitate an evaluation of changes in habitat conditions over time. Qualitative observations were also made along the entire FHEP enhanced reaches.

Reach 1 is located in the downstream reach of the FHEP starting at the Lillooet River FSR. Thirteen riffles were installed in Reach 1 and more than 120 pieces of large woody debris with total creation of 1,387 m^2 of enhanced fish habitat. In early November 2016, two months following Project completion, a significant rain-on-snow event occurred, resulting in a 1-in-20 year flood event on the Upper Lillooet River. As a result, there were some notable changes in some of the channel structures in Alena Creek, though none affected the overall quality or usability of the constructed habitat.

A total of 668 m^2 of new instream habitat and 1,139 m^2 of floodplain was created in the upstream enhanced reach, Reach 3. Twelve cobble riffles were installed with over 100 pieces of large woody debris. The high-water flood event in 2016 had a greater impact to the habitat features in Reach 3 than Reach 1; however, as in Reach 1, it has not diminished the overall function or usability of the constructed habitat. Three of the four surveyed cross-sections show evidence of erosion and deposition which has caused widening and some bank instability. We recommend undertaking repairs during the least risk timing window in August 2018. All repairs can be completed by a hand. All areas experiencing bank erosion should be stabilized using materials like cobble and small boulders; willow and red-osier stakes should also be planted at select bank sites to aid in short-term stability.

Fish Habitat Assessment

A baseline Fish Habitat Assessment Procedure (FHAP) was completed in 2014, following the methodology described in Johnston and Slaney (1996). A follow-up FHAP was conducted on October 3, 2017 as part of year 1 monitoring. A total of 1,344 m of habitat was surveyed, consisting of 1,312 m of primary and 32 m of secondary habitat. The surveyed section of the Alena Creek mainstem consisted of 24 primary habitat units, with a total wetted area of 10,361 m^2 and a bankfull area of 13,012 m^2.

In 2017, the mainstem of Alena Creek was dominated by pool habitat (72%) followed by glide (18%) and riffle (6%). Overall, sands and fines were the dominant substrate in the mainstem, with 58% of mainstem habitat units having sand and fines as the dominant substrate. Gravel was the sub-dominant substrate in 44% of habitat units. Of the gravel available, there were 48 total patches of functional spawning gravel and 19 patches of non-functional (i.e., dry) spawning gravel. The majority of the area of functional spawning gravel (78%) was characterized as suitable for both resident and anadromous fish. Similarly, the majority of functional patches (88%) were suitable for both resident and anadromous fish. If all observed spawning patches were wetted, there would be 1,049 m^2 of spawning habitat available.

There was a relatively high amount of cover available for fish in the Alena Creek mainstem, representing 51.8% of the total area. The dominant cover type for fish was large woody debris (LWD) (19.4%), followed by other forms of available cover including overhanging vegetation, instream vegetation and deep pools. LWD was present in all 24 habitat units surveyed in the mainstem. Of the 315 pieces of LWD that were counted during the survey, all were characterized as functional except one piece, with most of them being >50 cm in diameter.

Riparian vegetation along Alena Creek is a mix of deciduous pole saplings and shrubs. Canopy closure was 0 to 20% in 67% of habitat units, and 20 to 40% in 21% of habitat units.

A total of nine off-channel habitats to the Alena Creek mainstem were observed. The majority of these habitat units (8 of 9, or 89%) are side channels that are accessible at most flows (5 of 9, or 56%). A further two side channels, and a wetland, are accessible at high flows only. The major side-channel affected by FHEP construction was surveyed in full as secondary habitat to the Alena Creek mainstem. This channel has a total wetted area of 45 m^2 and a bankfull area of 48 m^2. The average gradient of this habitat unit was 0.5. The average wetted width was 2.8 m and the average bankfull width was 3.0 m. This side channel contained only one glide habitat unit. Sand/fines was the dominant substrate type and gravel was the sub-dominant substrate type. Cover was present in 10% of the secondary habitat unit provided primarily provided by functional LWD.

A comparison of the FHAP conducted in Alena Creek during baseline studies and Year 1 monitoring showed two principal differences. The first was a change in the dominant habitat type from shallow glide habitat to deeper pool habitat. This change was a result of the enhancement work in Reaches 1 and 3 along with beaver activity in Reaches 2 and 4. The second major difference was a 785. 2 m^2 increase in the amount of functional spawning gravel available. This increase in spawning gravel was directly attributable to the enhancement work.

Fish Community

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 in both 2016 and 2017. In both years, the peak counts of adult spawning Coho Salmon were greater than 100 individuals, with the peak count in 2017 being the same as that observed in 2011 during the baseline period. In contrast, the peak count in 2016 was 174, which represents a notable increase in the number of spawners compared to the two baseline years and 2017. A comparison of the 2016 and 2017 results also highlights the variability in run timing between years, with the peak count recorded on November 14, 2016 and similarly high numbers two weeks later (November 27), whereas the peak count in 2017 was observed on November 26. Although surveys are not conducted at a frequency to allow total spawner abundance to be compared among years, and peak counts may be influenced by survey timing and spawner residence time and predation, the counts nevertheless provide an indication of use and demonstrate that Alena Creek supports equivalent or greater use by Coho spawners relative to pre-enhancement.

Minnow trapping surveys were conducted at six sites in Alena Creek on September 27, 2017. The objective of minnow trapping was to determine catch-per-unit-effort (CPUE) by species and life history stage so that relative juvenile fish abundance could be tracked for the duration of the monitoring period and compared to CPUE prior to enhancement. Sampling was conducted in the same sites sampled during baseline monitoring, of which two were located in newly created/enhanced habitat and four were in habitat not directly enhanced.

All fish captured by minnow trapping were identified to species, enumerated, measured with scale samples collected for aging. Biological data from Cutthroat Trout and Coho Salmon were analyzed to define the age structure, size structure, length-weight relationship, length at age, and condition factor by species. Relative abundance was evaluated using catch-per-unit-effort (CPUE) for minnow trap data, which was calculated as the number of fish captured per 100 trap hours.

In 2017 sampling, seven Cutthroat Trout were captured minnow trapping, which represents a decrease compared to 2013 and 2014. In all sampling years, the most abundant age class of Cutthroat Trout captured was 1+. No Cutthroat Trout fry were captured in 2017, which is fairly consistent with baseline sampling when only four Cutthroat fry were captured during sampling 2013 and 2014. The lack of Cutthroat Trout fry captured during sampling is likely a result of the timing of emergence and the size of fry in late September / early October. In 2017, the combined condition factor for all age classes of Cutthroat Trout captured was 1.0, whereas average Cutthroat Trout condition was 1.1 in 2013 and 1.2 in 2014.

In 2017 sampling, 142 Coho Salmon were captured by minnow trapping, which represents a decrease compared to 2013 and 2014. During 2017 sampling, the average CPUE across all sites was 18.2 fish/100 hrs of minnow trapping which was lower than the CPUE values for 2013 and 2014. In all sampling years, the most abundant age class of Coho Salmon captured was 0+. In 2017, the combined condition factor for all age classes of Coho Salmon captured was 1.1, whereas average Coho Salmon condition was 1.2 in 2013 and 1.0 in 2014.

The reduced catch and CPUE for both Cutthroat Trout and Coho Salmon during year 1 monitoring may be the result of altered habitat conditions caused by beaver activity both at the minnow trap locations, which were selected during baseline studies, as well as in upstream locations. There was evidence of beaver activity along Alena Creek during baseline studies; however, all beaver dams appeared abandoned and dilapidated with no new activity observed. In 2016, Alena Creek saw a notable increase in beaver activity in reaches upstream of both enhanced FHEP reaches. Beaver activity resulted in a significant increase in the amount of rearing habitat available through the creation of extensive backwater areas and side channels in the unenhanced reaches of Alena Creek. This increase in habitat availability, in conjunction with the creation of 668 m^2 of new instream habitat in Reach 3 as part of the FHEP, is likely a contributory factor to the lower catch and CPUE in 2017 as a similar number of fish dispersed over a larger area will result in lower CPUE.

The beaver dam activity affected habitat availability and/or accessibility to all of the six minnow trap sites. The backwatering resulted in a significant increase in the amount of rearing habitat available, but also restricted movement under the flow conditions observed at the time of minnow trapping. The restriction of downstream movement may have contributed to the reduced number of Coho captured in the enhanced Reach 1 compared to baseline sampling. Cutthroat would have been equally affected by the large dams which would have restricted movement by spawning adults and fry. As the dams were unpassable during low to moderate flows this would limit access to spawning areas such as those in the enhanced reaches. This in turn would affect distribution throughout Alena by rearing fry and parr.

Based on the habitat changes caused by beaver activity, we recommend adjusting and increasing the sites minnow trapped in September 2018. In Reach 2, we recommend adjusting the sites sampled to be more representative of the habitat sampled under baseline conditions. We also recommend adding two minnow trap sites in the enhanced Reach 3 to monitor juvenile fish use of the pools and large woody debris complexes installed. These changes will result in the sampling of eight sites in total, four in unenhanced habitat and four in enhanced habitat. This will allow a better comparison between CPUE in enhanced and unenhanced habitat, as well as improving the ability to demonstrate that the FHEP supports equivalent or greater fish usage relative to pre-project densities in Alena Creek, as per the requirements of the *Fisheries Act* Authorization.

Riparian Habitat

The Alena Creek FHEP detailed specific restoration and enhancement prescriptions for the 30 m Alena Creek riparian compensation area to increase vegetation diversity by clearing gaps within the regenerating red alder (*Alnus rubra*) stands and planting clusters of western redcedar (*Thuja plicata*). The objective of the riparian restoration monitoring program is to qualify and quantify re-growth and planting success and to confirm that a diversity of native tree and shrub species with low observed mortality rates becomes established. Successful replanting is defined as a survival of at least 80% of the planted western redcedar stock within the first year of planting (DFO 2006). Three distinct methods are employed to monitor the success of the riparian restoration works and the overall function of the riparian habitat. These methods are: (1) permanent vegetation density monitoring; (2) percent vegetation ground cover estimates; and (3) photopoint comparisons.

Prior to the Meager Creek slide in 2010, the Alena Creek riparian area was dominated by mature red alder and black cottonwood (*Populus balsamifera* ssp. *trichocarpa*), with patches of older shifting mosaic seral stage forest approximately 121-140 years old (Harwood *et al.* 2016). When vegetation was assessed in 2014, four years following the slide, vegetation had been regenerating naturally, with red alder densely colonizing the understory. Overall density of woody vegetation was estimated as 46,250 ± 32,469 stems/ha in 2014.

After the implementation of riparian restoration works in 2016, estimated density decreased to 5,700 ± 5,002 stems/ha. A total of 21 conifers, including western hemlock (*Tsuga heterophylla*), western redcedar and Douglas-fir (*Pseudotsuga menziesii*), were recorded within the monitoring plots, along with a relatively diverse assemblage of at least seven shrub species.

Between 2016 and 2017, vigorous regeneration of black cottonwood and red alder caused the estimated density to increase to 43,200 ± 36,210 stems/ha. The DFO and MELP (1998) guided revegetation effectiveness target of 2,309 stems/ha was exceeded within all four permanent vegetation monitoring plots in both years. Some differences were observed in woody vegetation composition. Since 2016, the total number of conifers (15) decreased slightly while shrub diversity remained relatively similar.

Three planted western redcedar were recorded as dead within the permanent monitoring plots in 2017. Nevertheless, the survival rate of the western redcedar recorded within the permanent monitoring plots was 83%, higher than the minimum target of 80%, thus replanting is not required. Standard photos, taken in 2016 and 2017, show an increase in vegetation abundance from 2016 to 2017. No regionally or provincially noxious or invasive plant species were detected within the compensation area.

Vegetation ground cover is important within riparian areas to minimize erosion and resulting sedimentation in adjacent watercourses during early successional stages. Average percent vegetation cover recorded in 2017 (61%) was higher than in 2016 (23%) but lower than 2014 (82%). The riparian compensation area was also built to have low gradients; thus, erosion is not a concern. Moreover, the extent of natural recruitment within the riparian compensation area has shown that soil condition is appropriate for native vegetation and no soil conditioning is required.

Results from year 1 monitoring indicate that vegetation within the Alena Creek riparian compensation area is on a trajectory to become similar to that prior to the Meager Creek slide. No additional planting or remediation measures are recommended at this time. However, the overall density and potential crowding of pioneer species, red alder and black cottonwood, will be monitored to determine whether additional restoration works (e.g. thinning) would be required to support the establishment of conifers. Monitoring will occur late in the growing season in years 3 and 5 to ensure diverse riparian vegetation continues to establish (Harwood *et al.* 2018).

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1. INTRODUCTION

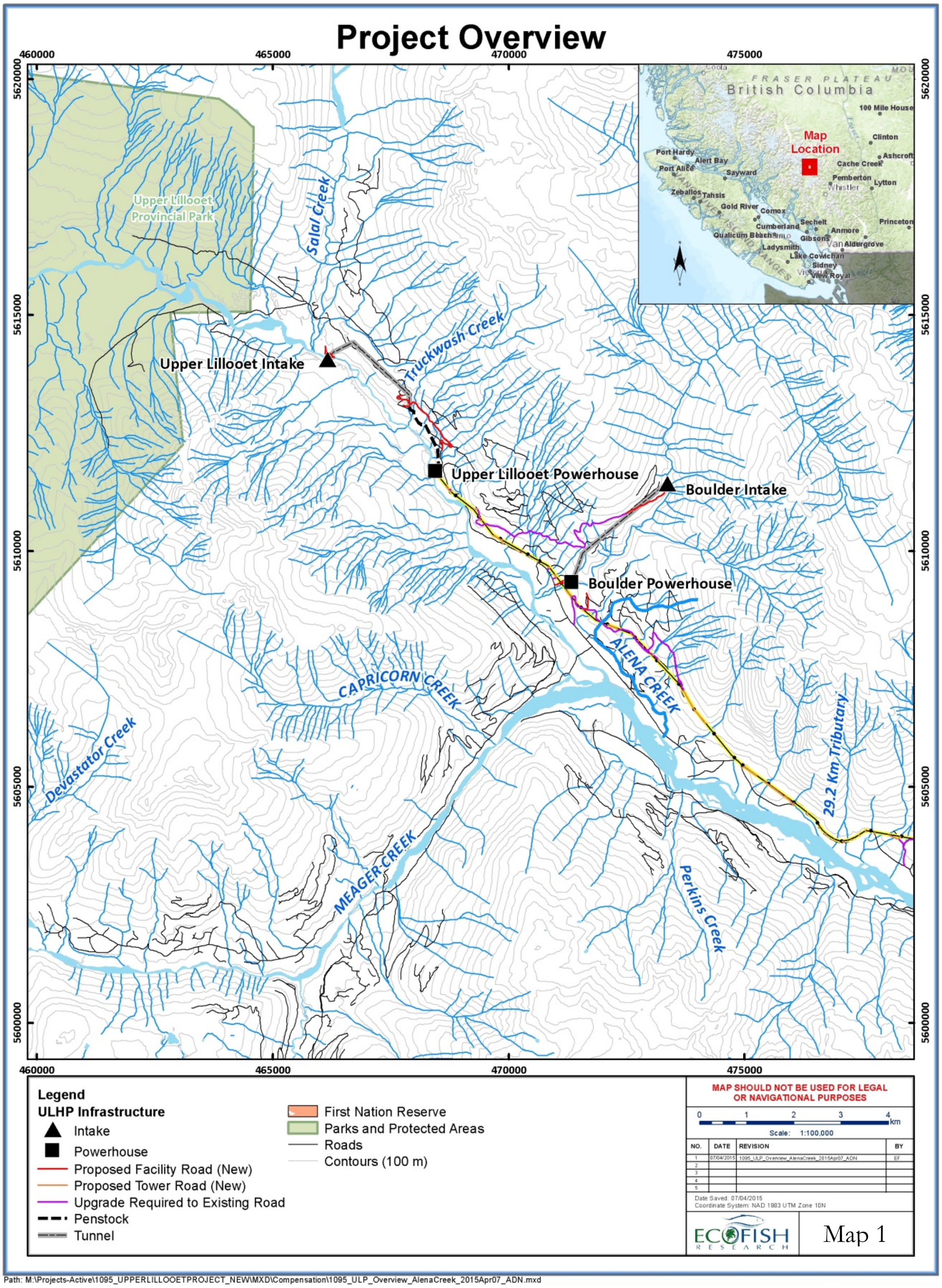
Ecofish Research Limited (Ecofish) was retained by the Upper Lillooet River Power Limited Partnership (ULRPLP) to conduct monitoring for the fish habitat enhancement constructed on Alena Creek (also known as Leanna Creek). The Fish Habitat Enhancement Project (FHEP) was designed by Hemmera Envirochem Inc. (Hemmera 2015) and Ecofish (Appendix A) to offset the footprint and operational habitat losses incurred by the Upper Lillooet Hydro Project (ULHP, the Project), which 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 Boulder Creek confluence 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. There were no offset requirements associated with construction and operation of the Boulder Creek HEF or impacts to riparian habitat under the amended Authorization.

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 thick heavy 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 heavy sediment. The FHEP 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 (*Oncorhynchus clarki*) and Bull Trout (*Salvelinus confluentus*). The FHEP consisted 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 design features constructed 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 enhancement habitat were originally described in the Alena Creek Long-Term Monitoring Program (LTMP) (Harwood *et al.* 2013). Long-term monitoring requirements were subsequently revised and integrated into Project's Operational Environmental Monitoring Plan (OEMP) (Harwood *et al.* 2018). Results of Year 1 and 2 of Alena Creek baseline monitoring are documented in Harwood *et al.* (2016). The purpose of this report is to provide results of the first year of the long term monitoring program to evaluate the effectiveness of the FHEP as per the *Fisheries Act* Authorization issued for the ULHP.

Map 1. **Overview map showing the location of Alena Creek relative to Project infrastructure.**



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2. OBJECTIVES AND BACKGROUND

2.1. 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).

2.2. Water Quality

2.2.1. Water Chemistry

The purpose of the long-term monitoring of water chemistry is to ensure the maintenance of suitable water quality for the protection of aquatic life, and monitor any improvements in water quality resulting from the construction of the habitat compensation features. Concerns were raised by DFO over potentially elevated concentrations of metals, particularly iron and arsenic, thus these parameters were included in baseline monitoring and the first year of the LTMP (Harwood *et al.* 2013).

Baseline water chemistry data were collected quarterly for general water quality parameters, nutrients and anions, dissolved oxygen, total metals and dissolved metals for one year between 2013 and 2014, with additional periodic *in-situ* sampling conducted in 2014. Baseline water quality data met the applicable BC Water Quality Guidelines (BC WQG) for the protection of aquatic life (MOE 2018) for all parameters with the exception of dissolved oxygen (applicable to buried life stages only), total iron (T-Fe) and dissolved iron (D-Fe), which exceeded the BC WQG at both the upstream control site and the downstream bridge site during baseline sampling (Harwood *et al.* 2016). Dissolved arsenic was below the applicable BC WQG during baseline sampling.

The most recent OEMP for the Upper Lillooet Hydro Project (Harwood *et al.* 2018) specified quarterly sampling for the first year followed by a cessation of water quality sampling if no concerns are identified. This report presents the water chemistry results for the baseline and first year of post-construction monitoring in 2016 and 2017 following completion of the habitat enhancement on Alena Creek.

2.2.2. Water Temperature

Small incremental changes in water temperature can potentially affect stream biota, including fish and their behaviour. 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 enhancement habitat support functional use for 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 compensation habitat over time. Water temperature may be influenced by the instream enhancement features and/or maturation of the riparian habitat restoration. This report provides a summary of Year 1 post-enhancement water temperature results, with discussion of results relative to the pre-construction monitoring period.

2.3. Fish Habitat

2.3.1. Stability Assessment

A stability assessment was conducted to monitor the structural integrity and functionality of each of the enhancement habitat features and ensure that any remedial action required to maintain the effectiveness of habitat features is taken in a timely manner.

2.3.2. Fish Habitat Assessment

A fish habitat assessment procedure (FHAP) was conducted over the enhanced section of Alena Creek to document changes in mesohabitat availability and to demonstrate the continued provision of spawning and rearing habitat for Coho Salmon and Cutthroat Trout.

2.4. Fish Community

The goal of enhancing Alena Creek aquatic and riparian habitat was to provide spawning and rearing habitat for Coho Salmon and Cutthroat Trout and support equivalent or greater fish usage relative to pre-project densities in Alena Creek. Fish habitat use in Alena Creek was assessed by comparing adult Coho Salmon spawner abundance and juvenile Cutthroat Trout and Coho Salmon abundance under baseline and post-enhancement conditions.

2.5. 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). The Alena Creek FHEP detailed specific restoration and enhancement prescriptions for the 30 m Alena Creek riparian area to increase vegetation diversity by creating clearing gaps within the regenerating red alder (*Alnus rubra*) stands and by planting clusters of western redcedar (*Thuja plicata*) (Hemmera 2015).

The objective of the riparian restoration monitoring program is to qualify and quantify re-growth and planting success and to confirm that a diversity of well-established native tree and shrub species with low observed mortality rates is achieved within the riparian portion of the Alena Creek FHEP (Harwood *et al.* 2016). Successful replanting is defined as a survival of at least 80% of the stock within the first year of planting (DFO and MELP 1998). If more than 20% of the planted stock dies over one year, replanting will be required. Results of the first year of monitoring are compared against three scenarios: 1) prior to the Meager Creek slide, 2) four years after the slide prior to restoration work, and 3) immediately following restoration work in 2016 (Harwood *et al.* 2016).

3. METHODS

3.1. Hydrology

KPL commenced monitoring water level in 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 only at the Alena Bridge site.

3.2. Water Quality

3.2.1. Water Chemistry

3.2.1.1. Monitoring Sites, Schedule, and Parameters Monitored

In 2016 and 2017, year 1 of the LTMP, water chemistry monitoring was conducted at the same two sites as sampled during baseline: a control site (ALE-USWQ1) located approximately 1,070 m upstream of the Alena Creek bridge, and a second site located approximately 20 m upstream of the Alena Creek bridge at the downstream end of the instream enhancement (Table 1, Map 3). Note that the control site (ALE-USWQ) was originally 500 m upstream of the Alena Creek bridge during baseline sampling, and was moved in November 2013 to ALE-USWQ1 due to modifications to the proposed enhancement plan. Representative photos are provided in Appendix B.

Water quality data were collected using two methods: *in-situ* sampling (physical parameters and dissolved gases) and laboratory analysis (physical parameters, anions and nutrients, and total and dissolved metals). *In-situ* and laboratory sampling procedures and assignment of proper laboratory detection limits were determined following the guidelines of the Ambient Fresh Water and Effluent Sampling Manual within the British Columbia Field Sampling Manual (Clark 2013). Baseline lab and *in-situ* sampling was conducted on July 8, 2013, September 16, 2013, November 18, 2013, and February 27, 2014. Additional *in-situ* baseline sampling was conducted in 2014 on April 29, September 25, and November 25. Following construction of the enhancement habitat, one year of quarterly lab and *in-situ* sampling was completed (November 23, 2016, March 5, 2017, June 5, 2017 and September 13, 2017).

Table 1. Alena Creek water chemistry sampling sites.

Site	UTM Coordinates (Zone 10U)		Elevation (masl)[1]
	Easting	Northing	
ALE-USWQ1	472,976	5,606,870	391
ALE-BDGWQ	473,336	5,606,095	382

[1] Elevation was determined from Google Earth.

3.2.1.2. Quality Assurance/Quality Control and Data Analysis

QA/QC of the water quality data was ensured through equipment maintenance, data collection methods, sampling protocols, laboratory procedures, and the processing and interpretation of data. *In-situ* water quality meters were maintained following the manufacturers recommendations. Maintenance included calibration, cleaning, periodic replacement of components, and proper storage. In the event of equipment malfunction and/or inaccessibility due to inclement field conditions, particular parameters or sampling dates may be omitted. *In-situ* measurements were made in triplicate unless otherwise indicated.

In-situ readings were recorded in triplicate, while water quality samples were collected for laboratory analysis in triplicate (2013 to 2016 sampling dates) or duplicate (2017 sampling dates). Duplicate and triplicate data reduce the risk of erroneous data resulting from travel or field contamination. The BC field sampling manual recommends that 20% to 30% of samples are designated for QA/QC (Clark 2013), while the RISC manual recommends a less conservative minimum of 10% of samples (RISC 1998a). Exceeding the more stringent QA/QC requirements, 26 of a total of 42 laboratory samples were QA/QC replicates, and therefore 62% of the lab sampling program consisted of QA/QC samples. For samples collected for laboratory analysis, sampling procedures and assignment of detection limits were determined following the guidelines of the Ambient Fresh Water and Effluent Sampling Manual within the British Columbia Field Sampling Manual (Clark 2013).

Appropriate collection procedures and use of a laboratory with its own established QC procedures were important components of QA/QC. Operational water quality samples were collected in plastic or amber glass bottles as required, with sample containers and preservatives provided by ALS. Samples were packaged in clean coolers filled with ice packs and couriered to ALS in Burnaby. Standard Chain of Custody procedure was strictly adhered to. ALS also maintains a Quality Management System that adheres to the requirements of the ISO:IEC 17025:2005 standards. Laboratory QC procedures included replicate analysis of a subset of samples, analysis of standard reference materials, and method blanks. QA/QC qualifiers and comments from laboratory analysis are provided in Appendix C.

Hold times for water quality parameters were adhered to when possible, but were sometimes exceeded. Exceedance of pH hold times (0.25 hours) was unavoidable and was therefore observed for all samples; pH is also measured *in-situ*. The analytical results for any parameters with hold time exceedances were compared to previous data collected at each site to determine if the results were within historical ranges and to identify any unusual analytical results that may be attributed to hold time exceedances. The hold time exceedance summary is provided in Appendix D.

QA/QC measures during data analysis included methods of addressing values less than or near laboratory method detection limits (MDL), use of established protocols for data analysis, and screening of outliers. The MDL for a given parameter occasionally differs between samples due to matrix effects in the sample or variations in analytical instruments. It is a common occurrence in clear fast flowing mountain streams to have concentrations of a number of parameters that are less than, or near, the MDL. When this occurs, there are a number of different methods that can be used to analyze these values. In this report, any values that were less than the MDL were assigned the actual MDL values and averaged with the results of the other replicates. In such cases, the average is also considered to be less than the value reported.

The RISC manual "Guidelines for Interpreting Water Quality Data" (RISC 1998b) was referred to for data analysis as it provides detailed direction for screening, editing, compiling, presenting, analyzing, and interpreting water quality data. Precision was evaluated by calculating the percent relative difference (RPD) for duplicates (duplicate RPD should be less than 25%) and the percent relative standard deviation (RSD) for triplicates (triplicate RSD should be less than 18%) as per the guidance provided in RISC (1998b). Precision analysis was only completed if the analytical results were greater than five times the parameter MDL. Exceedances of the precision guidelines are summarized in Appendix D, and data were evaluated for accuracy if the RPD or RSD exceeded recommended thresholds. If data were within historical ranges then the high variability was likely due to natural variability in the stream at the time of sampling.

3.2.1.3. Guidelines for the Protection of Aquatic Life

Water quality guidelines for the protection of aquatic life and typical ranges of water quality parameters in BC waters that were considered for this report are provided in Appendix D. Results were compared to provincial water quality guidelines where they exist. Provincial guidelines do not exist for total phosphate, and results were therefore compared to federal guidelines. For parameters without provincial or federal guidelines (e.g., orthophosphate, alkalinity, and specific conductivity), results were compared to typical ranges found in BC streams (Appendix D). Any results for water quality parameters that approached or exceeded guidelines for the protection of aquatic life or ranges typical for BC are discussed.

3.2.2. Water Temperature

Water temperature data were collected at the two water quality sites: ALE-USWQ1, immediately upstream of the instream works, and ALE-BDGWQ, at the downstream end of the works (Map 3). Pre-construction monitoring occurred from April 17, 2013 to December 31, 2014 and post-construction monitoring to date has occurred from November 23, 2016 to present (data up to November 10, 2017 are included in this report).

Pre-construction temperature data were recorded at 60-minute intervals using hydrometric gauges. The temperature sensors that were incorporated into the gauges had a temperature accuracy of ±0.3°C, a resolution of ±0.001°C, and were installed in aluminum standpipes. 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 single Tidbit logger was installed at ALE-USWQ1.

The data underwent a thorough QA to ensure that any suspect or unreliable data were excluded from data 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. Water temperature data were processed as follows. First, outliers were identified and removed. This was done for each logger by comparing temperature data from the duplicate site loggers and the loggers at the other sites. For example, occasional drops in water level which exposed the temperature loggers to the air were considered as outliers and removed from the dataset. Second, the records from duplicate loggers were averaged and records from different download dates were combined into a single time-series for each monitoring sites. The time series for both sites were then interpolated to a regular interval of 60 and 15 minutes (where data were not already logged on a 60 and 15-minute interval), starting at the full hour, for the pre- and post-construction phase, respectively.

Data were presented in plots that were generated from temperature data collected at, or interpolated to, 15 minute intervals. Plots were also generated for the hourly rates of change in water temperature as per the provincial guidelines for the protection of aquatic life (Oliver and Fidler 2001, see Table 1 in Appendix E).

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), instantaneous and daily average, minimum and maximum temperature, number of days with extreme mean daily temperature (e.g., >18°C, >20°C, and <1°C), the length of the growing season, and the accumulated thermal units in the growing season (i.e., degree days), and mean weekly maximum temperature (MWMxT). Table 2 defines these statistics and describes how they were calculated. Coho Salmon and Cutthroat Trout are target species for the Project (Section 2.4), and Bull Trout may also be present in the study area. Therefore, instantaneous minimum and maximum temperatures within critical periods for Bull Trout were compared to guideline limits for this species.

The length of the growing season and the number of degree days in the growing season are important indicators for the health of aquatic life. Here, the beginning of the growing season is defined as the beginning of the first week that average stream temperatures exceeded and remained above 5°C for the season; the end of the growing season is defined as the last day of the first week that average stream temperature dropped below 5°C as per modified Coleman and Fausch (2007). Herein, the threshold of MWMxT for the end of the growing season was modified from 4°C (as per Coleman and Fausch 2007) to 5°C, because the available observed MWMxT data at ALE-USWQ1 (during pre- and post-construction phase) never dropped below 4°C due to buffered groundwater during winter season.

Table 2. Water temperature summary parameters and method of calculation.

Parameter	Description	Method of Calculation
Water temperature	Instantaneous and daily averaged, maximum, and minimum	Calculated from 15 minute data (interpolated where necessary) and presented in graphical form.
Water temperature	Mean, minimum, and maximum on a monthly basis	Calculated from 15 minute data (interpolated where necessary) and presented in tabular format.
Degree days in growing season	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	>18°C , >20°C , and <1°C	Total number of days with daily mean water temperature >18°C , >20°C , and <1°C.
MWMxT (Mean Weekly Maximum Temperature)	Mean, minimum, and maximum on a weekly 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; this is calculated for every day of the year.

3.2.2.1. Applicable Guidelines

Daily 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.

Bull Trout / Dolly Varden Temperature Guidelines

Bull Trout are present throughout the Project area and their life history periodicity is provided in Section 1 of Appendix E. Additional Provincial water temperature guidelines exist specific to Bull Trout and Dolly Varden in streams (Table 1 of Appendix E). When either of these fish species are present, the guidelines state that:

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

Thus, the incidence of extreme daily mean water temperatures, and instantaneous minimum and maximum temperatures were calculated, for comparison to the above thresholds.

Mean Weekly Maximum Temperature (MWMxT)

The mean weekly maximum water temperature (MWMxT) is an important indicator of prolonged periods of cold and warm water temperatures that fish are exposed to. The guideline 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). Accordingly, MWMxT values were compared to the optimum temperature ranges given in Table 2 of Appendix E (modified from Oliver and Fidler 2001) for the fish species present.

The timing of life history stages in the Upper Lillooet River as reported in the periodicity table (Section 1 of Appendix E), was used to define the temporal bounds of the MWMxT analysis for each life stage where thermal optima are given by Oliver and Fidler (2001). Within this period, the completeness of the data record (% complete for all years in either pre- or post-construction period), the overall minimum and maximum MWMxT, and distribution of MWMxT values (above or within the optimal temperature range) was calculated.

3.3. Fish Habitat

3.3.1. Stability Assessment

To assist in the stability assessments, photo-points were established during the as-built survey (West *et al.* 2017), which was completed immediately following construction. A total of eight transects were surveyed at that time, including the installation of the permanent photo-points. At each of the transects a panorama of photographs were taken to facilitate an 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 line to aid with analysis of the topographic transect surveys. Photos were recreated for a visual comparison. Qualitative observations were also made along the entire FHEP constructed reaches.

3.3.2. FHAP Assessment

The FHAP Level 1, as described by Johnston and Slaney (1996), was used to collect quantitative information on fish habitat at a mesohabitat scale. The main objectives of the assessment were to quantify the habitat unit composition, delineating units into pools, glides, runs, riffles, cascades, chutes and falls.

The FHAP was completed following the methods described in Lewis *et al.* (2004). Data collection procedures and survey design were consistent with methods in Johnston and Slaney (1996); however, some modifications were necessary to address the objectives of this study:

1. The primary objective was altered from identifying the impacts of forest harvesting and/or opportunities for restoration to the one listed above.
2. The overview assessment, initial planning exercise, and Level 2 FHAP as described in Johnston and Slaney (1996) were not completed, as these were deemed unnecessary for this study. The overview assessment was not completed because a more detailed survey (Level 1 FHAP) was performed.
3. The methods of habitat evaluation were modified to focus on limitations to production rather than forestry impacts. This included a detailed assessment of spawning habitat throughout the surveyed section of stream.

Table 3 lists the physical parameters surveyed along with the units of measure and the equipment used. Parameters were measured rather than estimated wherever possible. However, estimates were made for pool depths greater than 1.5 m, dominant and subdominant bed materials, percent cover, canopy closure, and amounts of spawning gravel. All field data were collected by a two-person crew and recorded onto FHAP site cards (1996 Edition).

Habitat units were classified as pools, glides, runs, riffles, cascades, chutes and falls. Johnston and Slaney (1996) recommend using only pools, glide, riffle, cascade and "other"; however, we added run, chute and falls habitat types to better define the habitat units. Units were additionally classified by location within the stream as primary, secondary, and tertiary. Primary habitat units encompass greater than 50% of the total wetted width. Secondary units occur in minor channels that are isolated from the main channel by a vegetated island with perennial plants greater than 1 m in height. Tertiary units are habitat units within the larger channel that occupy less than 50% of the wetted width (i.e., are nested within primary or secondary units) and are of a different classification than the main channel (e.g., a pool that is part of a cascade unit). The habitat unit composition of each reach was determined based on the proportion of wetted area occupied by each habitat type over the total wetted area of the reach. Total wetted areas and bankfull areas were determined by summing the wetted areas and bankfull areas of individual habitat units within a given reach. For each habitat unit type, excluding falls, the average wetted and bankfull areas, widths, depths, and gradients were determined by averaging data from individual units within a given reach. Photographs of each habitat unit were taken. Potential barriers or obstructions to fish migration (e.g., beaver dams) were photographed and waypoints were taken.

Off-channel habitat such as side channels, sloughs, ponds and seasonally flooded wetlands were noted, along with their accessibility for fish (not accessible, accessible at high flow only, or accessible) and estimated length. However, due to the number of side channels present, there were not fully assessed as secondary habitat units unless they were directly affected by FHEP construction.

Substrate was classified according to a modified Wentworth scale into the following categories: fines (<2 mm), gravel (2 to 64 mm), cobble (64 to 256 mm), boulder (256 to 4,000 mm) and bedrock (>4,000 mm) (Lewis *et al.* 2004). The dominant and subdominant substrate type within each habitat unit was estimated based on coverage area. Dominant and subdominant substrate types were then determined from the percentage of habitat units in which a particular substrate type was either dominant or subdominant.

Total spawning habitat was estimated and classified according to the FHAP methodology (Johnston and Slaney 1996). Individual patches of gravel were measured with a meter stick and classified as suitable for anadromous or resident fish, or both, based on gravel size and patch area. According to the definitions in Johnston and Slaney (1996), patches at least 1.5 m^2 in area with gravel between 10 and 150 mm in size are classified as suitable for anadromous fish. In contrast, resident spawning gravel was reported in the following categories: R) patches greater than 0.1 m^2 with gravel between 10 and 75 mm in size are classified as suitable for resident trout and char; and, AR) patches that were at least 1.5 m^2 and composed of gravel between 10 and 75 mm in size were classified as suitable for anadromous and resident fish. Patches were also classified as functional or non-functional based on location from wetted edge and extent of compaction and embeddedness.

For each spawning gravel patch, the average length, average width, and average water depth were measured and recorded. If multiple small gravel patches were located in close proximity or separated by only a few large cobble or boulders, they were included as a single composite patch. Johnston and Slaney (1996) describe functional spawning habitat as having water depths greater than 15 cm and water velocities between 0.3 to 1.0 m/s during the spawning season. During our assessment flows were relatively low; therefore, to avoid underestimating functional spawning gravel only dry substrate and areas with velocities estimated to be below 0.01 m/s were classified as non-functional.

Compaction was subjectively classified as low (L), moderate (M), or high (H) using the 'Boot Test', which is a relative measure of gravel compaction, in which the substrate is kicked with a wading boot and the degree of penetration of the boot into the substrate is used to grade compaction. Compaction is classified as low if the boot easily and deeply penetrates the gravel substrate (>4 cm), moderate if a portion of the boot penetrates the gravel (approximately 2 to 4 cm), and high if the boot only slightly enters or does not enter the substrate completely (<2 cm).

The embeddedness of the gravel is a measure of the amount of fines (<2 mm) that are present in the substrate in each spawning gravel patch. Embeddedness was subjectively classified as trace (T, <5%), low (L, 5 to 25%), medium (M, 25 to 50%), high (H, 50 to 75%) and very high (VH, >75%) based on visual assessment.

Photographs were taken of each spawning gravel patch including a photo taken from above the water, and a photo taken underwater (if water was deep enough). A reference photo was also taken that showed the location of the gravel patch in relation to a distinguishable stream bank feature so that each patch can be located in the future. Photographs were taken at the start and end point of the survey and of significant stream features (e.g., log jam, gradient change). Photographs at these locations included views looking upstream, downstream and cross-stream from bank to bank.

Table 3. Physical parameters, units of measure, and equipment used during the FHAP surveys.

Parameter	Unit	Measured or Estimated	Equipment Used
Bankfull depth	m	Measured	Metre stick (0.05 m increments)
Bankfull width	m	Measured	30 m fibreglass tape
Bed material type	n/a	Visual estimate	Visual
Canopy closure	%	Visual estimate	Visual
Cover proportions	%	Visual estimate	Visual
Cover types	n/a	Visual estimate	Visual
Disturbance indicators	n/a	Visual estimate	Visual
Gradient	%	Measured	Suunto clinometer
Habitat unit length	m	Measured	30 m fibreglass tape/rangefinder
Maximum pool depth (>1.5 m)	m	Visual estimate	Visual
Maximum pool depth (<1.5 m)	m	Measured	Metre stick (0.05 m increments)
Pool crest depth	m	Measured	Metre stick (0.05 m increments)
Reach length	m	Measured	30 m fibreglass tape/rangefinder
Residual pool depth	m	Measured	Metre stick (0.05 m increments)
Riparian structure	n/a	Visual estimate	Visual
Riparian vegetation type	n/a	Visual estimate	Visual
Spawning gravel abundance	n/a	Visual estimate	Visual
Spawning gravel amount	m^2	Measured	Metre stick (0.05 m increments)
Spawning gravel type	n/a	Visual estimate	Visual
Substrate type	n/a	Visual estimate	Visual
Water and air temperature	°C	Measured	Alcohol thermometer
Wetted depth	m	Measured	Metre stick (0.05 m increments)
Wetted width	m	Measured	30 m fibreglass tape

3.4. Fish Community

3.4.1. Adult Spawner Abundance

Spawner surveys focused on Coho Salmon, the dominant species within Alena Creek, and consisted of bank walk surveys conducted every two weeks between early-November and early-December for a total of three surveys a year. Spawner surveys were completed between November 14 and December 9, 2016, and between November 10 and December 5, 2017. Results of these surveys are summarized in Section 4.4.1.

3.4.2. Juvenile Abundance

3.4.2.1. Minnow Trapping

Minnow trapping surveys were conducted in Alena Creek commencing on September 27, 2017. The objective of minnow trapping was to determine catch-per-unit-effort (CPUE) by species and life history stage so that relative juvenile fish abundance could be tracked for the duration of the monitoring period and compared to CPUE prior to enhancement.

Six sites were selected with five traps set at each site except for ALE-MT06, where 10 traps were set because it was a large pool that required greater sampling effort. Sampling was conducted in the same sites sampled during baseline monitoring (Map 4) (Harwood *et al.* 2016), of which two (ALE-MT01 and 02) were located in newly created/enhanced habitat and four were in habitat not directly enhanced. The minnow traps were baited using salmon roe and left overnight. When the traps were retrieved, captured fish were identified and measured.

3.4.2.2. Biological Information

All captured fish were identified to species using standard field keys and enumerated. The fork length of each captured fish was determined using a measuring board (±1.0 mm); after which 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 Squamish.

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.

3.4.2.3. Data Analysis

Individual Fish Data

Biological data from Cutthroat Trout and Coho Salmon 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 adult (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 grams, L is the length in millimeters, 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.

3.5. Riparian Habitat

Three distinct methods are employed to monitor the success of the riparian restoration works and the overall function of the riparian habitat. These methods are: (1) permanent vegetation density monitoring; (2) percent vegetation ground cover estimates; and (3) photopoint comparisons. Each of these techniques is discussed in more detail below. Any invasive species regionally or provincially designated as noxious were also documented when observed.

3.5.1. Permanent Vegetation Density Monitoring

Woody vegetation is the primary focus of riparian vegetation monitoring due to the long-term contribution to the maintenance and enhancement of riparian habitat and function. Consequently, the density (stems per hectare) of woody vegetation is an important metric and indicator of restored riparian habitat quality. Permanent vegetation monitoring plots were established to sample the density of perennial woody vegetation within a 50 m^2 circular plot, according to 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 vegetation monitoring plots were established in 2014, prior to construction of the compensation habitat; however, only one of these four plots (ALE-PRM03) ended up within the restored area, and was thus assessed in 2016 and 2017. Three additional plots were established in 2016 for a total of four plots that were assessed in 2016 and 2017. These permanent vegetation 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 disease and the host plant species were noted. Stems were defined as those stems of a plant that were distinctly individual at ground level. Tree or shrub seedlings having secondary leaves that were at least the size of a quarter and that were established on site were counted as trees or shrubs and were considered the minimum tree or shrub size. No minimum height requirements were used.

The DFO and MELP effective revegetation criteria provide a general target density for vegetation planted 2.0 m apart (DFO and MELP 1998). This equates to a final minimum target density of 2,309 stems per hectare. This target density for all tree and shrub species combined was considered when assessing whether a diverse assemblage of native tree and shrub species is becoming established within the Alena Creek FHEP area. Survival rate was calculated for planted western redcedar as the proportion of live plants divided by the total of live and dead plants.

3.5.2. Percent Vegetation Cover Estimates

Measurement of percent vegetation ground cover, including herbaceous and small woody species, is a useful indicator of substrate stabilization early in the revegetation process. Quadrat sampling is employed to determine the percent ground cover of all herbaceous and woody vegetation, excluding lichens, fungi and mosses. The assessment describes the percent ground cover of both the woody vegetation, and the forb and grass layer not captured by counting perennial woody vegetation within the permanent monitoring plots. This method is most meaningful during the early vegetation re-establishment period before perennial woody vegetation has established. The method consists of counting the number of 10 x 10 cm quadrat squares that contain vegetation within ten 0.25 m^2 quadrat replicates. Quadrat replicates were randomly located within the vicinity of the permanent vegetation monitoring plots and results from the ten replicates were averaged for the overall site. Photos of each quadrat replicate were taken.

3.5.3. Photopoint Comparison

Standard photographs provide insight into how the riparian function provided by grasses, forbs and smaller shrubs and trees changes over time. Photographs were taken facing 0 degrees (north) from 1.3 m above each permanent monitoring plot centre to qualitatively document change over time. Additional descriptive photographs were also taken of the monitoring sites.

4. RESULTS

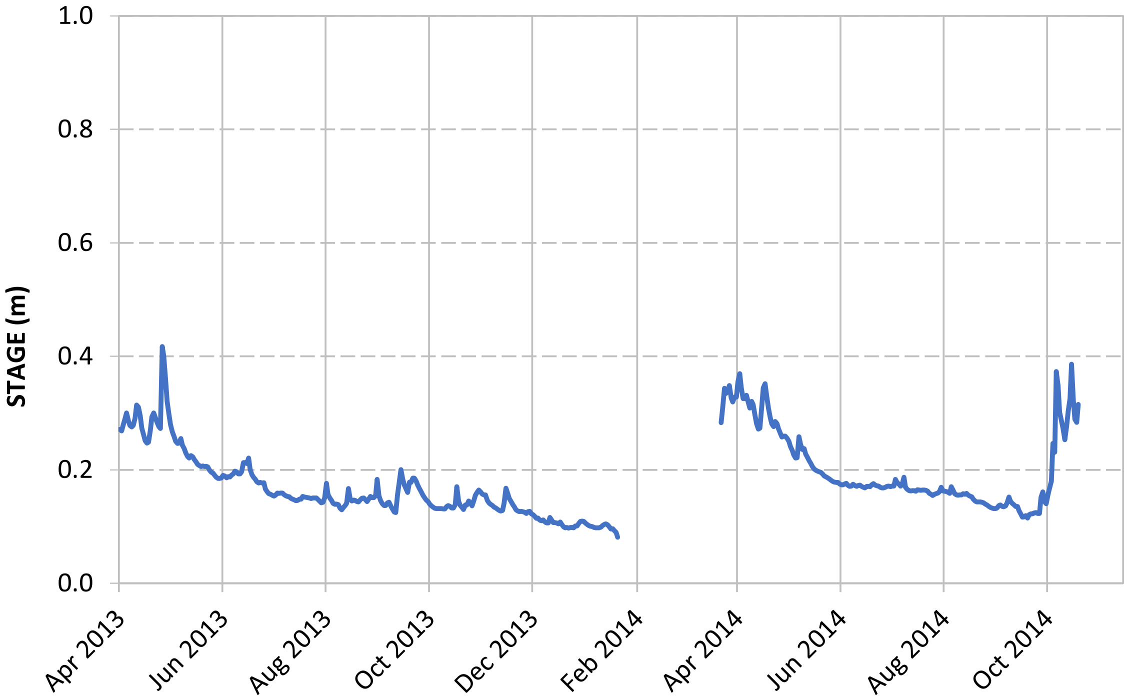
4.1. Hydrology

Seasonal trends in the Alena Creek hydrograph are consistent with a coastal, snow dominated watershed. Stage remained relatively low throughout the winter (January to mid-March) when precipitation was snow dominated, as well as from mid-July through the end of September when precipitation was minimal (Figure 1). The daily peak in stage was recorded on November 9, 2016 (0.95 m) during a flood event that represented a 1-in-20 year flood event on the Upper Lillooet River (McCoy, pers. comm. 2016). Stage also increased through March and April associated with the spring snow melt as was observed during baseline (Figure 1a). However, the high water levels in June and July 2017 (Figure 1b) are atypical, and were not observed during the baseline years when stage steadily declined through June and July. The high stage readings at the FSR Bridge site on Alena Creek in summer 2017 appear to be the result of backwatering caused by a new side channel of the Upper Lillooet River just downstream of the hydrometric gauge (Figure 2 and Figure 3) because there was little precipitation during this period. The new side channel formed during the peak flow in November 2016. Evidence that backwatering caused exaggerated stage readings at the bridge on Alena Creek during high flows in the Upper Lillooet River can be seen in Figure 4, which shows the Alena Creek stage readings responding to the diurnal fluctuation in stage experienced by the Upper Lillooet River during snow melt in summer.

Overall, mean daily stage (± SD) in Alena Creek from November 2016 to September 2017 was 0.28 m ± 0.12 m and stage did not drop below 0.16 m. However, these results are skewed by the likely backwatering effect caused by the Upper Lillooet River side channel.

Figure 1. **Stage in Alena Creek at the Lillooet River FSR bridge during a) baseline (Apr 2013 to Nov 2014) and b) year 1 monitoring (Nov 2016 to Oct 2017).**

a) Baseline



b) Year 1 monitoring

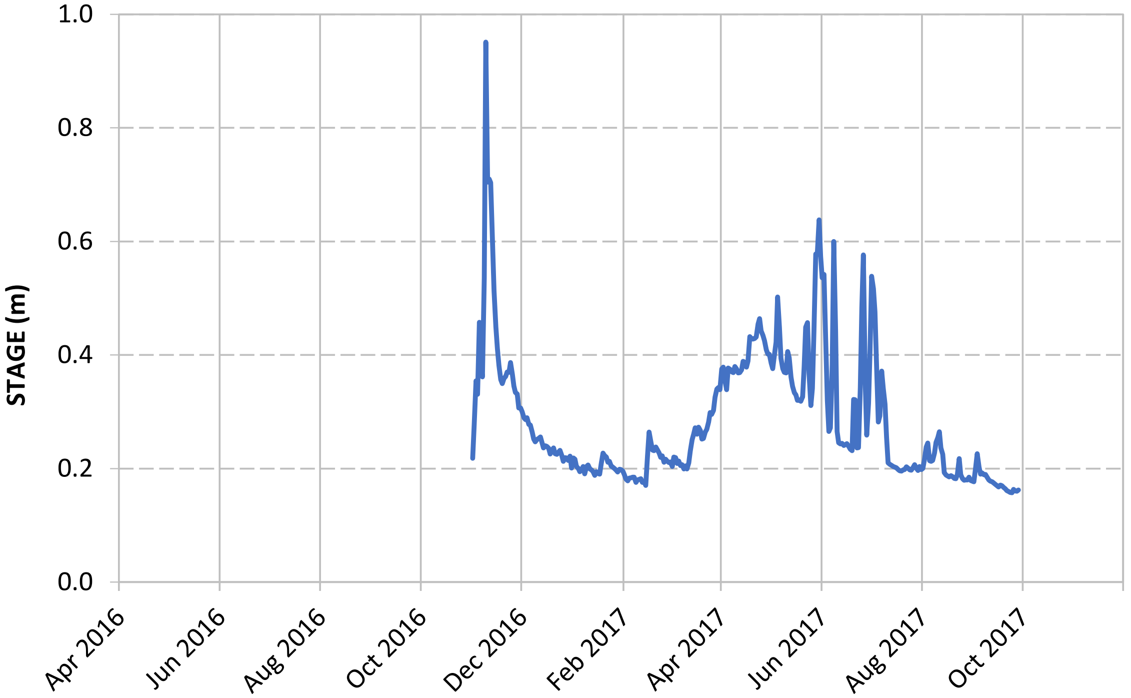
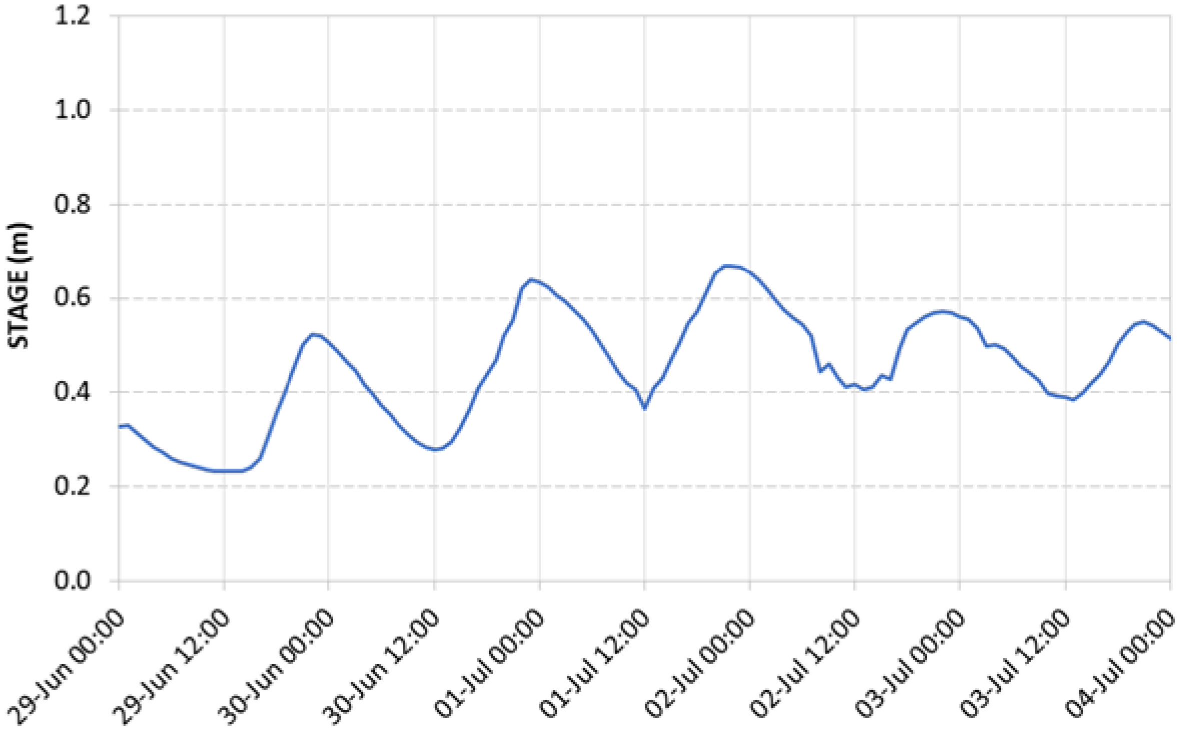


Figure 2. Looking upstream at a newly formed side channel of the Upper Lillooet River entering Alena Creek approximately 25 m downstream of the Lillooet FSR Bridge on November 14, 2016.

Figure 3. Looking downstream at Alena Creek from the Lillooet River FSR bridge in November 2016. The new Upper Lillooet River side channel is visible on river right.

Figure 4. **Stage in Alena Creek at the Lillooet River FSR bridge in late June and early July 2017 showing the diurnal fluctuation experienced by the Upper Lillooet River during snow melt in summer.**



4.2. Water Quality

4.2.1. Water Chemistry

Detailed data summary tables including baseline (2013 and 2014) and year 1 (2016 and 2017) data are provided in Appendix D along with applicable BC WQG (MOE 2017) for the protection of aquatic life (MOE 2018) and typical ranges of parameter values in BC watercourses (as provided in RISC 1998b). Laboratory reports from ALS including laboratory QA/QC results are provided in Appendix C.

Comparison of the range in concentration of water quality parameters between the baseline sampling period (2013 and 2014) and the first year of long term monitoring (2016 and 2017), and to BC WQG is provided in Table 4. During baseline and year 1 of long term monitoring, total iron, dissolved iron, and dissolved oxygen (applicable to buried life stages only) exceeded the BC short term water quality guidelines for the protection of aquatic life (MOE 2018). These exceedances are discussed in detail in the following sections.

Table 4. Summary of baseline and year 1 water quality data for key parameters. For metals, only parameters with BC WQG guideline exceedances are included.

Parameter	Range of parameter values				BC WQG
	Baseline (2013 - 2014)		Year 1 (2016 - 2017)		Instantaneous Min./Max.
	Min.	Max.	Min.	Max.	
Physical Tests (mg/L)					
Sp. Conductivity (*in-situ*, µS/cm)	37	70.8	50.1	85.9	
Sp. Conductivity (lab, µS/cm)	53.4	65.4	48.5	65.0	
Hardness (as $CaCO_3$)	22.6	27.3	18.4	25.5	
Dissolved Oxygen (*in-situ*, %)	65.0	84.5	54.6	94.7	
Dissolved Oxygen (*in-situ*)	7.89	11.24	6.54	10.81	< 9 (buried life stages)[1]; < 5 (other life stages)[1]
Temperature (*in-situ*, °C)	4.9	11.8	4.0	9.6	
Total Dissolved Solids	49	69	40	63	
Total Suspended Solids	<1.0	8.5	<1.0	5.6	EQ
Turbidity (lab, NTU)	0.72	8.68	0.23	4.69	
pH (*in-situ*, pH units)	5.87	8.30	6.41	7.17	n/a[2]
pH (lab, pH units)	7.28	7.59	7.11	7.45	n/a[2]
Biological Oxygen Demand	<2.00	<2.00	<2.00	<2.00	
Chemical Oxygen Demand	<20.0	<20.0	<20.0	<20.0	
Anions and Nutrients (mg/L)					
Alkalinity, Total (as $CaCO_3$)	22.9	29.9	16.1	26.8	
Ammonia, Total (as N)	<0.005	0.0383	<0.005	0.0416	0.68
Bromide (Br)	<0.05	<0.05	<0.05	<0.05	
Chloride (Cl)	<0.5	2.56	<0.5	0.58	600
Orthophosphate (as P)	<0.001	0.0039	<0.001	0.0033	
Fluoride (F)	0.023	0.031	0.022	0.032	EQ
Nitrate (as N)	0.0284	0.0495	0.0264	0.173	32
Nitrite (as N)	<0.001	0.0013	<0.001	<0.001	EQ
Sulfate (SO_4)	4.12	5.73	3.00	6.78	
Total Phosphate[3]	0.0024	0.0276	<0.002	0.0120	
Total Metals (mg/L)					
Iron (Fe)	0.329	3.610	0.065	1.340	1
Dissolved Metals (mg/L)					
Iron (Fe)	0.161	1.02	0.040	1.280	0.35

Yellow shading indicates exceedance of the instantaneous minimum BC WQG (MOE 2018).

EQ indicates that the applicable guideline is an equation as per MOE (2018). Total suspended solids data at the bridge site were compared to data collected at the upstream site on the same sample date; because data were available for total suspended solids, data were not screened against turbidity guidelines.

[1] Dissolved oxygen data were screened against the BC WQG for the instantaneous minimum water column concentration for both buried embryo/alevin life stages (9 mg/L) and other life stages (5 mg/L).

[2] When baseline values are between 6.5 and 9 there is no restriction on changes within this range (lethal effects observed below 4.5 and above 9.5). When baseline pH is < 6.5, there should be no statistically significant decrease in pH from background, and there is no restriction on the increase in pH except in boggy areas that have a unique fauna or flora.

[3] Total Phosphate measured during baseline, Total Phosphorus measured during Year 1.

4.2.1.1. Physical Parameters, Dissolved Oxygen and Nutrients

No discernable changes in the range of general physical water quality parameters are evident for specific conductivity, alkalinity, hardness, TDS, TSS, turbidity, biological oxygen demand (BOD), chemical oxygen demand (COD), and anions (fluoride, chloride, and sulfate) (Appendix D). Furthermore, these parameter values do not exceed BC WQGs where applicable.

Alkalinity values in Alena Creek are typical of BC coastal waters and indicate a moderate sensitivity to acidic inputs (RISC 1998b). Alena Creek exhibited predominantly clear flow conditions (TSS <25 mg/L and turbidity <8 NTU) in all cases during year 1 sampling. During baseline and year 1 monitoring, turbidity and TSS were typically slightly higher at the bridge site (ALE-BDGWQ) compared to the upstream site and varied between seasons at both sites (Appendix D).

In-situ pH was less than 6.5 on a number of occasions with the lowest pH measured at the ALE-USWQ1 site during both baseline (pH was 6.21) and year 1 monitoring (pH was 6.41). Coastal streams in BC commonly have pH values ranging from 5.5 to 6.5 and natural variation in pH is a common occurrence (RISC 1998b). Laboratory analyzed pH was between 7.11 and 7.59 in all cases. The BC WQG indicate that if pH is less than 6.5 then no statistically significant decrease from background pH should occur (MOE 2018). The ALE-USWQ1 site represents background conditions as no instream habitat enhancement work was conducted this far upstream (Map 3).

Biochemical oxygen demand and chemical oxygen demand were below the respective MDLs of 2.0 mg/L and 20 mg/L at all sites on all sample occasions during both baseline and year 1 sampling. The non-detectable concentrations of BOD and COD in Alena Creek suggest that the concentration of organic matter in the water is low.

In BC, surface waters generally have dissolved oxygen concentrations greater than 10 mg/L, with saturations that are close to equilibrium with the atmosphere (i.e., close to 100%) (RISC 1998b). Dissolved oxygen concentrations measured *in-situ* ranged from 7.89 mg/L to 11.24 mg/L during baseline sampling and from 6.54 mg/L to 10.81 mg/L during year 1 sampling (Table 5). During baseline and year 1 sampling, dissolved oxygen levels in the water column were less than the BC WQG minimum instantaneous value for the water column of 9 mg/L for the protection of buried life stages (eggs and alevin) on a number of occasions, predominantly at the upstream site (Table 5). The BC WQG for dissolved oxygen are more stringent when applied to buried life stages given that the dissolved oxygen in the interstitial water (in the spawning gravel) is expected to be less than that measured in the water column. Following the enhancement works, no exceedances of the minimum BC WQG at the bridge site were observed, with data indicating a well aerated condition with dissolved oxygen concentrations ranging from 10.38 mg/L to 10.81 mg/L at ALE-BDGWQ in 2016 and 2017 (Table 5).

Nutrient concentrations were within typical values for BC watercourses and well below the applicable BC WQG for the protection of aquatic life (Appendix D). Ammonia is expected to be present at concentrations of <0.100 mg/L in waters not affected by waste discharges (Nordin and

Pommen 1986). In general, ammonia concentrations were higher at the bridge site during both baseline and year 1 sampling (Appendix D). Nitrate concentrations were also slightly higher at the bridge site during both baseline and year 1 sampling (Appendix D).

Orthophosphate concentrations were often below detection limits at the upstream site and slightly higher at the bridge site. Very low orthophosphate concentrations are expected as it is a biologically readily available form of phosphorus and quickly utilized by biota. Coastal BC streams typically have orthophosphate concentrations <0.0001 mg/L (Slaney and Ward 1993, Ashley and Slaney 1997).

Table 5. Summary of dissolved oxygen data collected during baseline and year 1 monitoring.

Year	Date	Site[1]	Dissolved Oxygen %				Dissolved Oxygen[3] mg/L			
			Avg[2]	Min	Max	SD	Avg[2]	Min	Max	SD
2013	08-Jul	ALE-USWQ	79.1	79.0	79.1	0.1	8.20	8.20	8.21	0.01
		ALE-BDGWQ	82.8	82.7	82.9	0.1	8.76	8.75	8.77	0.01
	16-Sep	ALE-USWQ	80.4	79.9	81.1	0.6	9.04	8.95	9.16	0.11
		ALE-BDGWQ	82.6	80.1	84.5	2.3	9.20	9.06	9.29	0.12
	18-Nov	ALE-USWQ1	65.4	65.0	66.1	0.6	7.93	7.89	7.97	0.04
		ALE-BDGWQ	76.9	76.5	77.3	0.4	9.67	9.64	9.71	0.04
2014	27-Feb	ALE-USWQ1	79.4	79.3	79.4	0.1	9.20	9.20	9.21	0.01
		ALE-BDGWQ	82.5	82.5	82.6	0.1	10.01	10.00	10.01	0.01
	29-Apr	ALE-USWQ1	88.2	88.1	88.3	0.1	10.90	10.89	10.91	0.01
		ALE-BDGWQ	95.4	95.3	95.5	0.1	11.23	11.22	11.24	0.01
	25-Nov	ALE-BDGWQ	86.6	86.5	86.6	0.1	10.95	10.95	10.96	0.01
2016	23-Nov	ALE-USWQ1	71.8	71.7	72.0	0.2	8.87	8.86	8.88	0.01
		ALE-BDGWQ	83.5	83.4	83.6	0.1	10.55	10.55	10.56	0.01
2017	05-Mar	ALE-USWQ1	78.7	78.4	78.9	0.3	-	-	-	-
		ALE-BDGWQ	85.8	85.8	85.8	0.0	-	-	-	-
	05-Jun	ALE-USWQ1	74.6	74.5	74.7	0.1	8.77	8.74	8.80	0.03
		ALE-BDGWQ	89.4	89.3	89.5	0.1	10.38	10.38	10.39	0.01
	13-Sep	ALE-USWQ1	55.0	54.6	55.7	0.6	6.56	6.54	6.58	0.02
		ALE-BDGWQ	94.7	94.6	94.7	0.1	10.80	10.80	10.81	0.01

[1] ALE-USWQ was moved 570 m upstream to ALE-USWQ1 in November 2013 to ensure the site was sufficiently upstream of the instream enhancement works.

[2] Average of three replicate *in-situ* measurements (n=3) on each date unless otherwise indicated. A single data listed under Avg. indicates n=1.

[3] DO data were screened against the BC WQG for the instantaneous minimum water quality concentration for both buried embryo / alevin life stages (9 mg/L) and other life stages (5 mg/L). Yellow shading indicates an exceedance of the instantaneous minimum water column concentration of 9 mg/L for buried embryo / alevin life stages (MOE 2018).

4.2.1.2. Total and Dissolved Metals

The baseline and year 1 total and dissolved metals results are provided in summary tables in Appendix D and the ALS lab reports for 2016 and 2017 are provided in Appendix C (ALS lab reports for the baseline period are provided in Appendix B of Harwood *et al.* 2016). Note that dissolved metals results for November 2016 are not available due to an error where samples were not filtered prior to analysis. With the exception of iron (Table 6), total and dissolved metals concentrations were not in exceedance of the short-term maximum BC WQG (MOE 2018) during baseline or year 1 sampling. Due to the exceedance of the BC WQGs for iron, these results are discussed in more detail below.

Total and Dissolved Iron

The consequences of high background iron concentrations on the Alena Creek fish populations were evaluated in detail in the baseline report (Harwood *et al.* 2016). Several studies have demonstrated that fish can acclimatize to moderately high total iron concentrations within four to six weeks exposure at concentrations ranging from 1.8 mg/L to 18.6 mg/L (Phippen *et al.* 2008). Total iron concentrations in Alena Creek are either below or within the lower end of the range used in these acclimatization studies (Table 6). This, combined with the presence of a well-established, self-sustaining fish population in Alena Creek, suggests that iron concentrations are not high enough to be toxic to fish present in Alena Creek. In addition, the Ministry of Environment recognizes that the total iron water quality guideline of 1 mg/L may be over-protective in many cases (Phippen *et al.* 2008). This is in part due to the reliance on bioassay data, which in the case of iron may be confounded by the complexity of iron chemistry that includes pH shifts, changes from Fe^{2+} and Fe^{3+}, and changes from the dissolved to particulate phase (Phippen *et al.* 2008). In all situations, Phippen *et al.* (2008) recommends that dissolved iron concentrations are the most appropriate way to measure risk; however, they also acknowledge that the development of a guideline for dissolved iron is difficult due to the lack of clear data specifically differentiating between the effects of dissolved and total iron.

Dissolved iron exceeded the BC WQG less frequently during year 1 sampling than during baseline sampling because exceedances were only observed at the bridge site. Concentrations of dissolved iron exceeded the short-term maximum BC WQG of 0.35 mg/L at the bridge site during all sampling periods, with the range of concentrations similar between baseline and year 1 monitoring (Table 6).

Total iron exceeded the short-term maximum BC WQG of 1 mg/L at one or both sites on all sampling dates during baseline sampling, however only one exceedance occurred during year 1 sampling (ALE-BDGWQ on Sep 13, 2017). The frequency of exceedances and concentration of total iron decreased during year 1 in comparison to baseline values (Table 6) at both sites.

Fish, including young-of-the-year, are distributed throughout the area sampled for water quality (Section 4.4.2) and do not appear to be adversely affected by the iron concentrations observed.

Table 6. Summary of total and dissolved iron (Fe) results during baseline (2013 and 2014) and year 1 (2016 and 2017) sampling.

Year	Date	Site	n	Iron (Fe) - Dissolved mg/L				Iron (Fe) - Total mg/L			
				Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD
2013	08-Jul	ALE-USWQ	3	0.596	0.589	0.600	0.006	1.06	1.04	1.09	0.03
		ALE-BDGWQ	3	1.013	1.010	1.020	0.006	1.96	1.95	1.98	0.02
	16-Sep	ALE-USWQ	3	0.772	0.740	0.801	0.031	1.19	1.15	1.22	0.04
		ALE-BDGWQ	3	0.821	0.811	0.832	0.011	2.11	2.08	2.13	0.03
	18-Nov	ALE-USWQ1	3	0.207	0.204	0.209	0.003	0.34	0.33	0.35	0.01
		ALE-BDGWQ	3	0.809	0.783	0.829	0.024	1.18	1.16	1.21	0.03
2014	27-Feb	ALE-USWQ1	3	0.172	0.161	0.183	0.011	1.45	0.34	3.61	1.87
		ALE-BDGWQ	3	0.456	0.452	0.460	0.004	0.80	0.77	0.82	0.03
Baseline Summary			*24*	*0.606*	*0.161*	*1.020*	-	*1.26*	*0.33*	*3.61*	-
2016	23-Nov	ALE-USWQ1	3	0.197	0.191	0.201	0.005	0.22	0.22	0.23	0.01
		ALE-BDGWQ	3	0.871	0.857	0.887	0.015	0.93	0.91	0.94	0.02
2017	05-Mar	ALE-USWQ1	2	0.109	0.105	0.112	0.005	0.11	0.11	0.11	0.00
		ALE-BDGWQ	2	0.877	0.871	0.882	0.008	0.90	0.88	0.93	0.03
	05-Jun	ALE-USWQ1	2	0.070	0.066	0.074	0.006	0.07	0.07	0.07	0.00
		ALE-BDGWQ	2	0.669	0.660	0.678	0.013	0.65	0.64	0.65	0.01
	13-Sep	ALE-USWQ1	2	0.041	0.040	0.042	0.001	0.19	0.17	0.20	0.02
		ALE-BDGWQ	2	1.007	0.733	1.280	0.387	1.34	1.34	1.34	0.00
Year 1 Summary			*18*	*0.480*	*0.040*	*1.280*	-	*0.55*	*0.07*	*1.34*	-

[1] Average of three (n=3) or two (n=2) replicates on each date.

Yellow shading indicates exceedance of the short-term maxiumum (0.35 mg/L for dissovled iron and 1.0 mg/L for total iron, MOE 2018).

4.2.2. Water Temperature

4.2.2.1. Overview

The period of record for post-construction analysis in Year 1 was from November 23, 2016 to November 10, 2017 (Table 7). Data availability is based on the most recent download of water temperature loggers. During the Year 1 monitoring period, both monitoring sites had complete data records, but data gaps did occur during pre-construction monitoring (Table 7). Data gaps can occur due to equipment failure or loss, and out-of-water events during low flows, or if sensors become buried in sediment.

For the pre-construction phase, the processed record corresponded to a period of 568 days from April 17, 2014 to December 31, 2014 at ALE-USWQ1, and 460 days from August 27, 2013 to December 31, 2014 at ALE-BDGWQ, with the sizes of gaps in the records ranging from 6.3% to 8.9% of this period (Table 7). For the post-construction phase, the processed record to date corresponded to a period of 352 days with zero gaps in the records (Table 7).

Detailed plots of water temperature at both sites for all monitoring years (pre- and post-construction) are shown in Figure 5 and Figure 6, respectively. Detailed plots of annual water temperature for each site during pre- and post-construction phase are provided in Section 2 of Appendix E. The water temperature records from the monitoring sites show seasonal and interannual variability. This variability is displayed in Section 3 of Appendix E and summarized in Section 4 of Appendix E for the pre- and post-construction phase, respectively, which provides the mean, minimum, and maximum water temperatures for each month of the period of record.

In post-construction Year 1, the pattern in daily temperature has been largely similar to pre-construction phase. There has been no substantial change in the pattern of inter-site differences in water temperature compared to pre-construction phase (Section 3 of Appendix E). In general, water temperature at ALE-USWQ1 varied in a narrower range than observed at ALE-BDGWQ. Typically, water temperatures at upstream sites are cooler (58% and 54% of the data record during pre- and post-construction phase) than that of downstream site, due to higher elevation. However, this is not the case for all months of the year in Alena Creek where the upstream site is observed to be warmer (42% and 46% of the data record during pre- and post-construction phase) than the downstream site, possibly due to buffered groundwater, during the late fall and winter months.

There are differences in water temperature between the ALE-USWQ1 and ALE-BDGWQ sites during the winter and summer seasons, despite the short distance (~1 km) and elevation (11 m) difference between the two sites. There are likely two main reasons for these differences. First, the narrow range of temperatures observed at ALE-USWQ1 suggests that surface water temperature is buffered by groundwater at this site. Second, a tributary flows into Alena Creek between the two sites and this alters the influence of the groundwater entering Alena Creek near ALE-USWQ1. Some heating and cooling of the water will also occur along the 1 km reach between the two gauges.

Table 7. Period of record and source of water temperature data collected from Alena Creek sites.

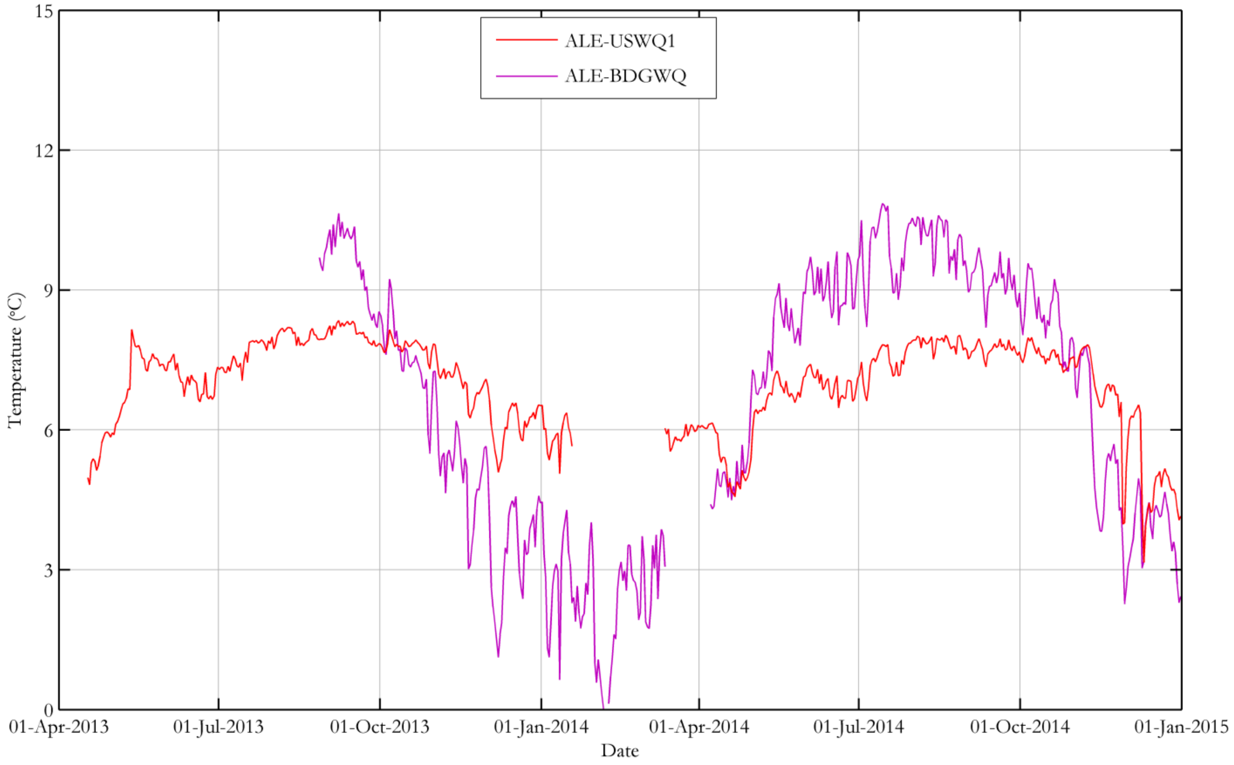
Site	Project Phase	Periods of Record		No of Datapoints	Logging Interval	Number of Days with Valid Data	Gaps in Record (%)
		Start Date	End Date				
ALE-USWQ1	Pre-construction[1]	4/17/2013	12/31/2014	13,627	60 minute	568	8.9
	Post-construction[2]	11/23/2016	11/10/2017	33,780	15 minute	352	0
ALE-BDGWQ	Pre-construction[1]	8/27/2013	12/31/2014	11,049	60 minute	460	6.3
	Post-construction[2]	11/23/2016	11/10/2017	33,780	15 minute	352	0

[1] Pre-construction (2013-2014) water temperature was monitored via hydrometric gauges maintained by KPL.

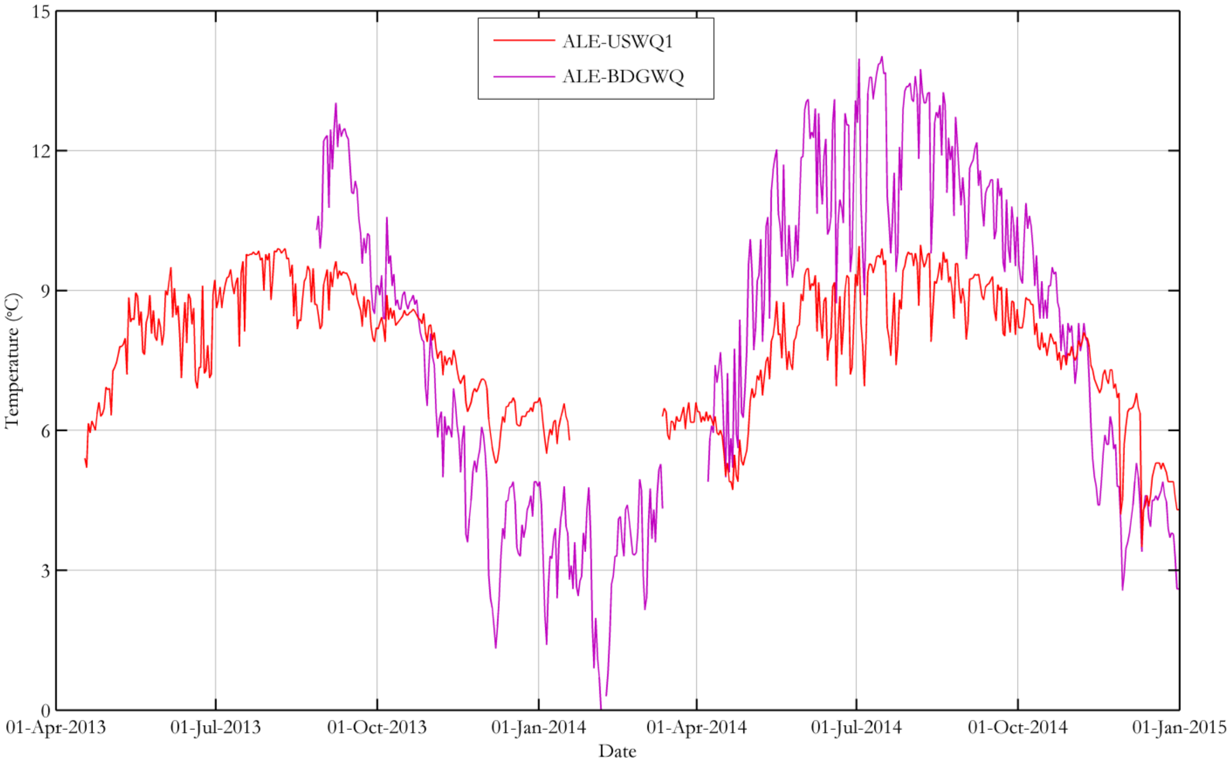
[2] Post-construction water temperature Tidbit monitoring commenced on November 23, 2016.

Figure 5. Pre-construction daily (a) average, (b) maximum, and (c) minimum water temperature data at all monitoring sites in the Alena Creek from May 2013 to December 2014.

(a) Daily Average



(b) Daily Maximum



(c) Daily Minimum

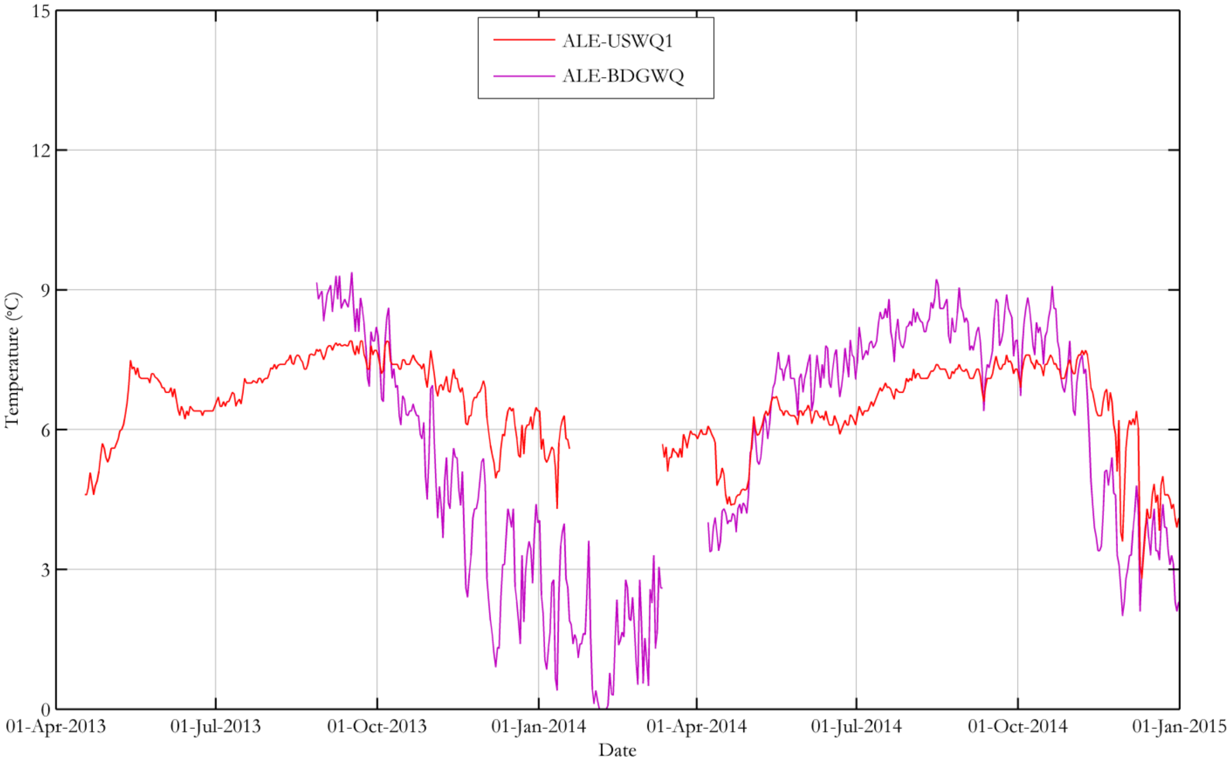
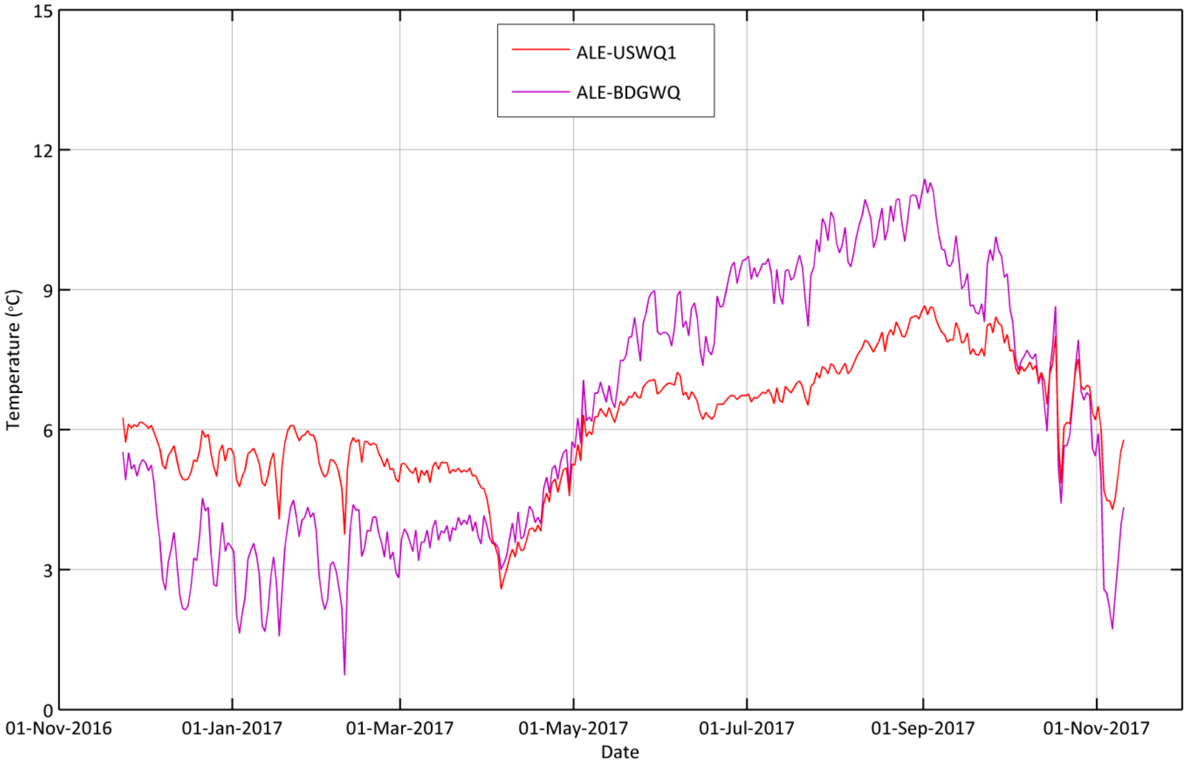
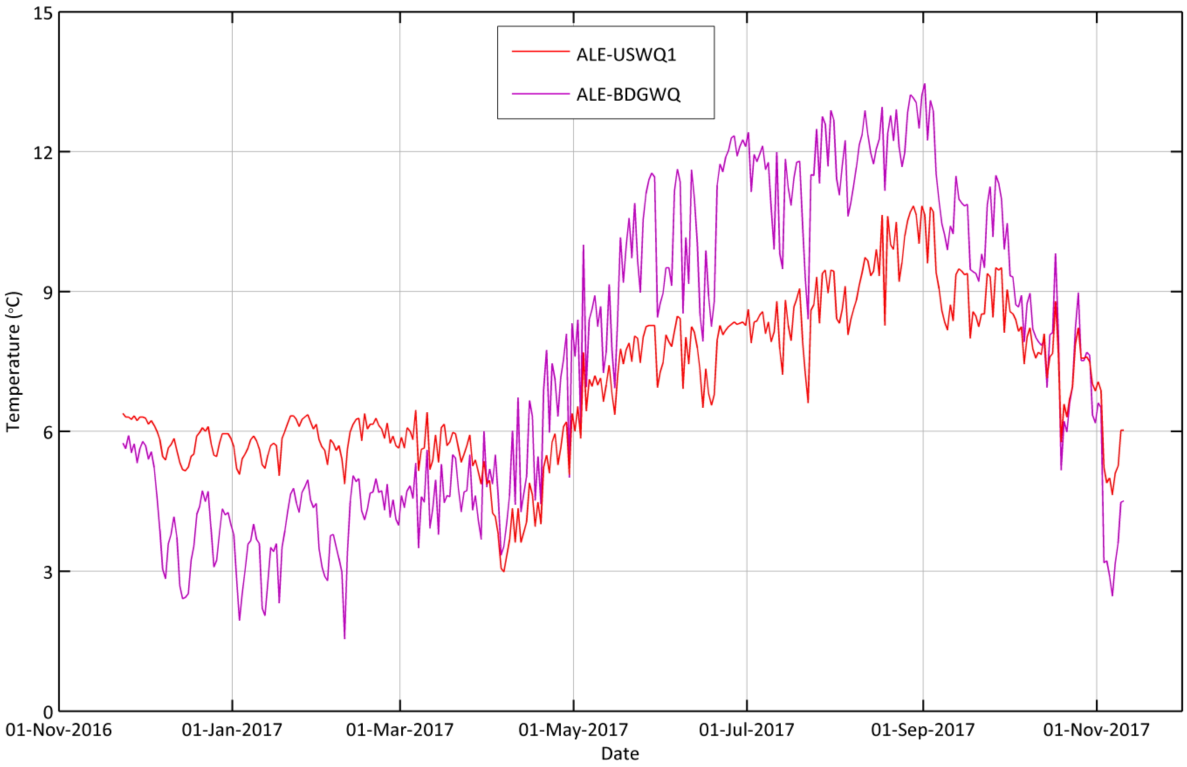


Figure 6. Post-construction daily (a) average, (b) maximum, and (c) minimum water temperature data at all monitoring sites in the Alena Creek from November 2016 to November 2017.

(a) Daily Average



(b) Daily Maximum



(c) Daily Minimum

4.2.2.1. Monthly Statistics, Growing Season, and Daily Extremes

The range of monthly average temperatures was similar between the pre- and post-construction phases at both sites. The coolest temperatures were observed between December to April, while the warmest months were July to September. Over the available data record, monthly average temperatures at the upstream site (ALE-USWQ1) ranged from 5.0°C to 8.1°C pre-construction, and from 4.0°C to 8.1°C post-construction (Section 4 of Appendix E). At the downstream site (ALE-BDGWQ) monthly average temperatures ranged from 2.2°C to 10.1°C pre-construction, and from 3.2°C to 10.4°C post-construction.

Post-construction monthly minimum and maximum temperatures at site ALE-BDGWQ were within the range observed during pre-construction monitoring (0°C to 14°C), while the minimum and maximum values were slightly different at site ALE-USWQ1 under post-construction (0.8°C vs. 2.8°C and 10.8°C vs. 10.0°C). Note that a data gap occurred during pre-construction monitoring in February/March 2014, so there is some uncertainty in whether the coolest temperatures were captured during this phase. Nevertheless, no substantial change in monthly temperature statistics has been observed within the available pre and post-construction data period of record.

There has been no apparent change to the growing season start dates post-construction compared to pre-construction; the growing season started at the end of April during pre- and post-construction phase at both sites (Table 8). However, the growing season end dates (early November) during the post-construction phase are earlier than those observed during pre-construction phase (between mid-November and mid-December) at both monitoring sites. As a result, a decrease in cumulative degree days during the growing season at both sites during post-construction phase. Additional post-construction data are required to confirm growing season trends.

With respect to daily extreme temperatures, Alena Creek is classified as a cool stream based on there being no days with mean water temperatures >18°C in either pre or post-construction conditions, at either site (Table 9). The highest hourly temperature was 14.0°C, which occurred at the downstream site, ALE-BDGWQ, on July 15, 2014. At ALE-USWQ1, no days when the mean temperature was <1°C were observed pre-construction; however, this excludes a period in early February 2014 that was removed from the dataset due to suspected icing conditions when water temperature approached -2°C (Section 2.2.2) (McCarthy, pers. comm. 2014). Only one day was observed when the mean temperature was <1°C at ALE-BDGWQ.

In the post-construction phase, the number of days where the mean temperature was <1°C ranged from 0 days (ALE-USWQ1) to 1 days (ALE-BDGWQ). Note that, the post-construction record does not yet cover a complete year; the temperature extremes for a complete post-construction year for both sites will be reported in the Year 2 report, following additional data collection.

Table 8. Degree days in the growing season at ALE-USWQ1 and ALE-BDGWQ.

Site	Project Phase	Year	Number of days with valid data	Growing Season				
				Start Date	End Date	Length (day)	Gap (day)	Accumulated Thermal Units
ALE-USWQ1	Pre-construction	2013[†]	256	-	-	-	-	-
		2014	306	24-Apr	12-Dec	233	3	1,665
	Post-constructio	2016[‡]	38	-	-	-	-	-
		2017	312	26-Apr	7-Nov	196	1	1,375
ALE-BDGWQ	Pre-construction	2013[†]	125	-	24-Nov	-	-	-
		2014	328	20-Apr	16-Nov	211	1	1,833
	Post-constructio	2016[‡]	38	-	-	-	-	-
		2017	312	20-Apr	4-Nov	199	1	1,675

[†] Growing season could not be estimated because data are not available for complete year.

[‡] Temperature monitoring began on November 23, 2016, limiting the ability to estimate the start date and accumulated thermal units.

Table 9. Summary of the number of days with mean daily water temperatures >20°C, >18°C , and <1°C at ALE-USWQ1 and ALE-BDGWQ.

Site	Project Phase	Year	*n* (days)[±]	Days T_{water} > 18°C	Days T_{water} > 20°C	Days T_{water} < 1°C
ALE-USWQ1	Pre-construction	2013	256	0	0	0
		2014[†]	306	0	0	0
	Post-construction[‡]	2016	38	0	0	0
		2017	312	0	0	0
ALE-BDGWQ	Pre-construction	2013	125	0	0	0
		2014	328	0	0	1
	Post-construction[‡]	2016	38	0	0	0
		2017	312	0	0	1

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

[†] Value excludes the period in February 2014 that was excluded from the dataset based on suspected ice conditions.

[‡] To date, post-construction water temperature Tidbit monitoring commenced on November 23, 2016 and ended on November 10, 2017.

4.2.2.2. Bull Trout / Dolly Varden Temperature Guidelines

Provincial water temperature guidelines specific to Bull Trout and/or Dolly Varden in streams (Table 1 of Appendix E) were compared to the observed temperature at each monitoring site (ALE-USWQ1 and ALE-BDGWQ), as Bull Trout are present throughout the Alena Creek Project area. The incidence of extreme daily mean water temperatures compared to Bull Trout/Dolly Varden water temperature guidelines is presented in Table 10. In addition, minimum and maximum instantaneous water temperature statistics at ALE-USWQ1 and ALE-BDGWQ monitoring site compared to guideline limits are presented in Section 5 of Appendix E.

The maximum (instantaneous) water temperature recorded within the Project area was 13.75°C, recorded at site ALE-BDGWQ in 2015 (Section 5 of Appendix E). Therefore, the highest maximum instantaneous temperatures did not exceed the prescribed guideline upper threshold of daily temperature for Bull Trout for the entire period of record at any site.

In addition, the highest maximum daily temperatures did not exceed the prescribed guideline upper threshold for spawning and incubation (10°C) at site ALE-USWQ1, under pre or post-construction conditions (Table 10). The highest instantaneous maximum temperature observed at this site was 10.8°C in 2017. At site ALE-BDGWQ, the upper temperature threshold for spawning and incubation was exceeded under both pre- and post-construction conditions (Table 10). This occurred because of warm temperatures in August and September; in general, water temperatures at this site do not cool below 10°C until late September/October at this site.

Daily mean water temperatures did fall outside the lower threshold range for incubation (2°C) at site ALE-BDGWQ, under both pre- and post-construction conditions (Table 10): the frequency of occurrence was lower post-construction. No exceedances of the daily mean temperature threshold occurred at the upstream site (ALE-USWQ1), although some instantaneous records were less than 2°C (Section 5 of Appendix E).

In general, it appears site ALE-USWQ1 is more suitable for spawning and incubation of Bull Trout across the stated periodicity for this species, than site ALE-BDGWQ.

Table 10. Summary of incidence of extreme daily mean water temperatures compared to Bull Trout/Dolly Varden water temperature guidelines.

Site	Project Phase	Year	*n* (days)[*]	Days T_{water} > 15°C (Year Round)	Days T_{water} > 10°C (i.e., max spawning temperature, Aug 01 -Dec 08)	Days T_{water} > 10°C (i.e., max incubation temperature, Aug 01 -Mar 01)	Days T_{water} < 2°C (i.e., min incubation temperature, Aug 01 -Mar 01)
ALE-USWQ1	Pre-construction	2013	256	0	0	0	0
		2014[†]	306	0	0	0	0
	Post-construction	2016	38	0	0	0	0
		2017	312	0	0	0	0
ALE-BDGWQ	Pre-construction	2013	125	0	14	14	25
		2014	328	0	20	20	0
	Post-construction	2016	38	0	0	0	5
		2017	312	0	32	32	1

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

[†] Value excludes the period in February 2014 that was excluded from the dataset based on suspected ice conditions.

[‡] Post-construction water temperature monitoring commenced on November 23, 2016 and data are available to November 10, 2017.

4.2.2.3. Mean Weekly Maximum Temperatures (MWMxT)

A comparison of MWMxT temperature data to optimum temperature ranges was completed for each fish species using pre- and post-construction data collected at both sites. Results for upstream and downstream baseline water temperature data for all years combined is presented in Table 11 and Table 12. Post-construction data are presented in Table 13 and Table 14. The tables show the percent complete of the data record as well as the minimum and maximum MWMxT during the life stages of each fish species. For each life stage, the table also shows the percentage of MWMxT data that were above, within, and below the optimum ranges for fish life stages during baseline monitoring, as well as the percentage of MWMxT data more than 1°C above and below the optimum ranges.

Complete temperature records are not available for all life stages for each year, thus for each life history stage the percentage of data available is also provided in the summary tables. If the percent complete for a particular life stage is less than 50%, comparisons to the provincial guidelines were not calculated. Note that post-construction monitoring began near the end of 2016, and the MWMxT data during 2016 does not cover the complete life stage of any fish species (except for incubation for Coho Salmon). In addition, the current post-construction monitoring ended on November 2017; thus the spawning and incubation periods for Coho Salmon and incubation period for Bull Trout data are missing during 2017. MWMxT statistics for incubation will be calculated in Year 2, when a more complete period of record is available.

In general, water temperature at the monitoring sites was optimal for the fish species and life stages present under both pre- and post-construction periods, although some sub-optimally cool temperatures were recorded within most periods as well. Notable exceptions for both baseline and post-construction periods where MWMxTs were sub-optimally cool for the majority of, or the entire period, include: Coho Salmon rearing and Cutthroat Trout spawning and incubation at site ALE-USWQ1. Temperatures were also cooler than optimal at times for Coho Salmon rearing, Bull Trout spawning at site ALE-BDGWQ.

Sub-optimally warm temperatures were observed in August and September at both sites during Bull Trout spawning and incubation periods and for a small proportion of the record at site ALE-BDGWQ during Cutthroat Trout incubation. Warm surface waters during incubation may be partially mitigated by the groundwater upwelling at site ALE-USWQ1, such that temperature within the redds may be lower.

Overall, the minimum and maximum MWMxT was greatest at site ALE-BDGWQ and more moderate at site ALE-USWQ1, perhaps due to a thermal buffering effect of groundwater at the upstream site. No substantial change in the range of MWMxTs was observed at site ALE-BDGWQ between pre- and post-construction phases: MWMxT ranged from 2.1°C to 13.7°C pre-construction and from 2.8°C to 13.0°C post-construction. The range of MWMxTs observed at site ALE-USWQ1 was slightly greater post-construction (3.5°C to 10.5°C post vs. 4.4°C to 9.9°C pre) but was small enough to be explained by inter-annual variability.

Post-construction conditions will be assessed further following the collection of Year 2 data as a longer period of record will complete the period of record for all life history stages.

Table 11. **Pre-construction mean weekly maximum water temperatures for Bull Trout, Cutthroat Trout, and Coho Salmon life stages at ALE-USWQ1.**

Species	Life Stage			Year	Percent Complete	MWMxT (°C)			% of MWMxT			
	Periodicity	Optimum Temperature Range (°C)	Duration (days)			Min.	Max.	Below Lower Bound by >1°C	Below Lower Bound	Between Bounds	Above Upper Bound	Above Upper Bound by >1°C
Coho Salmon	Migration (Sep. 01 to Dec. 31)	7.2-15.6	122	2013	98.4	5.6	9.4	6.7	37.5	62.5	0.0	0.0
			122	2014	98.4	4.4	9.3	25.0	39.2	60.8	0.0	0.0
	Spawning* (Oct. 15 to Jan. 01)	4.4-12.8	79	2013	97.5	5.6	8.5	0.0	0.0	100.0	0.0	0.0
			79	2014	96.2	4.4	7.9	0.0	1.3	98.7	0.0	0.0
	Incubation* (Oct. 15 to Apr. 01)	4.0-13.0	169	2013	53.8	5.6	8.5	0.0	0.0	100.0	0.0	0.0
			169	2014	45	-	-	-	-	-	-	-
	Rearing (Jan. 01 to Dec. 31)	9.0-16.0	365	2013	70.1	5.6	9.8	36.3	77.3	22.7	0.0	0.0
			365	2014	83.8	4.4	9.7	53.9	81.7	18.3	0.0	0.0
Cutthroat Trout	Spawning (Apr. 01 to Jul. 01)	9.0-12.0	92	2013	81.5	5.8	8.9	45.3	100.0	0.0	0.0	0.0
			92	2014	100	5.0	9.2	56.5	94.6	5.4	0.0	0.0
	Incubation (May. 01 to Sep. 01)	9.0-12.0	124	2013	100	6.8	9.8	16.9	65.3	34.7	0.0	0.0
			124	2014	100	6.3	9.7	17.7	62.9	37.1	0.0	0.0
	Rearing (Jan. 01 to Dec. 31)	7.0-16.0	365	2013	70.1	5.6	9.8	3.5	22.7	77.3	0.0	0.0
			365	2014	83.8	4.4	9.7	16.0	34.6	65.4	0.0	0.0
Bull Trout	Spawning (Aug. 01 to Dec. 08)	5.0-9.0	130	2013	98.5	5.6	9.8	0.0	0.0	75.0	25.0	0.0
			130	2014	98.5	5.7	9.7	0.0	0.0	71.1	28.9	0.0
	Incubation* (Aug. 01 to Mar. 01)	2.0-6.0	213	2013	77.9	5.6	9.8	0.0	0.0	6.0	94.0	64.5
			213	2014	70.9	4.4	9.7	0.0	0.0	18.5	81.5	76.2
	Rearing (Jan. 01 to Dec. 31)	6.0-14.0	365	2013	70.1	5.6	9.8	0.0	3.5	96.5	0.0	0.0
			365	2014	83.8	4.4	9.7	4.2	16.0	84.0	0.0	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).

Grey shading indicates the percent complete is less than 50%, comparisons to the provincial guidelines are not included for <50% of data.

* statistics presented are for the calendar year in which the period started, and include data for the following calendar year when period lasts through the winter.

Table 12. Pre-construction mean weekly maximum water temperatures for Bull Trout, Cutthroat Trout, and Coho Salmon life stages at ALE-BDGWQ.

Species	Life Stage			Year	Percent Complete	MWMxT (°C)			% of MWMxT			
	Periodicity	Optimum Temperature Range (°C)	Duration (days)			Min.	Max.	Below Lower Bound by >1°C	Below Lower Bound	Between Bounds	Above Upper Bound	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	43.8	49.6	50.4	0.0	0.0
			122	2014	99.2	3.2	11.7	40.5	42.1	57.9	0.0	0.0
	Spawning* (Oct. 15 to Jan. 01)	4.4-12.8	79	2013	98.7	2.1	8.8	10.3	30.8	69.2	0.0	0.0
			79	2014	97.5	3.2	9.1	3.9	28.6	71.4	0.0	0.0
	Incubation* (Oct. 15 to Apr. 01)	4.0-13.0	169	2013	82.2	2.1	8.8	13.7	52.5	47.5	0.0	0.0
			169	2014	45.6	-	-	-	-	-	-	-
	Rearing (Jan. 01 to Dec. 31)	9.0-16.0	365	2013	34.2	-	-	-	-	-	-	-
			365	2014	89.9	2.2	13.7	44.8	50.3	49.7	0.0	0.0
Cutthroat Trout	Spawning (Apr. 01 to Jul. 01)	9.0-12.0	92	2013	0	-	-	-	-	-	-	-
			92	2014	92.4	5.9	12.7	24.7	31.8	60.0	8.2	0.0
	Incubation (May. 01 to Sep. 01)	9.0-12.0	124	2013	4.0	-	-	-	-	-	-	-
			124	2014	99.2	8.5	13.7	0.0	3.3	61.0	35.8	13.8
	Rearing (Jan. 01 to Dec. 31)	7.0-16.0	365	2013	34.2	-	-	-	-	-	-	-
			365	2014	89.9	2.2	13.7	34.5	40.2	59.8	0.0	0.0
Bull Trout	Spawning (Aug. 01 to Dec. 08)	5.0-9.0	130	2013	78.5	2.1	12.5	5.9	13.7	46.1	40.2	26.5
			130	2014	99.2	3.5	13.3	3.9	11.6	30.2	58.1	48.1
	Incubation* (Aug. 01 to Mar. 01)	2.0-6.0	213	2013	83.1	2.1	12.5	0.0	0.0	55.4	44.6	37.9
			213	2014	70.9	3.2	13.3	0.0	0.0	32.5	67.5	66.2
	Rearing (Jan. 01 to Dec. 31)	6.0-14.0	365	2013	34.2	-	-	-	-	-	-	-
			365	2014	89.9	2.2	13.7	30.2	34.5	65.5	0.0	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).
Grey shading indicates the percent complete is less than 50%, comparisons to the provincial guidelines are not included for <50% of data.
* statistics presented are for the calendar year in which the period started, and include data for the following calendar year when period lasts through the winter.

Table 13. Post-construction mean weekly maximum water temperatures for Bull Trout, Cutthroat Trout, and Coho Salmon life stages at ALE-USWQ1.

Species	Life Stage			Year	Percent Complete	MWMxT (°C)			% of MWMxT			
	Periodicity	Optimum Temperature Range (°C)	Duration (days)			Min.	Max.	Below Lower Bound by >1°C	Below Lower Bound	Between Bounds	Above Upper Bound	Above Upper Bound by >1°C
Coho Salmon	Migration (Sep. 01 to Dec. 31)	7.2-15.6	122	2016	30.3	-	-	-	-	-	-	-
			122	2017	57.4	5.2	10.4	11.4	22.9	77.1	0.0	0.0
	Spawning* (Oct. 15 to Jan. 01)	4.4-12.8	79	2016	49.4	-	-	-	-	-	-	-
			79	2017	32.9	-	-	-	-	-	-	-
	Incubation* (Oct. 15 to Apr. 01)	4.0-13.0	169	2016	76.3	4.6	6.3	0.0	0.0	100.0	0.0	0.0
			169	2017	15.4							
	Rearing (Jan. 01 to Dec. 31)	9.0-16.0	365	2016	10.1	-	-	-	-	-	-	-
			365	2017	85.5	3.5	10.5	66.3	87.2	12.8	0.0	0.0
Cutthroat Trout	Spawning (Apr. 01 to Jul. 01)	9.0-12.0	92	2016	0	-	-	-	-	-	-	-
			92	2017	98.9	3.5	8.3	90.1	100.0	0.0	0.0	0.0
	Incubation (May. 01 to Sep. 01)	9.0-12.0	124	2016	0	-	-	-	-	-	-	-
			124	2017	99.2	6.2	10.5	43.1	77.2	22.8	0.0	0.0
	Rearing (Jan. 01 to Dec. 31)	7.0-16.0	365	2016	10.1	-	-	-	-	-	-	-
			365	2017	85.5	3.5	10.5	34.3	47.1	52.9	0.0	0.0
Bull Trout	Spawning (Aug. 01 to Dec. 08)	5.0-9.0	130	2016	10.8	-	-	-	-	-	-	-
			130	2017	77.7	5.2	10.5	0.0	0.0	64.4	35.6	10.9
	Incubation* (Aug. 01 to Mar. 01)	2.0-6.0	213	2016	46.0	-	-	-	-	-	-	-
			213	2017	47.4	-	-	-	-	-	-	-
	Rearing (Jan. 01 to Dec. 31)	6.0-14.0	365	2016	10.1	-	-	-	-	-	-	-
			365	2017	85.5	3.5	10.5	7.1	34.3	65.7	0.0	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).
Grey shading indicates the percent complete is less than 50%, comparisons to the provincial guidelines are not included for <50% of data.
* statistics presented are for the calendar year in which the period started, and include data for the following calendar year when period lasts through the winter.

Table 14. Post-construction mean weekly maximum water temperatures for Bull Trout, Cutthroat Trout, and Coho Salmon life stages at ALE-BDGWQ.

Species	Life Stage			Year	Percent Complete	MWMxT (°C)			% of MWMxT			
	Periodicity	Optimum Temperature Range (°C)	Duration (days)			Min.	Max.	Below Lower Bound by >1°C	Below Lower Bound	Between Bounds	Above Upper Bound	Above Upper Bound by >1°C
Coho Salmon	Migration (Sep. 01 to Dec. 31)	7.2-15.6	122	2016	30.3	-	-	-	-	-	-	-
			122	2017	57.4	3.3	12.9	12.9	22.9	77.1	0.0	0.0
	Spawning* (Oct. 15 to Jan. 01)	4.4-12.8	79	2016	49.4	-	-	-	-	-	-	-
			79	2017	32.9	-	-	-	-	-	-	-
	Incubation* (Oct. 15 to Apr. 01)	4.0-13.0	169	2016	76.3	2.8	5.7	1.6	41.9	58.1	0.0	0.0
			169	2017	15.4	-	-	-	-	-	-	-
	Rearing (Jan. 01 to Dec. 31)	9.0-16.0	365	2016	10.1	-	-	-	-	-	-	-
			365	2017	85.5	2.8	13.0	49.4	56.1	43.9	0.0	0.0
Cutthroat Trout	Spawning (Apr. 01 to Jul. 01)	9.0-12.0	92	2016	0	-	-	-	-	-	-	-
			92	2017	98.9	4.3	12.2	39.6	52.7	42.9	4.4	0.0
	Incubation (May. 01 to Sep. 01)	9.0-12.0	124	2016	0.0	-	-	-	-	-	-	-
			124	2017	99.2	7.4	13.0	4.9	14.6	60.2	25.2	0.8
	Rearing (Jan. 01 to Dec. 31)	7.0-16.0	365	2016	10.1	-	-	-	-	-	-	-
			365	2017	85.5	2.8	13.0	37.8	41.3	58.7	0.0	0.0
Bull Trout	Spawning (Aug. 01 to Dec. 08)	5.0-9.0	130	2016	10.8	-	-	-	-	-	-	-
			130	2017	77.7	3.3	13.0	5.9	7.9	28.7	63.4	53.5
	Incubation* (Aug. 01 to Mar. 01)	2.0-6.0	213	2016	46.0	-	-	-	-	-	-	-
			213	2017	47.4	-	-	-	-	-	-	-
	Rearing (Jan. 01 to Dec. 31)	6.0-14.0	365	2016	10.1	-	-	-	-	-	-	-
			365	2017	85.5	2.8	13.0	34.6	37.8	62.2	0.0	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).
Grey shading indicates the percent complete is less than 50%, comparisons to the provincial guidelines are not included for <50% of data.
* statistics presented are for the calendar year in which the period started, and include data for the following calendar year when period lasts through the winter.

4.3. Fish Habitat

4.3.1. Stability Assessment

4.3.1.1. Reach 1

Reach 1 is located in the downstream reach of the FHEP starting at the Lillooet River Forest Service Road (FSR) (Figure 7). Thirteen riffles were installed in Reach 1 and more than 120 pieces of large woody debris with total creation of 1,387 m^2 of enhanced fish habitat. In early November 2016, two months following Project completion, a significant rain-on-snow event occurred, resulting in a 1-in-20 year flood event on the Upper Lillooet River (McCoy, pers. comm. 2016) (Figure 1b). As a result, there were some notable changes in some of the channel structures in Alena Creek, though none affected the overall quality or usability of the constructed habitat. A comparison of photos is available in Appendix F; however, a selection of comparison photos is presented below.

Figure 7 shows a plan view of the enhancements conducted in Reach 1, with Figure 8 and Figure 10 showing a comparison of the furthest downstream cross-section (ALE-XS1). The stream channel at this location has widened slightly with wetted access to the constructed floodplain on river left, as intended. Just upstream of this cross-section the river bends to the right and a series of root wads were installed along the outside left bank (Figure 10). Following the high water in November 2016, the bank at 0+185 has eroded up to 0.85 cm back from its original configuration (Figure 11). Currently, the root wads and woody debris are stable; however, this bank should be monitored over the duration of the LTMP term to note any changes. There were no other significant changes along the other transects in Reach 1 (ALE-XS2, ALE-XS3 and ALE-XS4; Figure 7).

Figure 7. Alena Creek Reach 1, UAV imagery from the as-built Survey (West *et al.* 2017).

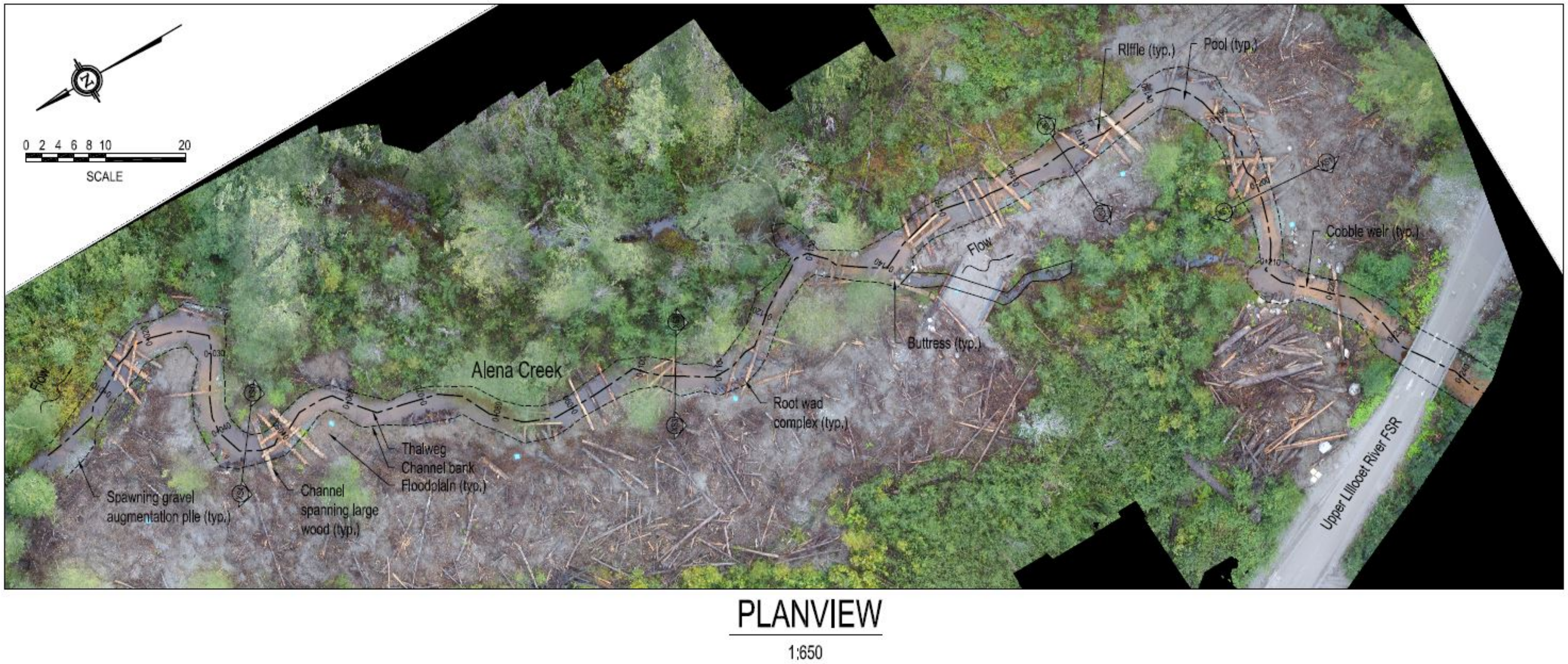


Figure 8. Looking RR-RL at ALE-XS1 on Sep 19, 2016.

Figure 9. Looking RL-RR at ALE-XS1 on Nov 10, 2017.

Figure 10. Looking upstream at bend at installed rootwads on Oct 26, 2016.

Figure 11. Looking upstream at bend at installed rootwads where bank has eroded on Nov 10, 2017.

4.3.1.2. Reach 3

A total of 668 m^2 of new instream habitat and 1,139 m^2 of floodplain was created in the upstream reach, Reach 3 (Figure 12). Twelve cobble riffles were installed with over 100 pieces of large woody debris. The flood event in 2016 had a greater impact to the habitat features in Reach 3 than Reach 1; however, as in Reach 1, it has not diminished the overall function or usability of the constructed habitat. Downcutting is evident at ALE-XS5 (Figure 13, Figure 14). This is because the further downstream riffle crest at 0+185 has been eroded along the river right bank (Figure 15, Figure 16). The gradient downstream of this constructed riffle crest to the confluence of the existing habitat was the greatest of all the constructed riffles. Further upstream downcutting is prevented by the stable riffle crest constructed at 0+165.

At transect ALE-XS6, the channel has remained unchanged from construction. However, just upstream of the transect, a mid-channel bar has formed as the result of erosion along the right bank (Figure 17, Figure 18). The bank erosion is caused by a new storm water channel that flows into Alena Creek from the Lillooet FSR.

At transect ALE-XS7, the cross-sectional geometry has changed significantly following the high flow in 2016. Immediately following construction, the bankfull width was measured at 5.3 m and the wetted width at 4.4m. The current bankfull and wetted width are greater, respectively, at 6.2 m and 5.7 m. The widening of the channel is caused by a deposition of gravel just upstream of the transect (Figure 19). The deposition is caused by a small breach in the riffle crest along the left bank at 0+0.050 (Figure 20).

Beaver activity has created significant damming upstream of both Reach 1 and Reach 3. This activity has not affected either of the constructed reaches to date; however, the backwatered areas and new channel formation has the potential to affect both constructed reaches in the future. For example, immediately upstream of ALE-XS8, a new side channel has formed that has the potential to create erosion at this site if it becomes more established.

Figure 12. Alena Creek Reach 3, UAV imagery from the as-built Survey (West *et al.* 2017).

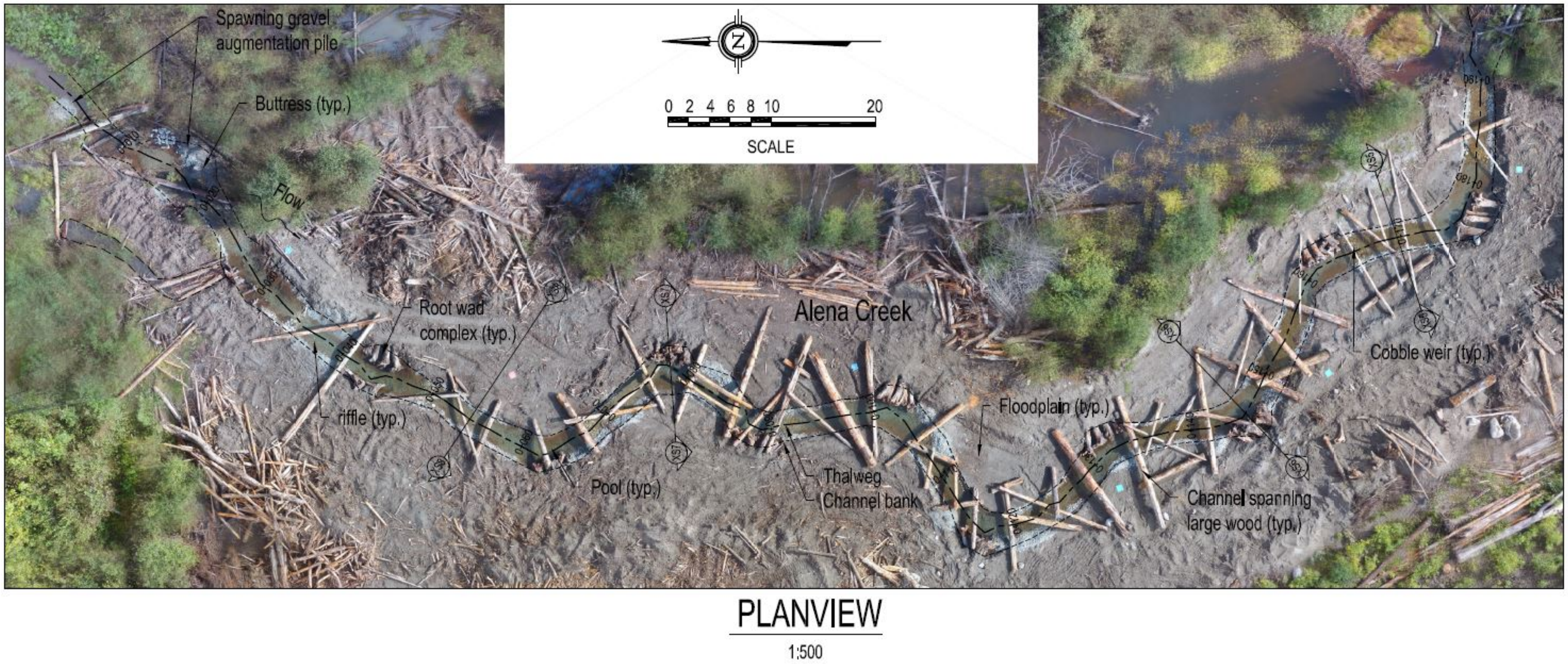


Figure 13. Looking RL-RR at ALE-XS5 on Sep 19, 2016. Note wetted width at yellow arrow.

Figure 14. Looking RL-RR at ALE-XS5 on Nov 10, 2017. Note wetted width at yellow arrow.

Figure 15. Looking upstream at riffle crest (0+185, Reach 3) on Sep 16, 2016.

Figure 16. Looking upstream at riffle crest (0+185, Reach 3) at right bank erosion on Nov 10, 2017.

Figure 17. Looking upstream of ALE-XS6 at the formation of a mid-channel bar on Nov 10, 2017.

Figure 18. Looking upstream of ALE-XS6 at the formation of a mid-channel bar on Nov 10, 2017.

Figure 19. Looking RR-RL at ALE-XS7 on Nov 10, 2017. Note upstream mid-channel bar formation.

Figure 20. Looking upstream at riffle crest at 0+050 at breach along the RL bank on Nov 10, 2017.

4.3.2. Fish Habitat Assessment

The FHAP was conducted on October 3, 2017. A total of 1,344 m of habitat was surveyed, consisting of 1,312 m of primary and 32 m of secondary habitat. The mesohabitat units identified in the FHAP were digitized and a detailed map of the surveyed area was created (Map 2). FHAP information collected for the Alena Creek mainstem (primary units) and secondary units are provided below. The one secondary unit (side channel) that was directly associated with the construction activities was surveyed in full. All other off-channel habitat was assessed for access only. A summary table of the FHAP data is provided in Appendix G and photographs for individual units are presented in Appendix H.

The surveyed section of the Alena Creek mainstem consisted of 24 primary habitat units, with a total wetted area of 10,361 m^2 and a bankfull area of 13,012 m^2 (Table 15, Map 2). The average gradient of the primary units was 0.6% (SD = 0.5). Average wetted width was 7.2 m (SD = 8.3) and average bankfull width was 9.0 m (SD = 10.1).

The mainstem of Alena Creek is dominated by pool habitat (72%) followed by glide (18%) and riffle (6%) (Table 15). Numerically, total wetted area of different habitat types follows the same order as habitat units; pool habitat has a total wetted area of 7,505 m^2 followed by glide habitat with a total of 2,227 m^2 of total wetted area (Table 15). One tertiary pool with a depth of 0.7 m was identified within the primary channel (Table 16).

Overall, sands and fines were the dominant substrate in the mainstem, with 58% of mainstem habitat units having sand and fines as the dominant substrate (Table 17). Gravel was the sub-dominant substrate in 44% of habitat units. Of the gravel available, there were 48 total patches of functional spawning gravel and 19 patches of non-functional (i.e., dry) spawning gravel (Table 18). The majority of the area of functional spawning gravel (78%) was characterized as suitable for both resident and anadromous fish. Similarly, the majority of functional patches (88%) were suitable for both resident and anadromous fish. If all observed spawning patches were wetted, there would be 1,049 m^2 of spawning habitat available.

There was a relatively high amount of cover available for fish in the Alena Creek mainstem, representing 51.8% of the total area (Table 17). The dominant cover type for fish was large woody debris (LWD) (19.4%), followed by other forms of available cover including overhanging vegetation, instream vegetation and deep pools (Table 17). LWD was present in all 24 habitat units surveyed in the mainstem (Table 19). Of the 315 pieces of LWD that were counted during the survey, all were characterized as functional except one piece, with most of them being >50 cm in diameter.

Riparian vegetation along Alena Creek is a mix of deciduous pole saplings and shrubs (Table 20). Canopy closure was 0 to 20% in 67% of habitat units, and 20 to 40% in 21% of habitat units (Table 21).

A total of nine off-channel habitats to the Alena Creek mainstem were observed. The majority of these habitat units (8 of 9, or 89%) are side channels that are accessible at most flows (5 of 9, or

56%) (Table 22). A further two side channels, and a wetland, are accessible at high flows only. The major side-channel affected by FHEP construction was surveyed in full as secondary habitat to the Alena Creek mainstem (Table 23). This channel has a total wetted area of 45 m^2 and a bankfull area of 48 m^2. The average gradient of this habitat unit was 0.5. The average wetted width was 2.8 m and the average bankfull width was 3.0 m. This side channel contained only one glide habitat unit (Table 23). Sand/fines was the dominant substrate type and gravel was the sub-dominant substrate type (Table 24). Cover was present in 10% of the secondary habitat unit (Table 24) and was primarily provided by LWD, all of which was classified as functional (Table 25).

A comparison of the FHAP conducted in Alena Creek during baseline studies in 2014 (Harwood *et al.* 2016) and Year 1 monitoring (conducted in 2017) showed two principal differences. The first was a change in the dominant habitat type from shallow glide habitat (mean ± SD depth of 0.3 m ± 0.2 m) to deeper (0.8 m ± 0.5 m) pool habitat (0.8 m ± 0.5 m). This change was a result of the enhancement work in Reaches 1 and 3 along with beaver activity in Reaches 2 and 4. The second major difference was a significant increase in the amount of functional spawning gravel available (an increase from 205.8 m^2 in 2014 to 991.0 m^2 in 2017). This increase in spawning gravel was directly attributable to the enhancement work.

Table 15. Summary of fish habitat assessment results for Alena Creek primary units, October 3, 2017.

Habitat Type	Number of Units	% of Total Habitat	Total Wetted Area (m^2)	Total Bankfull Area (m^2)	Mean Wetted Area (m^2)	Wetted Width (m)		Bankfull Width (m)		Wetted Depth (m)		Bankfull Depth (m)		Total Length (m)	Individual Length (m)		Gradient (%)		Weighted Gradient (%)
						Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		Mean	SD[1]	Mean	SD[1]	
Pool	8	72%	7,505	9,438	938	16.1	9.2	19.8	11.4	0.8	0.5	1.4	0.8	422	53	43	0.2	0.2	0.3
Riffle	6	6%	641	960	107	2.1	0.8	3.0	1.2	0.2	0.0	0.5	0.1	317	53	55	1.2	0.3	1.3
Run	3	3%	307	387	102	3.3	0.5	4.1	0.7	0.2	0.1	0.4	0.1	88	29	25	1.2	0.3	1.1
Glide	7	18%	1,908	2,227	273	3.0	1.7	3.7	1.7	0.4	0.3	1.0	0.4	485	69	65	0.4	0.2	0.3
Total	24	100%	10,361	13,012	432	7.2	8.3	9.0	10.1	0.5	0.4	0.9	0.6	1,312	55	50	0.6	0.5	0.6

[1] There are no standard deviation when habitat data was collected for only one unit

Table 16. Tertiary pool in the Alena Creek mainstem identified during FHAP, October 3, 2017.

Category	Number of Units	Length (m)		Width (m)		Water Depth (m)		Area (m^2)		Total Area (m^2)	% of Wetted Area
		Average	SD[1]	Average	SD[1]	Average	SD[1]	Average	SD[1]		
Primary	1	8.0	-	3.5	-	0.7	-	28.0	-	28.0	0.3

[1] There are no standard deviation when habitat data was collected for only one unit

Table 17. Summary of substrate and cover available in the mainstem habitat units of Alena Creek, October 3, 2017.

Substrate		Cover							
Dominant	Sub-dominant	% Boulder	% Deep Pool	% LWD	%SWD	% Undercut Banks	% Instream Vegetation	% Overhanging Vegetation	% Total
Sands/Fines (58%)	Gravel (44%)	0.0	10.0	19.4	0.0	0.7	10.3	11.3	51.8

Substrate percentages represent the percentage of habitat units in which the substrate type was dominant or sub-dominant.

Cover percentages represent percentages of total habitat area.

Table 18. Summary of the gravel habitat in the Alena Creek mainstem, October 3, 2017.

Spawner Type	Functional[a]				Non-functional[a]			
	# of Patches	Total Area (m^2)	Mean Area (m^2)	Standard Deviation (m^2)[b]	# of Patches	Total Area (m^2)	Mean Area (m^2)	Standard Deviation (m^2)[b]
Resident (R)	19	214.6	11.3	34.3	7	6.8	1.0	0.4
Both (AR)	29	776.4	26.8	51.1	12	50.8	4.2	4.6
Total	***48***	***991.0***	***20.6***	***45.4***	***19***	***57.6***	***3.0***	***4.0***

[a] Functional = wetted at time of survey, Non-functional = dry at time of survey.

[b] There are no standard deviation values when less than two patches were present.

AR = Suitable for both anadromous salmon and resident trout and char (10-75 mm, at least 1.5 m^2).

R = Suitable for resident trout and char (10-75 mm, at least 0.1 m^2).

A = Suitable for anadromous salmon (10-150 mm, at least 1.5 m^2).

Table 19. Summary of the LWD characteristics in Alena Creek mainstem, October 3, 2017.

Reach	Habitat Units Total	Habitat Units with LWD	Total LWD Tally	Functional LWD (Tally)			Non-Functional LWD (Tally)
				10-20 cm Diameter	20-50 cm Diameter	>50 cm Diameter	
Total	24	24	315	112	87	115	1

Table 20. Summary of the riparian characteristics for Alena Creek mainstem, October 3, 2017.

Riparian Vegetation	Stage					Total
	Initial	Shrub	Pole Saplings	Young Forest	Mature Forest	
Mixed Conifer-Deciduous	0	1	0	0	0	*1*
Deciduous	0	6	14	0	0	*20*
Shrub/Herb	0	3	0	0	0	*3*
Total	*0*	*10*	*14*	*0*	*0*	*24*

Table 21. Canopy closure data for Alena Creek mainstem, October 3, 2017.

Reach	Canopy Closure				
	0 to 20 %	20 to 40 %	40 to 70 %	70 to 90 %	> 90%
Total	16	5	3	0	0

Table 22. Summary of Off Channel Habitat associated with the Alena Creek Mainstem, October 3, 2017.

Type	Access	n	Length (m)	
			Average[1]	S.D.[2]
Side Channel	Accessible at Most Flows	5	40	n/a
	No Access	1	nc	-
	Accessible at High Flows Only	2	20	n/a
Wetland	Accessible at High Flows Only	1	0	-

[1] nc = not collected

[2] There are no standard deviation when length data was collected for only one unit

Table 23. Fish habitat assessment results summary for Alena Creek secondary units, October 3, 2017.

Habitat Type	Number of Units	% of Total Habitat	Total Wetted Area (m^2)	Total Bankfull Area (m^2)	Mean Wetted Area (m^2)	Wetted Width (m)		Bankfull Width (m)		Wetted Depth (m)		Bankfull Depth (m)		Total Length (m)	Individual Length		Gradient (%)		Weighted Gradient (%)
						Mean	SD[1]	Mean	SD[1]	Mean	SD[1]	Mean	SD[1]		Mean	SD[1]	Mean	SD[1]	
Glide	1	100%	45	48	45	2.8	n/a	3.0	n/a	0.1	n/a	0.5	n/a	16	16	n/a	0.5	n/a	0.5
Total	1	100%	45	48	45	2.8	n/a	3.0	n/a	0.1	n/a	0.5	n/a	16	16	n/a	0.5	n/a	0.5

[1] There are no standard deviation when habitat data was collected for only one unit

Table 24. Substrate and cover summary for Alena Creek secondary units, October 3, 2017

Substrate		Cover							
Dominant	Sub-dominant	% Boulder	% Deep Pool	% LWD	%SWD	% Undercut Banks	% Instream Vegetation	% Overhanging Vegetation	% Total
Sands/Fines (100%)	Gravel (100%)	0.0	0.0	10.0	0.0	0.0	0.0	0.0	10.0

Substrate percentages represent the percentage of habitat units in which the substrate type was dominant or sub-dominant.

Cover percentages represent percentages of total habitat area.

Table 25. Summary of the LWD characteristics in Alena Creek secondary units, October 3, 2017

Reach	Habitat Units Total	Habitat Units with LWD	Total LWD Tally	Functional LWD (Tally)			Non-Functional LWD (Tally)
				10-20 cm Diameter	20-50 cm Diameter	>50 cm Diameter	
Total	1	1	4	2	0	2	0

4.4. Fish Community

4.4.1. Adult Spawner Abundance

Observations of Coho Salmon during fall spawner surveys were made in 2016 (Table 26) and 2017 (Table 27). In both years, the peak counts of adult spawning Coho Salmon (Figure 21) were greater than 100 individuals, with the peak count in 2017 being the same as that observed in 2011 during the baseline period (Table 27). In contrast, the peak count in 2016 was 174, which represents a notable increase in the number of spawners compared to the two baseline years and 2017. A comparison of the 2016 and 2017 results also highlights the variability in run timing between years, with the peak count recorded on November 14, 2016 and similarly high numbers two weeks later (November 27), whereas the peak count in 2017 was observed on November 26. Although surveys are not conducted at a frequency to allow total spawner abundance to be compared among years, and peak counts may be influenced by survey timing and spawner residence time and predation, the counts nevertheless provide an indication of use and demonstrate that Alena Creek supports equivalent or greater use by Coho spawners relative to pre-enhancement.

Table 26. Number of Coho Salmon observed during fall spawner surveys in 2016.

Stream	Sampling Event 1 (Nov 14, 2016)	Sampling Event 2 (Nov 27, 2016)	Sampling Event 3 (Dec 9, 2016)	2010 Peak Count	2011 Peak Count
Alena Creek	174	168	3	127	110

Table 27. Number of Coho Salmon observed during fall spawner surveys in 2017.

Stream	Sampling Event 1 (Nov 10, 2017)	Sampling Event 2 (Nov 26, 2017)	Sampling Event 3 (Dec 05, 2017)	2010 Peak Count	2011 Peak Count	2016 Peak Count
Alena Creek	3	110	76	127	110	174

Figure 21. **Spawning Coho Salmon observed spawning in enhanced habitat on November 14, 2016.**

4.4.2. Juvenile Abundance

In September 2017, 35 minnow traps were set overnight in riffle, pool and glide habitat ranging in depth from 0.23 to 1.5 m (Table 28). Raw data tables and representative photos of the minnow trap sites are presented in Appendix I. A total of 150 fish were captured during minnow trap sampling consisting of 142 Coho Salmon, seven Cutthroat Trout and one Bull Trout. Due to the high number of Coho Salmon captured, in some cases only a portion of the captured fish were measured (Table 29).

The distribution of species and age classes throughout Alena Creek is evaluated by breaking the sampled portion of Alena Creek into Reach 1 (enhanced, ALE-MT01 and 02), Reach 2 (ALE-MT03, 04 and 06), Reach 3 (enhanced), and Reach 4 (ALE-MT05) sections (Map 4).

Table 28. Summary of minnow trapping habitat characteristics and catch in Alena Creek on September 27, 2017.

Site	Enhancement Status	# of Traps	Total Soak Time (hrs)	Mesh Size (mm)	Habitat Type	Cover Types	Trap Depth Range (m)	Avg Water Temp (ºC)	Total Catch		
									BT	CO	CT
ALE-MT01	Enhanced	5	117.3	3-6	Riffle	BO	0.23 - 0.41	8.5	0	6	1
ALE-MT02	Enhanced	5	118.5	6	Riffle	LWD	0.23 - 0.46	8.5	0	15	0
ALE-MT03	Unenhanced	5	116.4	3-6	Glide	LWD, OV	0.38 - 0.73	8.5	0	69	0
ALE-MT04	Unenhanced	5	126.0	3-6	Riffle	LWD	0.25 - 0.39	8.5	0	18	2
ALE-MT05	Unenhanced	5	126.8	3-6	Glide	DP, LWD, OV, SWD	0.30 - 0.83	8.5	0	13	2
ALE-MT06	Unenhanced	10	282.0	3-6	Pool	DP, LWD, OV, SWD	0.43 - 1.50	9.0	1	21	2
								Total	**1**	**142**	**7**
								Average	**0.2**	**23.7**	**1.2**

Table 29. Catch and processed fish counts for 2017 sampling.

Site	Date	Enhancement Status	# of Coho Salmon Captured	# of Coho Salmon Measured
ALE-MT01	27-Sep-17	Enhanced	6	6
ALE-MT02	27-Sep-17	Enhanced	15	15
ALE-MT03	27-Sep-17	Unenhanced	69	30
ALE-MT04	27-Sep-17	Unenhanced	18	18
ALE-MT05	27-Sep-17	Unenhanced	13	12
ALE-MT06	27-Sep-17	Unenhanced	21	21
	Total		**142**	**102**

4.4.2.1. Cutthroat Trout

Seven Cutthroat Trout, ranging in length from 90 to 140 mm in length, were captured during 2017 sampling. Raw data tables are presented in Appendix I. Scale samples were collected and analysed from all Cutthroat Trout. The length-at-age data from the scale analyses are presented Figure 22. Based on a review of the aging data and length-frequency histogram, discrete fork length ranges were defined for each age class (Table 30). Summary statistics of fish length, weight, and condition factor are presented for each age class in Table 31. The length-frequency histogram and length-weight regression for the fish captured in 2017 sampling are presented in in Figure 23 and Figure 24, respectively. Summary statistics of fish length, weight, and condition factor are presented for these age classes in Table 31.

Cutthroat Trout Fry (0+)

No Cutthroat Trout fry (0+) were captured at any of the sampling sites in 2017 (Table 32).

Cutthroat Trout Parr (1+)

Cutthroat Trout parr (1+) were captured at ALE-MT01 in Reach 1 (enhanced), ALE-MT04 and 06 in Reach 2 (unenhanced), and ALE-MT05 in Reach 4 (unenhanced) (Table 32). A total of five Cutthroat Trout 1+ parr were captured, with an average CPUE of 0.6 fish/100 hrs. CPUE ranged from 0.0 to 1.6 fish/100 hrs. Based on the CPUE data, Cutthroat Trout parr were distributed mostly in the unenhanced Reaches 2 and 4 (Table 32), which is consistent with the distribution observed during baseline sampling (Section 4.4.2.4).

Cutthroat Trout Parr (2+)

Only two Cutthroat Trout 2+ parr were captured in 2017, resulting in an average CPUE of 0.2 fish/100 hrs (Table 32). The 2+ parr were captured at ALE-MT04 and ALE-MT06 in the unenhanced Reach 2.

Figure 22. Fork length versus age for Cutthroat Trout captured during the 2017 abundance sampling in Alena Creek.

Table 30. **Age breaks for Cutthroat Trout captured during the 2017 sampling in Alena Creek.**

Age Class	Fork Length Range (mm)
Fry (0+)	-
Parr (1+)	90-120
Parr (2+)	131-140

Figure 23. **Fork length frequency for Cutthroat Trout captured in Alena Creek, during the 2017 sampling in Alena Creek.**

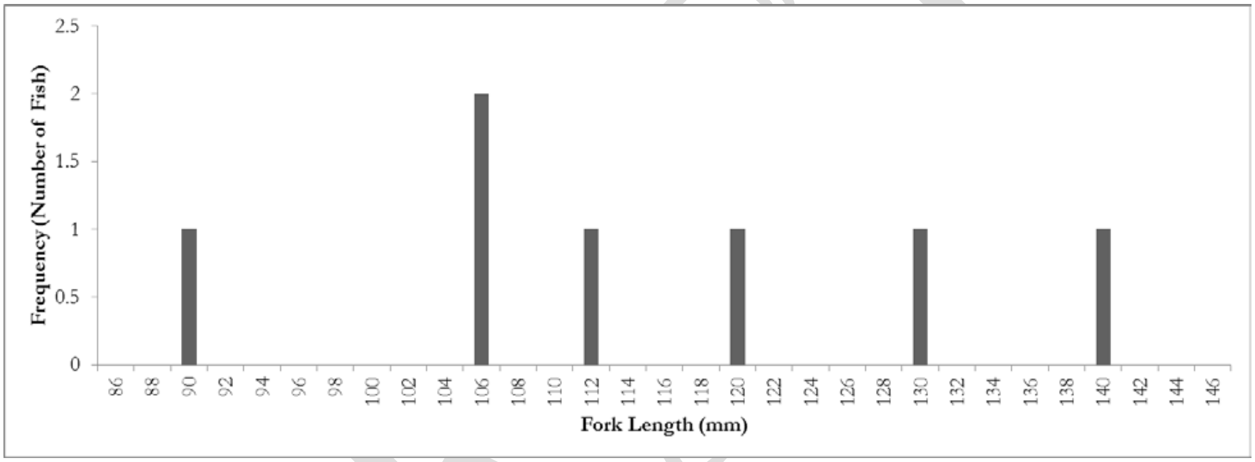


Figure 24. **Length-weight regression Cutthroat Trout captured in Alena Creek, during the 2017 sampling in Alena Creek.**

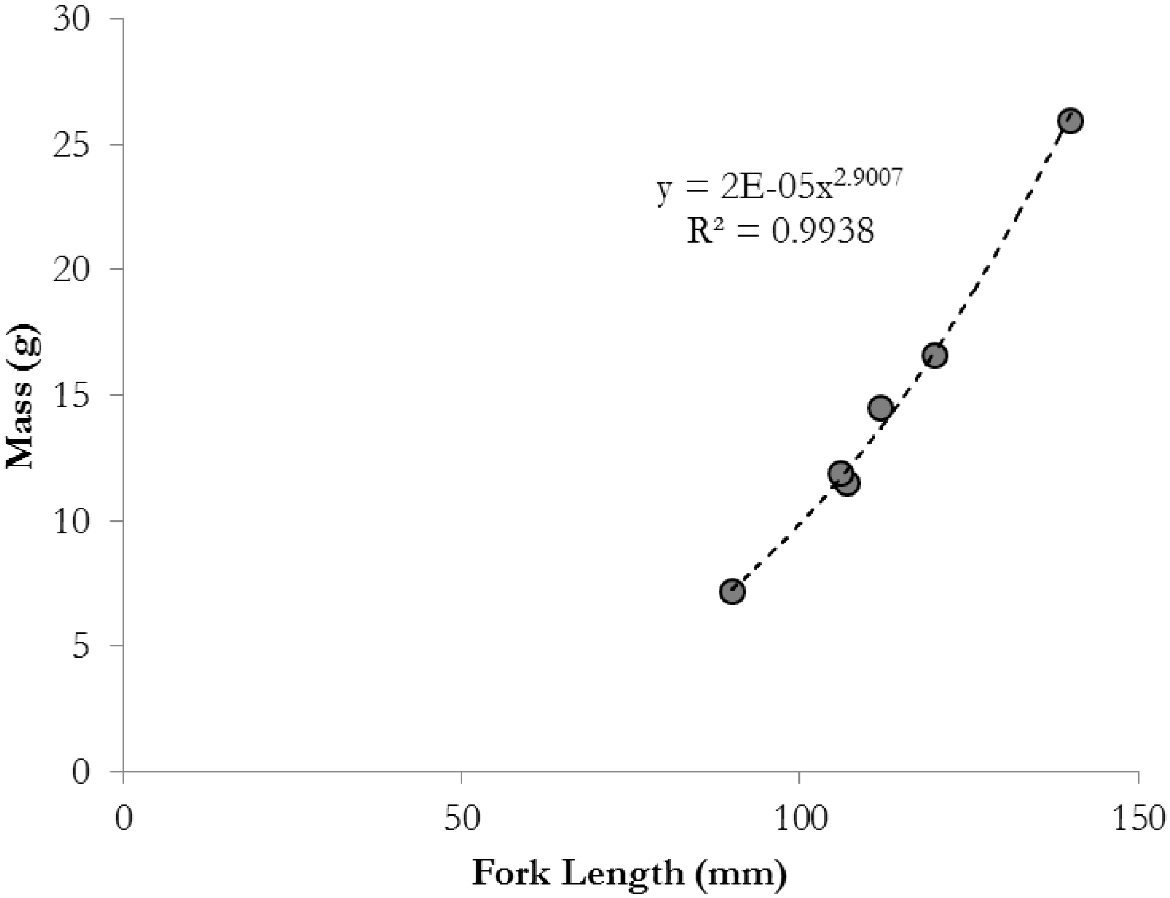


Table 31. **Summary of fork length, weight and condition for Cutthroat Trout captured during the 2017 sampling in Alena Creek.**

Age Class	Fork Length (mm)				Weight (g)				Condition Factor (K)			
	n	Average	Min	Max	n	Average	Min	Max	n	Average	Min	Max
Fry (0+)	0	-	-	-	0	-	-	-	0	-	-	-
Parr (1+)	5	107	90	120	5	12.3	7.2	16.6	5	0.98	0.94	1.03
Parr (2+)	1	140	140	140	1	25.9	25.9	25.9	1	0.94	0.94	0.94
All	6	113	90	140	6	14.6	7.2	25.9	6	0.98	0.94	1.03

Table 32. Catch and CPUE for Cutthroat Trout during minnow trapping in 2017.

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	27-Sep-17	Enhanced	5	117.3	0	1	0	1	0.0	0.9	0.0	0.9
ALE-MT02	27-Sep-17	Enhanced	5	118.5	0	0	0	0	0.0	0.0	0.0	0.0
ALE-MT03	27-Sep-17	Unenhanced	5	116.4	0	0	0	0	0.0	0.0	0.0	0.0
ALE-MT04	27-Sep-17	Unenhanced	5	126.0	0	1	1	2	0.0	0.8	0.8	1.6
ALE-MT05	27-Sep-17	Unenhanced	5	126.8	0	2	0	2	0.0	1.6	0.0	1.6
ALE-MT06	27-Sep-17	Unenhanced	10	282.0	0	1	1	2	0.0	0.4	0.4	0.7
		Total	35	**886.9**	**0.0**	**5.0**	**2.0**	**7.0**	**0.0**	**3.6**	**1.1**	**4.7**
		Average	n/a	**147.8**	**0.0**	**0.8**	**0.3**	**1.2**	**0.0**	**0.6**	**0.2**	**0.8**
		SD	n/a	**65.9**	**0.0**	**0.8**	**0.5**	**1.0**	**0.0**	**0.6**	**0.3**	**0.7**

4.4.2.2. Coho Salmon

A total of 142 Coho Salmon, ranging in length from 42 to 104 mm were captured minnow trapping in Alena Creek in September 2017. Raw data tables are presented in Appendix I. The length-at-age data from the scale analyses are presented in Figure 25. Based on a review of the aging data and length-frequency histogram, discrete fork length ranges were defined for each age class (Table 33). The length-frequency histogram for Coho Salmon captured during 2017 sampling is presented in Figure 26; the length-weight regression is presented in Figure 27. Summary statistics of fish length, weight, and condition factor are presented for these age classes in Table 34.

Coho Salmon Fry (0+)

Coho Salmon fry (0+) were captured at all sampling sites in 2017 and are distributed throughout the sampled portion of Alena Creek (Table 35). Coho Salmon fry were most abundant at ALE-MT03 in the unenhanced Reach 2. In total, 140 Coho Salmon fry were captured, with an average CPUE of 17.9 fish/100 hrs of minnow trapping. Coho Salmon fry CPUE ranged from 5.1 fish/100 hrs (at ALE-MT01) to 58.4 fish/100 hrs (at ALE-MT03).

Coho Salmon Parr (1+)

Coho Salmon 1+ parr were only captured at ALE-MT03 and ALE-MT05 in Reaches 2 and 4, respectively (Table 35). Average CPUE at these two sites was 1.0 fish/100 hrs of minnow trapping.

Figure 25. Fork length versus age for Coho Salmon captured during the 2017 abundance sampling in Alena Creek.

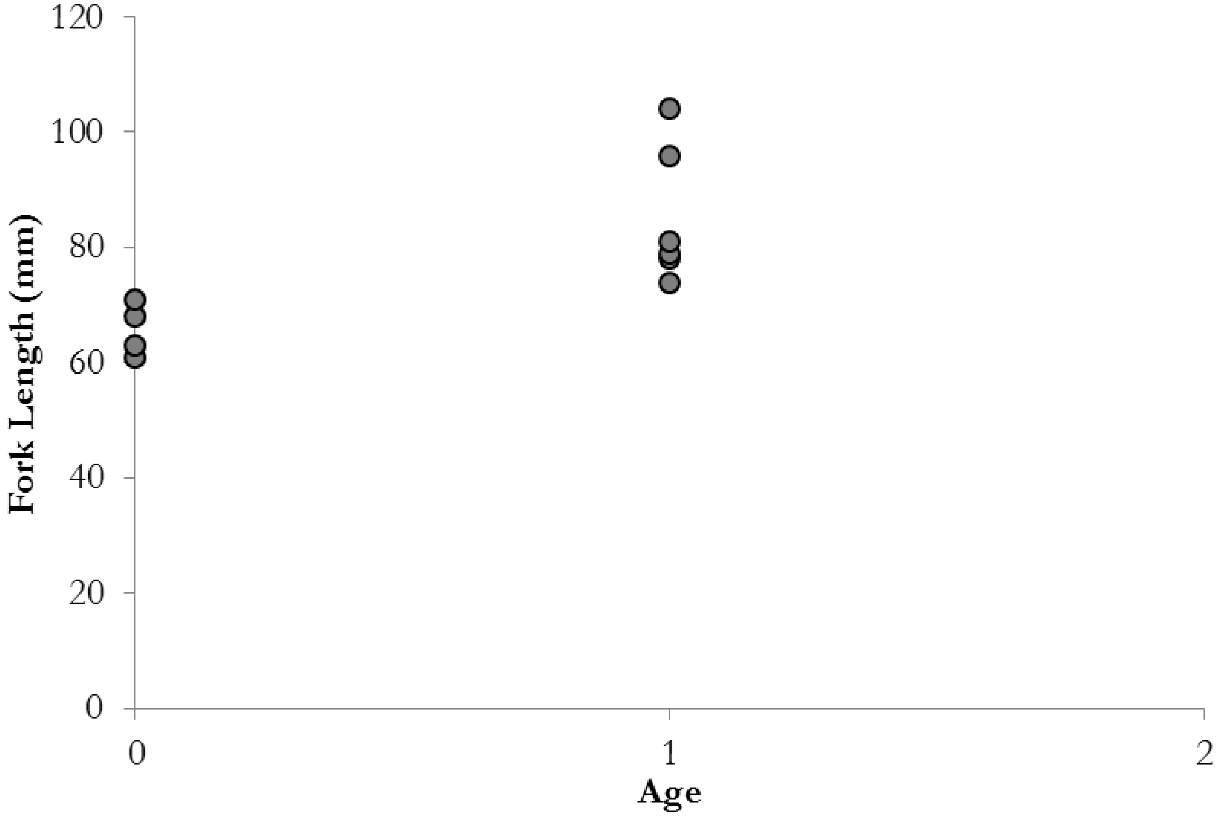


Table 33. Age breaks for Coho Salmon captured during the 2017 abundance sampling in Alena Creek.

Age Class	Fork Length Range (mm)
Fry (0+)	42-87
Parr (1+)	96-104

Figure 26. Fork length frequency for Coho Salmon captured in Alena Creek during 2017 sampling.

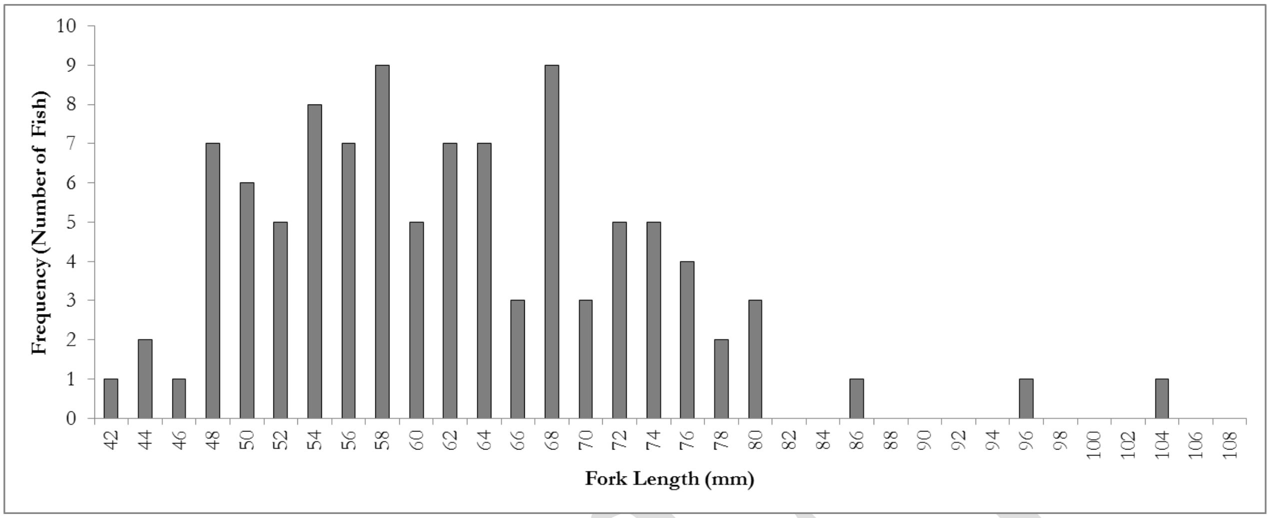


Figure 27. Length-weight regression for Coho Salmon captured in Alena Creek in 2017.

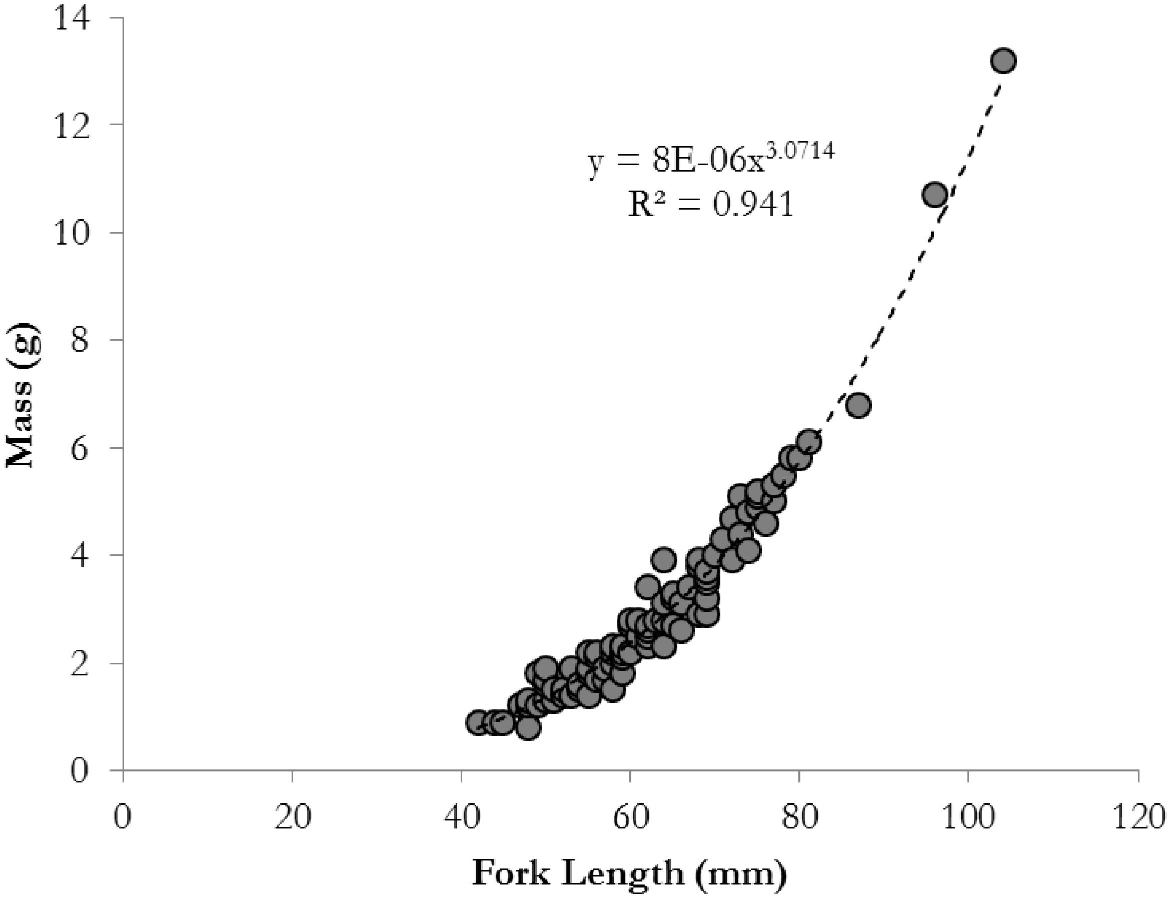


Table 34. Summary of fork length, weight and condition for Coho Salmon captured during the 2017 sampling in Alena Creek.

Age Class	Fork Length (mm)				Weight (g)				Condition Factor (K)			
	n	Average	Min	Max	n	Average	Min	Max	n	Average	Min	Max
Fry (0+)	99	62	42	87	99	2.8	0.8	6.8	99	1.11	0.72	1.53
Parr (1+)	2	100	96	104	2	12.0	10.7	13.2	2	1.19	1.17	1.21
All	101	63	42	104	101	3.0	0.8	13.2	101	1.11	0.72	1.53

Table 35. Catch and CPUE for Coho Salmon during minnow trapping in 2017.

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+	All	0+	1+	All
ALE-MT01	27-Sep-17	Enhanced	5	117.3	6	0	6	5.1	0.0	5.1
ALE-MT02	27-Sep-17	Enhanced	5	118.5	15	0	15	12.7	0.0	12.7
ALE-MT03	27-Sep-17	Unenhanced	5	116.4	68	1	69	58.4	0.9	59.3
ALE-MT04	27-Sep-17	Unenhanced	5	126.0	18	0	18	14.3	0.0	14.3
ALE-MT05	27-Sep-17	Unenhanced	5	126.8	12	1	13	9.5	0.8	10.3
ALE-MT06	27-Sep-17	Unenhanced	10	282.0	21	0	21	7.4	0.0	7.4
			Total	**886.9**	**140.0**	**2.0**	**142.0**	**107.4**	**1.6**	**109.1**
			Average	**147.8**	**23.3**	**0.3**	**23.7**	**17.9**	**0.3**	**18.2**
			SD	**65.9**	**22.5**	**0.5**	**22.8**	**20.1**	**0.4**	**20.4**

4.4.2.3. Bull Trout

A single Bull Trout with a fork length of 130 mm was captured at ALE-MT06 in the unenhanced Reach 2 during 2017 sampling.

4.4.2.4. Comparison between Years

Cutthroat Trout

In 2017 sampling, seven Cutthroat Trout were captured minnow trapping, which represents a decrease compared to 2013 (27 Cutthroat captured during two sampling events: 14 on September 21, and 13 on September 22) and 2014 (16 Cutthroat captured). In 2017, most Cutthroat Trout were captured in Reach 2 (ALE-MT03, 04 and 06) and Reach 4 (ALE-MT05), which is similar to 2013 and 2014 sampling results (Figure 28). Cutthroat Trout CPUE in the enhanced Reach 1 (ALE-MT01 and 02) was lower in 2017 compared to pre-enhancement in 2013 and 2014.

During 2017 sampling, the average CPUE across all sites was 0.8 fish/100 hrs of minnow trapping (± 0.7 SD) (Table 32, Figure 29), which was lower than the CPUE values for 2013 (1.7 fish/100 hrs minnow trapping (± 1.1 SD) on September 21, and 1.9 fish/100 hrs minnow trapping (± 1.0 SD) on September 22) and 2014 (7.4 fish/100 hrs minnow trapping (± 7.0 SD)) (Harwood *et al* 2016). However, the 2014 CPUE results are biased high by the short daytime sets and the likelihood that catchability is not constant throughout the trap's soak time, with a high initial catch rate that diminishes over time (Harwood *et al*. 2016).

In all sampling years, the most abundant age class of Cutthroat Trout captured was 1+. No Cutthroat Trout fry were captured in 2017, which is fairly consistent with baseline sampling when only three Cutthroat fry were captured during two sampling events in September 2013, and only one fry was captured in October 2014. The lack of Cutthroat Trout fry captured during sampling is likely a result of the timing of emergence and the size of fry in late September / early October.

In 2017, the combined condition factor for all age classes of Cutthroat Trout captured was 1.0 (Table 31), whereas average Cutthroat Trout condition was 1.1 in 2013 and 1.2 in 2014 (Harwood *et al*. 2016).

Coho Salmon

In 2017 sampling, 142 Coho Salmon were captured by minnow trapping, which represents a decrease compared to 2013 (485 Coho captured during two sampling events: 291 on September 21, and 194 on September 22) and 2014 (336 Coho captured) (Harwood *et al* 2016). In 2017, the highest Coho Salmon catch was observed in Reach 2, specifically at ALE-MT03, whereas in 2013 most fish were captured at ALE-MT06 (Figure 30). In 2014, Coho Salmon CPUE was highest at ALE-MT03, 04 and 06, although CPUE at ALE-MT03 and 04 was biased high in 2014 due to the need to employ short daytime sets due to bear activity (Harwood *et al* 2016). Within the enhanced Reach 1, Coho CPUE in 2017 was similar to that in 2013 and 2014 at ALE-MT02, but lower than baseline CPUE at ALE-MT01 (Figure 30). The distribution of Coho Salmon in 2017 may have been affected by beaver activity in Reaches 2 and 4, as discussed in more detail in the following section.

During 2017 sampling, the average CPUE across all sites was 18.2 fish/100 hrs of minnow trapping (± 20.4 SD) (Table 35, Figure 31), which was lower than the CPUE values for 2013 (24.2 fish/100 hrs minnow trapping (± 16.9 SD) on September 21, and 22.5 fish/100 hrs minnow trapping (± 19.7 SD) on September 22) and 2014 (62.6 fish/100 hrs minnow trapping (± 34.0 SD)) (Harwood *et al* 2016). However, the 2014 CPUE results are biased high by the short daytime sets and the likelihood that catchability is not constant throughout the trap's soak time, with a high initial catch rate that diminishes over time (Harwood *et al*. 2016). The 2017 CPUE was highly variable, with the largest reduction compared to baseline sampling observed at ALE-MT06 at the upstream end of Reach 2.

In all sampling years, the most abundant age class of Coho Salmon captured was 0+. In 2017, the combined condition factor for all age classes of Coho Salmon captured was 1.1, whereas average Coho Salmon condition was 1.2 in 2013 and 1.0 in 2014.

Changes in Site Conditions

The reduced catch and CPUE for both Cutthroat Trout and Coho Salmon during year 1 monitoring may be the result of altered habitat conditions caused by beaver activity both at the minnow trap locations, which were selected during baseline studies, as well as in upstream locations. There was evidence of beaver activity along Alena Creek during baseline studies; however, all beaver dams appeared abandoned and dilapidated with no new activity observed.

In 2016, Alena Creek saw a notable increase in beaver activity in Reach 2, in which ALE-MT03, 04 and 06 are located (Map 4). The largest dam was located approximately 100 m upstream of the upper extent of the enhancement work conducted in Reach 1. This dam was approximately 50 m in length and up to 1.8 m high (Figure 32). This was the key dam responsible for the backwatering seen throughout Reach 2, though there were other large dams constructed, including ones that diverted water away from the primary channel surveyed during baseline studies. The beavers were trapped and removed from the area in late 2016, though the dams remained intact. The 1-in-20 year flow on November 9, 2016 allowed enough water over the key dam to allow Coho Salmon access to upstream spawning areas, though the dam was undamaged (Figure 33). The dam(s) resulted in a significant increase in the amount of rearing habitat available at ALE-MT03, but also restricted movement downstream to Reach 1 under the flow conditions observed at the time of sampling in September 2017. This likely contributed to the higher catch of Coho Salmon observed at ALE-MT03 in 2017 compared to 2013; the higher catch observed in 2014 is biased high by the short daytime sets and the likelihood that catchability is not constant throughout the trap's soak time, with a high initial catch rate that diminishes over time (Figure 30, Harwood *et al.* 2016). The restriction of downstream movement may also have contributed to the reduced number of Coho captured in the enhanced Reach 1 compared to baseline sampling. The key dam in Reach 2 was breached during a rain event on November 26, 2017, and a new channel was carved around the dam (Figure 34). This rain event allowed spawning Coho access through Reach 2 into the upstream reaches, including the enhancement work in Reach 3. This breach ultimately resulted in a dewatering of the channels throughout Reach 2 and a change of channel configuration compared to baseline years.

In 2017, beaver activity upstream of the enhancement work in Reach 4 increased drastically (see large pool in Map 2). A series of large dams ranging from approximately 20-70 m in length, and of various heights, were constructed creating significant areas of backwater (Figure 35). Extensive damming was constructed approximately every 50 m. Beaver activity resulted in a significant increase in the amount of rearing habitat available through the creation of extensive backwater areas and side channels. This increase in habitat availability, in conjunction with the creation of 668 m^2 of new instream habitat in Reach 3 as part of the FHEP, is likely a contributory factor to the lower catch and CPUE at ALE-MT05 in 2017 as a similar number of fish dispersed over a larger area will result in lower CPUE.

Overall, the beaver dam activity in Reaches 2 and 4 affected habitat availability and accessibility at ALE-MT03, 04 and 06, which were the three sites that had the highest catch and CPUE during baseline studies (Figure 28, Figure 30, Harwood *et al.* 2016). Coho Salmon CPUE at ALE-MT06 was much lower in 2017 than in 2013 and 2014 (Figure 30) and this may have been affected by the series of beaver dams in Reach 4, which increased the availability of rearing pool habitat in Reach 4 and restricted access throughout the reach and downstream to Reaches 2 and 3. At ALE-MT04, most of the flow was directed away from the site by an upstream dam and access into the site was restricted by both an upstream and downstream dam.

Cutthroat Trout would have been equally affected by the large beaver dams, which would have restricted movement by spawning adults and rearing fry and parr. As the dams were unpassable during low to moderate flows this would have limited access for fish resident in Reach 2 to spawning areas such as those constructed in Reach 1 and 3, and the distribution of rearing fish throughout Alena.

Based on these habitat changes, we recommend adjusting and increasing the sites minnow trapped in September 2018 (Section 5.4).

Figure 28. Comparison of minnow trap CPUE for Cutthroat Trout at each site in 2013, 2014 and 2017. Error bars represent standard error.

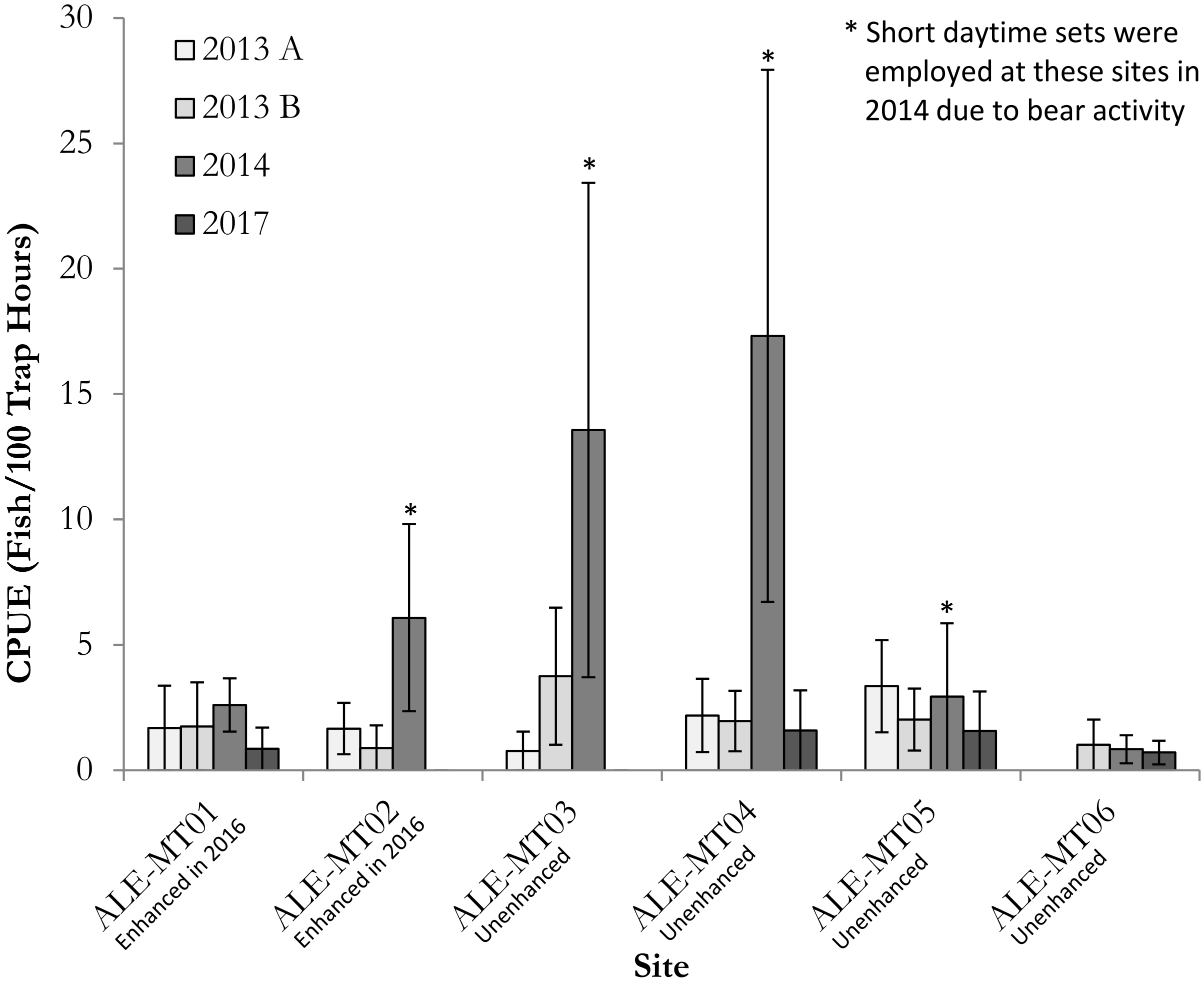


Figure 29. Comparison of minnow trap CPUE for Cutthroat Trout from 2013, 2014 and 2017. Error bars represent standard error among sites. Note that 2014 CPUE is biased high by short daytime sets at some sites.

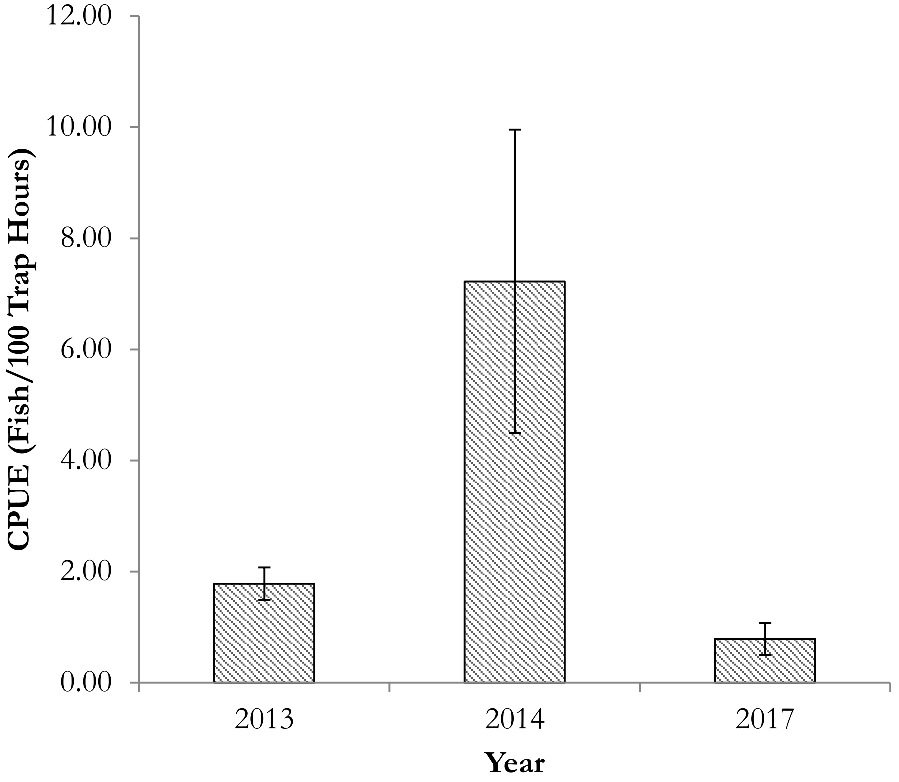


Figure 30. **Comparison of minnow trap CPUE for Coho Salmon at each site in 2013, 2014 and 2017. Error bars represent standard error.**

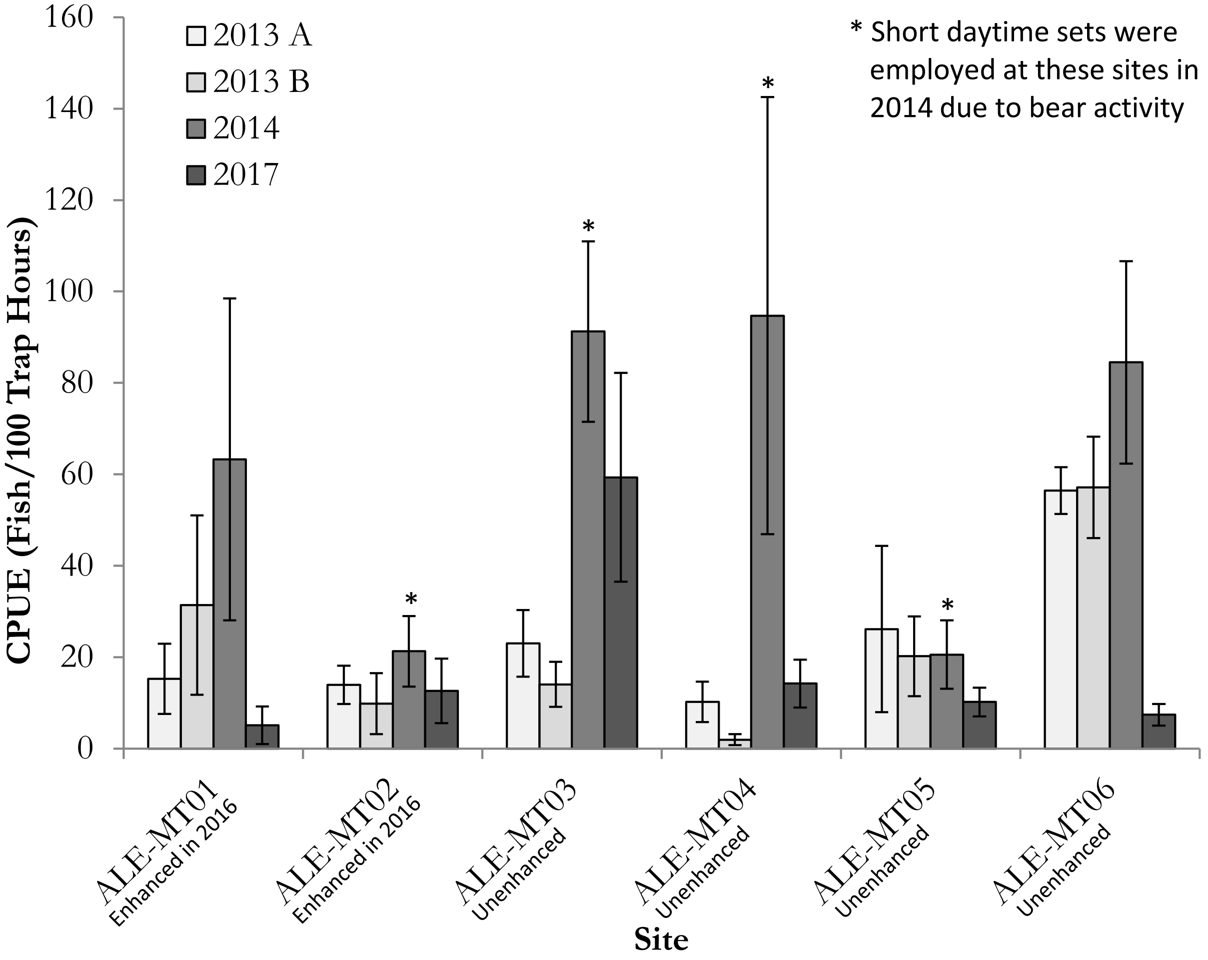


Figure 31. Comparison of minnow trap CPUE for Coho Salmon from 2013, 2014 and 2017. Error bars represent standard error among sites. Note that 2014 CPUE is biased high by short daytime sets at some sites.

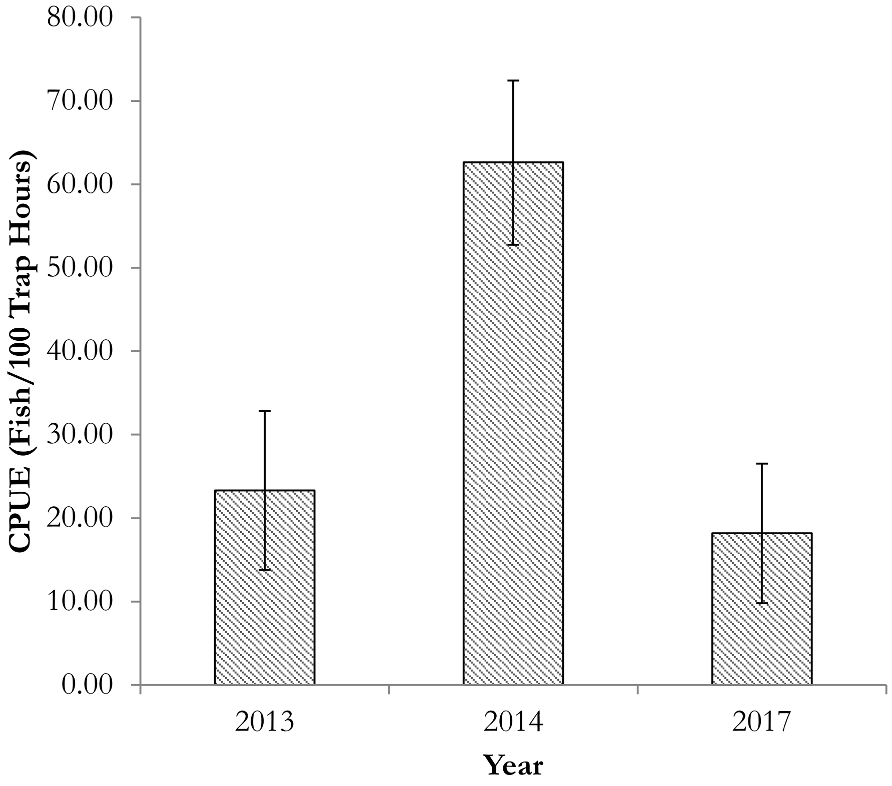


Figure 32. Panoramic view looking upstream at the primary dam 100 m upstream of Reach 1 on December 9. 2016.

Figure 33. Looking river right to left at the dam 100 m upstream of Reach 1 showing sufficient overflow to allow Coho Salmon migration on November 10, 2016.

Figure 34. **Looking upstream at the primary dam 100 m upstream of Reach 1 showing the formation of a new channel on river right (photo left) on November 26, 2017.**

Figure 35. Comparison of water levels at ALE-MT05 site on a) February 27, 2014 and b) November 10, 2017.

a)

b)

4.5. Riparian Habitat

4.5.1. Permanent Vegetation Density Monitoring

Prior to the Meager Creek slide in 2010, the Alena Creek riparian area was dominated by mature red alder and black cottonwood (*Populus balsamifera* ssp. *trichocarpa*), with patches of older shifting mosaic seral stage forest approximately 121-140 years old (Harwood *et al.* 2016). When vegetation was assessed in 2014, four years following the slide, vegetation had been regenerating naturally, with red alder densely colonizing the understory and at least ten different shrub species recorded within the permanent vegetation monitoring plots established in 2014. A single conifer, a western redcedar, was recorded within the monitoring plots (in ALE-PRM01) in 2014. Overall density of woody vegetation was estimated as 46,250 ± 32,469 stems/ha in 2014 (Harwood *et al.* 2016).

Shortly after clearing and creating gaps within the regenerating red alder stands and planting clusters of western redcedar in 2016, estimated density decreased to 5,700 ± 5,002 stems/ha (Table 36, Table 37). A total of 21 conifers, including western hemlock, western redcedar and Douglas-fir (*Pseudotsuga menziesii*), were recorded within the monitoring plots in 2016, along with a relatively diverse assemblage of eight shrub species. Devil's club (*Oplopanax horridus*) stems were most abundant, followed by red-osier dogwood (*Cornus stolonifera*), Sitka willow, salmonberry (*Rubus spectabilis*), thimbleberry (*Rubus parviflorus*), black raspberry (*Rubus leucodermis*), an unknown species of willow (*Salix sp.*) and red elderberry (*Sambucus racemosa*).

Between 2016 and 2017, vigorous regeneration of black cottonwood and red alder was observed (Figure 36). These floodplain pioneer species, with high initial growth rates, rapidly recolonized and infilling the compensation area (Figure 36, Figure 37, Appendix J). The estimated density for the four monitoring plots increased to 43,200 ± 36,210 stems/ha, with 90% certainty that the density of trees and shrubs ranges from 6,900 to 79,410 stems/ha (Table 36, Table 38). The DFO and MELP (1998) guided revegetation effectiveness target of 2,309 stems/ha was exceeded within all four permanent vegetation monitoring plots in 2016 and 2017 (Table 36).

Between 2016 and 2017, the total number of conifers species decreased slightly and the diversity of shrub species recorded within the monitoring plots also differed (Table 37, Table 38). Similar to 2016, western hemlock and western redcedar were recorded within the monitoring plots in 2017; however, no live Douglas-fir was detected in 2017. In 2017, thimbleberry stems followed by devil's club were the most abundant within the plots whereas in 2016 devil's club was the most abundant shrub followed by red-osier dogwood. In 2017, no black raspberries were observed. This species was only observed in ALE-PRM03 (Table 38). However, in 2017 an additional species, trailing blackberry (*Rubus ursinus*), was observed in the monitoring plot. ALE-PRM03 also supported the greatest diversity of shrubs in 2016. However, in 2017, most species of shrubs were observed at ALE-PRM06. Results from plots assessed in 2014 cannot be directly compared to results from plots assessed in 2016 and 2017 as only one of the plots established in 2014 (ALE-PRM03) fell within the construction area and was assessed again in 2016 and 2017; nevertheless, the density of woody vegetation within the plots decreased following thinning between 2014 and 2016 and rebounded to

2014 levels again in 2017. Conifer density recorded in 2016 and 2017 was higher than in 2014 and shrub species diversity was relatively similar between all three years.

Red alder is recognized for its ability to fix nitrogen, and thus increase soil quality in preparation for later successional stage species. Early successional stands of red alder and black cottonwood are commonly replaced with western redcedar and western hemlock in later successional stages within the CWHds1 biogeoclimatic zone (MFR 2000). If conifer density continues to decrease in future monitoring years, additional thinning of red alder and black cottonwood and/or additional planting of conifers, may be recommended to increase the diversity of woody vegetation and accelerate the transition to a later successional stage.

Permanent monitoring plot data was employed to estimate survival of planted western redcedar. Standing dead woody vegetation was recorded within only two of the four permanent vegetation monitoring plots in 2017 (Table 39). A total of three dead planted western redcedars were recorded, two in ALE-PRM05, within the Meager Creek slide path where the substrate has a low organic component, and one in ALE-PRM03. The survival rate of the planted western redcedars within the permanent monitoring plots was 83%, higher than the minimum target of 80%, thus replanting is not required (DFO and MELP 1998). Other dead woody vegetation was also recorded, one dead Douglas-fir and one large dead red alder was recorded in ALE-PRM03 (Table 39).

No regionally or provincially noxious or invasive plant species were detected within the compensation area. Although riparian monitoring is focused on the permanent vegetation monitoring plots, Ecofish crews have been looking out for noxious plant species while conducting other fieldwork within the compensation area, particularly in the vicinity of access roads, construction areas, and riparian areas.

Table 36. **Summary of riparian habitat data collected in 2014 four years after the Meager Creek slide, 2016 immediately after restoration works, and in 2017 one year after riparian restoration works, as part of Alena FHEP.**

Permanent Vegetation Monitoring Plot	UTM Coordinates			Year	Woody Vegetation Density			Estimated Vegetation Cover (%)	Comments
	Zone	Easting	Northing		Count of Live Stems/Plot	Count of Dead Stems/Plot	Estimated Live Vegetation Density (stems/ha)		
ALE-PRM03	10U	473335	5606225	2014[1]	305	0	61,000	88	Extensive regeneration of red alder under a mostly dead red alder overstory, with a few large living red alder.
				2016	60	0	12,000	30	
				2017	62	3	12,400	80	Good revegetation with horsetail, grass, and ferns. Most of the planted plugs have survived.
ALE-PRM05	10U	473014	5606707	2016	18	0	3,600	8	
				2017	107	2	21,400	37	Some natural revegetation occurring, especially along and within 10 m of the streambank.
ALE-PRM06	10U	473348	5606089	2016	22	0	4,400	16	
				2017	327	0	65,400	59	Good natural regeneration, good survival rate for planted vegetation.
ALE-PRM07	10U	473338	5606166	2016	14	0	2,800	39	
				2017	368	0	73,600	66	Good regeneration of horsetail, grass, bunchberry, fireweed, ferns, red alder and black cottonwood, especially in the ground divots.
Expected Density (stems/ha)				**2016**			**5,700**		
				2017			**43,200**		
Confidence Interval ± per ha				**2016**			**5,002**		
				2017			**36,210**		

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

Table 37. **Live species counted within each of the permanent vegetation monitoring plots in 2016, immediately following riparian restoration works, as part of the Alena Creek FHEP.**

Permanent Vegetation Monitoring Plot	Trees					Shrubs								Total
	black cottonwood *(Populus balsamifera ssp. trichocarpa)*	coastal Douglas-fir *(Pseudotsuga menziesii var. menziesii)*	red alder *(Alnus rubra)*	western hemlock *(Tsuga heterophylla)*	western redcedar *(Thuja plicata)*	black raspberry *(Rubus leucodermis)*	devil's club *(Oplopanax horridus)*	red elderberry *(Sambucus racemosa)*	red-osier dogwood *(Cornus stolonifera)*	salmonberry *(Rubus spectabilis)*	Sitka willow *(Salix sitchensis)*	thimbleberry *(Rubus parviflorus)*	willow (unknown species) *(Salix sp.)*	
ALE-PRM03	4	2	27	0	2	4	14	1	0	0	0	3	3	60
ALE-PRM05	0	0	0	2	3	0	1	0	8	2	0	2	0	18
ALE-PRM06	1	0	0	1	7	0	2	0	4	5	2	0	0	22
ALE-PRM07	0	0	0	0	4	0	0	0	2	0	8	0	0	14
Mean	1.25	0.50	6.75	0.75	4.00	1.00	4.25	0.25	3.50	1.75	2.50	1.25	0.75	28.50
Standard Deviation	1.89	1.00	13.50	0.96	2.16	2.00	6.55	0.50	3.42	2.36	3.79	1.50	1.50	21.25
Standard error of the mean	0.95	0.50	6.75	0.48	1.08	1.00	3.28	0.25	1.71	1.18	1.89	0.75	0.75	10.63
t-value_90%	2.353	2.353	2.353	2.353	2.353	2.353	2.353	2.353	2.353	2.353	2.353	2.353	2.353	2.353
Confidence Interval	2.23	1.18	15.89	1.13	2.54	2.35	7.71	0.59	4.02	2.78	4.45	1.77	1.77	25.01
Expected Density (stems/ha)	**250**	**100**	**1,350**	**150**	**800**	**200**	**850**	**50**	**700**	**350**	**500**	**250**	**150**	**5,700**
Confidence Interval ± per ha	**445**	**235**	**3,177**	**225**	**508**	**471**	**1,542**	**118**	**804**	**556**	**891**	**353**	**353**	**5,002**

Table 38. Live species counted within each of the permanent vegetation monitoring plots in 2017, one year after riparian restoration works, as part of Alena Creek FHEP.

Permanent Vegetation Monitoring Plot	Trees				Shrubs							Total
	black cottonwood (*Populus balsamifera ssp. trichocarpa*)	red alder (*Alnus rubra*)	western hemlock (*Tsuga heterophylla*)	western redcedar (*Thuja plicata*)	devil's club (*Oplopanax horridus*)	red elderberry (*Sambucus racemosa*)	red-osier dogwood (*Cornus stolonifera*)	salmonberry (*Rubus spectabilis*)	thimbleberry (*Rubus parviflorus*)	trailing blackberry (*Rubus ursinus*)	willow (unknown species) (*Salix sp.*)	
ALE-PRM03	18	14	0	0	12	3	0	0	10	5	0	62
ALE-PRM05	72	16	0	3	1	0	4	2	9	0	0	107
ALE-PRM06	169	129	1	8	0	1	7	7	3	0	2	327
ALE-PRM07	203	157	0	3	0	3	2	0	0	0	0	368
Mean	115.50	79.00	0.25	3.50	3.25	1.75	3.25	2.25	5.50	1.25	0.50	216.00
Standard Deviation	85.47	74.78	0.50	3.32	5.85	1.50	2.99	3.30	4.80	2.50	1.00	153.86
Standard error of the mean	42.74	37.39	0.25	1.66	2.93	0.75	1.49	1.65	2.40	1.25	0.50	76.93
t-value_90%	2.353	2.353	2.353	2.353	2.353	2.353	2.353	2.353	2.353	2.353	2.353	2.353
Confidence Interval	100.58	88.00	0.59	3.90	6.89	1.77	3.51	3.89	5.64	2.94	1.18	181.05
Expected Density (stems/ha)	**23,100**	**15,800**	**50**	**700**	**650**	**350**	**650**	**450**	**1,100**	**250**	**100**	**43,200**
Confidence Interval ±/ha	**20,115**	**17,600**	**118**	**781**	**1,377**	**353**	**703**	**778**	**1,129**	**588**	**235**	**36,210**

Table 39. Dead tree species counted within each of the permanent vegetation monitoring plots one year after riparian restoration works, as part of Alena Creek FHEP.

Permanent Vegetation Monitoring Plot	Douglas-fir (*Pseudotsuga menziesii*)	red alder (*Alnus rubra*)	western redcedar (*Thuja plicata*)	Total
ALE-PRM03	1	1	1	3
ALE-PRM05	0	0	2	2
ALE-PRM06	0	0	0	0
ALE-PRM07	0	0	0	0
Mean	0.25	0.25	0.75	1.25
Standard Deviation	0.50	0.50	0.96	1.50
Standard error of the mean	0.25	0.25	0.48	0.75
t-value_90%	2.353	2.353	2.353	2.353
Confidence Interval	0.59	0.59	1.13	1.77
Expected Density (stems/ha)	50	50	150	250
Confidence Interval ±/ha	118	118	225	353

Figure 36. Natural regeneration observed at ALE-PRM07. Photo is representative of vigorous re-establishment of red alder and black cottonwood, within the Alena Creek FHEP, on October 5, 2017.

Figure 37. Photo of ALE-PRM07 after the implementation of riparian restoration works, on October 25, 2016.

4.5.2. Percent Vegetation Cover Estimates

The percent vegetation ground cover was relatively high in 2014, ranging from 64 to 98% with an average of 82%. Immediately following riparian restoration works in 2016, the average percent vegetation cover was lower, ranging from 8 to 30% with an average of 23%, to permit the establishment of planted western redcedar and promote tree and shrub diversity. Average percent vegetation cover recorded in 2017 (61%) was higher than in 2016 but lower than 2014, likely due to the shorter recovery time since establishing and creating the clearing gaps (i.e., one year between restoration works and 2017 data collection versus four years between the Meager Creek slide and 2014 data collection).

In 2017, vegetation cover was relatively high at three of the four sites surrounding the permanent vegetation monitoring plots. Vegetation cover ranged from 37% to 80%, with an average of 61% cover across all sites (Table 36). Vegetation cover was highest around the plot at ALE-PRM03 (Figure 38), where the substrate is dominated by native soils, and lowest around the plot at

ALE-PRM05. As previously noted, ALE-PRM05 is situated within the Meager Creek slide path; where the substrate is primarily mineral soil and sand, with a low organic component (Figure 39, Map 4). Vegetation ground cover is important within riparian areas to minimize erosion and resulting sedimentation in adjacent watercourses during early successional stages. Establishment of herbaceous vegetation also aids in the later establishment of woody vegetation, the ultimate goal in riparian habitat restoration.

The LTMP stated that additional erosion control and soil conditioning may be required to stabilize vegetation on steep, erodible soils and ensure successful long-term vegetation survival. In consideration of erosion risk, the final grade and structure of the riparian compensation area was constructed to have a shallow, low gradient. Consequently, erosion is not a current concern. Although the Meager Creek slide dramatically changed soil conditions within the slide path, the extent of natural vegetation recruitment between 2016 and 2017 has shown that the soil condition is generally appropriate for native vegetation and no soil conditioning is required.

Figure 38. Higher percent vegetation cover (80%), primarily horsetail, grass and ferns, at ALE-PRM03, October 5, 2017.

Figure 39. **Lower percent vegetation cover (37%), primarily horsetail, at ALE-PRM05 located within the Meager Creek slide path, October 5, 2017.**

4.5.3. Photopoint Comparison

Standard photos taken in 2016 and 2017 at 1.3 m above the plot centre, facing 0 degrees (north) are presented in Appendix J to compare vegetation condition in 2016 and 2017 at each plot. Representative photos of the general site condition surrounding each permanent monitoring plot is also provide. The photos show an increase in vegetation abundance from 2016 to 2017.

5. RECOMMENDATIONS

The success of the enhancement habitat 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 enhancement habitat were described in the Project's OEMP (Harwood *et al.* 2018), but based on the results of year 1 monitoring we recommend the following adjustments be made.

5.1. Hydrology

To 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 moving the gauge upstream. A suitable location will need to be confirmed in the field, but there is a large boulder near the temporary crossing that was used during enhancement works (10U 472240 5606169) that may provide a suitable location.

5.2. Water Quality

5.2.1. Water Chemistry

Water quality in Alena Creek has generally improved since baseline sampling began in 2013. The only parameters that have exceedances of BC WQG for the protection of aquatic life over the course of baseline and year 1 monitoring are dissolved oxygen (buried life stage guideline only), total iron, and dissolved iron.

In year 1 monitoring, no exceedances of the minimum BC WQG for dissolved oxygen were observed at the site in the enhancement habitat, with data indicating a well aerated condition (dissolved oxygen concentrations ranging from 10.38 mg/L to 10.81 mg/L).

Concentrations of dissolved iron exceeded the short-term maximum BC WQG of 0.35 mg/L at the site in the enhancement habitat during all sampling periods, with the range of concentrations similar between baseline and year 1 monitoring. Total iron exceeded the short-term maximum BC WQG of 1 mg/L at one or both sites on all sampling dates during baseline sampling. However, only one exceedance occurred during year 1 sampling at the site in the enhancement habitat, and concentrations at this site in year 1 were on average lower than observed during baseline sampling.

Considering these observations and that instream enhancement is not expected to result in adverse effects on water quality, it is recommended that water quality monitoring on Alena Creek be ceased.

5.2.2. Water Temperature

The most recent OEMP for the Upper Lillooet Hydro Project (Harwood *et al.* 2018) noted that if no issues were identified with water temperature or the fish community in Alena Creek, annual reporting would be suspended, with final results reported following year 5. Although no issues with water temperature were identified, given the recommended changes to the fish community monitoring program and the lack of a complete water temperature data set for some life-history stages (e.g., spawning and incubation periods for Coho Salmon), we recommend water temperature results be reported on in year 2.

5.3. Fish Habitat

The overall function and quality of the constructed habitats remains high despite the flood flows experienced in Alena Creek since construction. In the downstream reach, Reach 1, we recommend continued monitoring of the bank erosion at 0+185 just upstream of ALE-XS1. In Reach 3, we recommend undertaking repairs during the least risk timing window in August 2018. All repairs can be completed by a hand, utilizing a crew of four. 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 all upstream concerns with further channel incision. 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, or it may need to be sourced locally and brought into site. This could be done using small equipment, such as an ATV with a trailer and manual labor. In addition to using materials like cobble and small boulder, willow and red-osier stakes should be planted at select bank sites to aid in short-term stability.

We also recommend that beaver activity continue to be monitored and controlled to ensure the enhanced habitat remains functional.

5.4. Fish Community

Based on the habitat changes caused by beaver activity in Reach 2, we recommend adjusting the sites sampled in this reach to be more representative of the habitat sampled under baseline conditions. We recommend replacing ALE-MT04 with a site just upstream of Reach 1 at the gravel augmentation pile installed as part of the enhancement works. Habitat conditions at this site are similar to conditions during baseline studies at ALE-MT03 and ALE-MT04, prior to the backwatering and braiding of the channels. This location is situated within the primary flow of Alena Creek, downstream of where all side channels converge again into a single channel. There is little risk that this location will be affected by beavers or braiding in the future based on the nature of the steep banks at the gravel augmentation pile and further upstream. To the extent feasible based on habitat alterations caused by beaver activity, the precise location sampled at ALE-MT03 should also be adjusted to be representative of the habitat sampled during baseline (i.e., the new primary channel at ALE-MT03 should be sampled).

We also recommend adding two minnow trap sites in the enhanced Reach 3 to monitor juvenile fish use of the pools and large woody debris complexes installed. These changes will result in the sampling of eight sites in total, four in unenhanced habitat and four in enhanced habitat. This will allow a better comparison between CPUE in enhanced and unenhanced habitat, as well as improving the ability to demonstrate that the FHEP supports equivalent or greater fish usage relative to pre-project densities in Alena Creek, as per the requirements of the *Fisheries Act* Authorization.

5.5. Riparian Habitat

Results from year 1 monitoring indicate that vegetation within the Alena Creek riparian compensation area is on a trajectory to become similar to that prior to the Meager Creek slide. No additional planting or remediation measures are recommended at this time. However, the overall density and potential crowding of pioneer species, red alder and black cottonwood, will be monitored to determine whether additional restoration works (e.g., thinning) are required. We will continue to monitor vegetation density, composition, and diversity late in the growing season in years 3 and 5 (Harwood *et al.* 2018).

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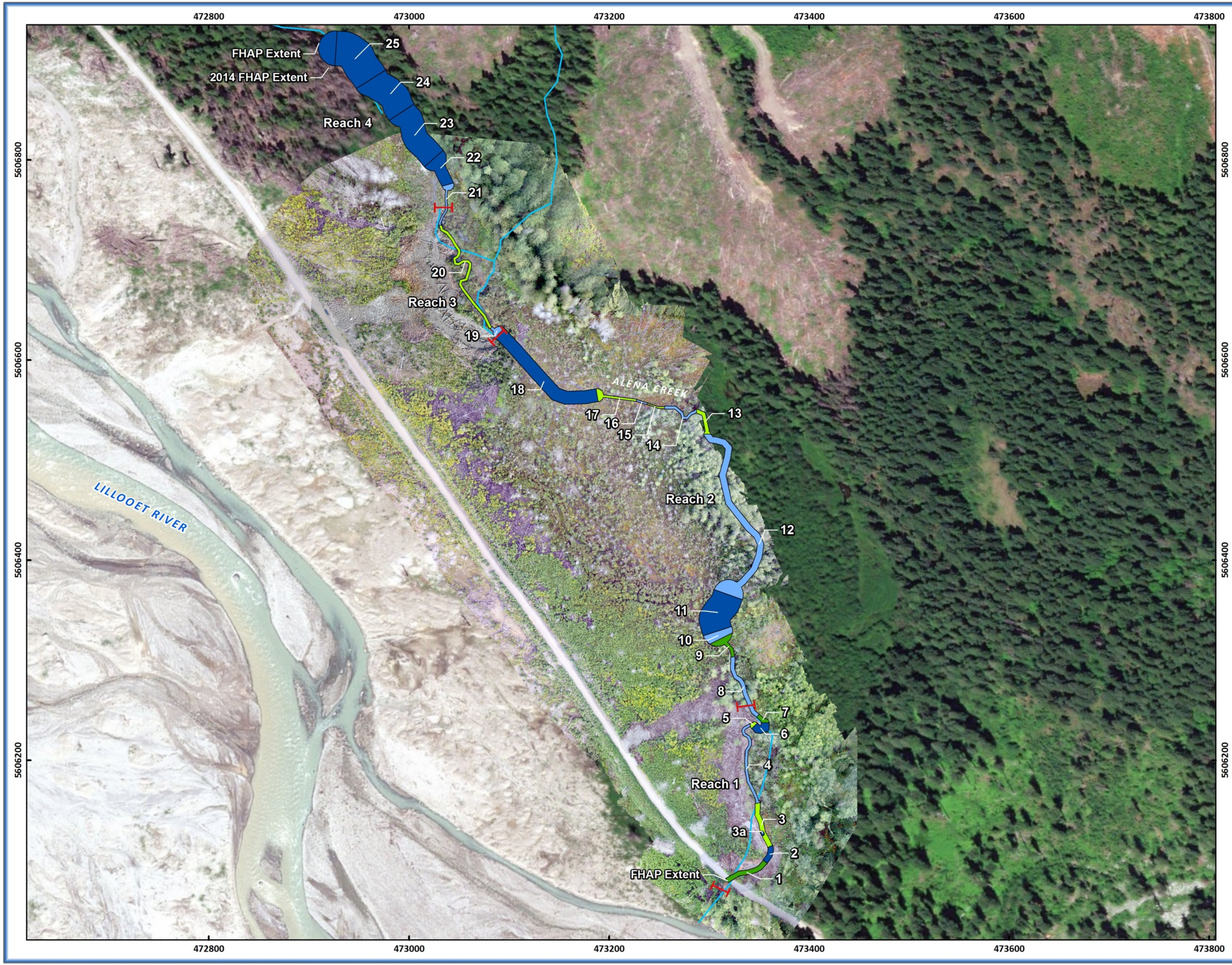
PROJECT MAPS



UPPER LILLOOET HYDRO PROJECT

Alena Creek
Fish Habitat Assessment

Legend

FHAP Type

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

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

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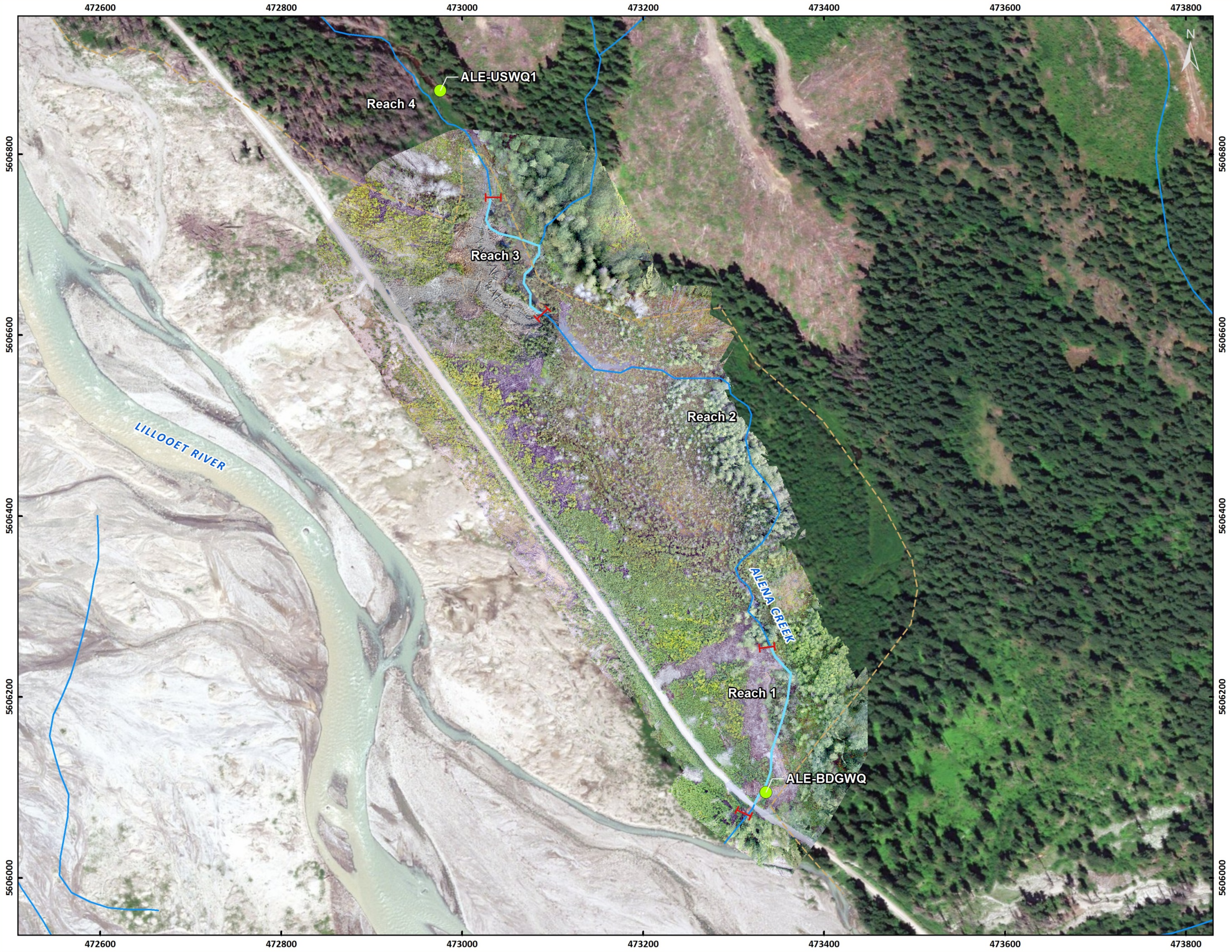

UPPER LILLOOET HYDRO PROJECT

Alena Creek
Water Quality Sites

Legend

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

0 25 50 100 150 200 m

Scale: 1:4,000

NO.	DATE	REVISION	BY
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3			
4			
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Date Saved: 17/04/2018
Coordinate System: NAD 1983 UTM Zone 10N

ECOFISH RESEARCH

Map 3

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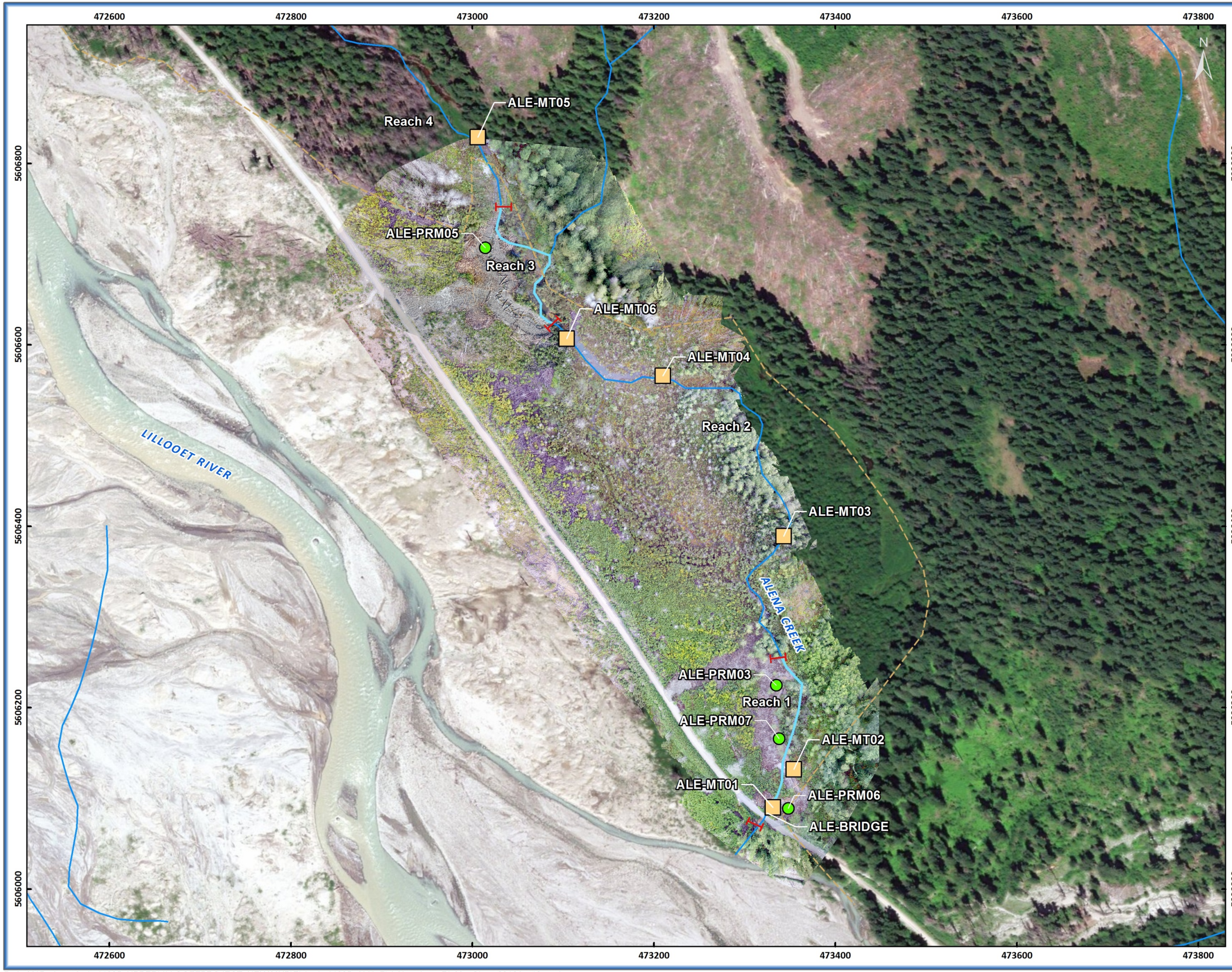

UPPER LILLOOET HYDRO PROJECT

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)
- - - Meager Creek Slide Extent
- — Streams

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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ECOFISH RESEARCH

Map 4

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APPENDICES