Aberfeldie Project Water Use Plan

Effectiveness Monitoring Fish Habitat Works

Implementation Year 4

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Final Report

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Aberfeldie Side Channel
Effectiveness Monitoring of Fish Habitat Works (Year 4)

Project ABFMON 5 (Contract Q9-9260)

Final Report

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Cover Photo

Reproductive Kokanee pair at Aberfeldie side channel (September 23, 2012)

Executive Summary

The Aberfeldie side channel was constructed in the fall of 2008 to compensate for fish habitat and productivity losses predicted to result from the redevelopment of the Aberfeldie Generating Station and associated alterations to the flow regime over the dam and through the diversion reach of the Bull River. The present study monitored the fish and fish habitat effectiveness of the side channel in its fifth year of establishment and forms Year 4 of a 5-year monitoring program. Year 4 monitoring included: 1) a review of structural stability of the channel; 2) the collection of seasonal water quality and quantity data; 3) an intra-gravel dissolved oxygen assessment; 4) a spring spawning assessment; 5) a juvenile habitat use assessment; 6) a fall spawning assessment; and 7) overwintering habitat assessment.

The side channel is designed to provide spawning and rearing habitat to Westlope Cutthroat Trout and Kokanee. Other local fish species, including Bull Trout, Rainbow Trout, and Mountain Whitefish, may also use the side channel for rearing. Year 4 of the monitoring program confirmed results from previous years that water quality conditions in the Aberfeldie side channel rarely met the requirements for rearing and reproduction of fish species as set in BC MoE guidelines (BC MoE, 2006). Dissolved oxygen (DO) concentration and low discharge were the factors most limiting to fish production in the side channel. Measured DO levels (measured in the water column) marginally met the minimum requirement for the support of aquatic life in summer and fall (5 mg/L) and never met the minimum requirements for successful development of embryo and alevins (9mg/L) (MoE, 2001). Kokanee embryos usually do not survive in locations where intra-gravel DO concentration is lower than 3 mg/L (or approximately 6 to 7 mg/L in the water column (Cope, 1996; MoE, 2001). Results from the Year 4 intra-gravel DO monitoring demonstrated that the DO concentrations in the hyporheic layer marginally met these conditions but were sufficient for successful Kokanee egg development. Although the channel was initially designed to ensure optimal water velocity on constructed spawning platforms (0.3-0.5 m/s; Reid *et al.*, 2008), water velocities measured in the fall in glide habitat only ranged between 0.01 and 0.31 m/s. Despite sub-optimal conditions, an estimated 3,955 Kokanee entered the side channel for spawning, which is consistent with numbers of Kokanee spawners counted in Years 1 and 3 of the monitoring program. Kokanee fry were observed in the channel but the incubation success rate of deposited eggs is unknown. In winter, the channel outlet remained open but overwintering habitat availability appears to be limited by low DO concentration in pools and low water levels in glides. Persistent bank erosion was noted throughout the constructed channel as a result of precipitation and animal activity (i.e., wildlife and cattle). Bank erosion has led to the introduction of fine sediments into the channel, which is detrimental to spawning habitat suitability and reduces the effective width of the channel.

In conclusion, Vast recommends that the following concerns be addressed by BC Hydro:

- Address DO and water velocity issues by remodelling the channel morphology and/or increasing water inflow from the Bull River; and,
- Revegetate and reslope the channels banks to prevent erosion and input of fine sediments in the channel, and reduction of the effective width of the channel.

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1 Introduction

The Aberfeldie Generating Station is a run-of-the river hydroelectric facility located on the Bull River, approximately 12 km upstream from the confluence of the Bull and Kootenay Rivers, and about 35 kilometres east of Cranbrook, BC (Figure 1). The facility was recently redeveloped to replace outdated equipment and to create additional energy and capacity. The facility layout includes a concrete dam at the upper end of a canyon stretch of the Bull River, a gravity penstock that directs water around the canyon (diversion reach) through a surge tower, and the powerhouse (Figure 2). The water is then directed back to the mainstem of the Bull River at the tailrace pool. To meet capacity objectives, the Water Use Plan for the redevelopment required a reduction in the amount of spill over the dam and annual flows through the canyon (diversion reach) to the powerhouse, resulting in annual dewatering of instream glide, riffle, pool and channel margin habitat (Cope 2006, BC Hydro 2006). This was quantified as an annual dewatering of 2991 m^2 of primary and secondary productivity habitat (DFO 2006). An additional 170 m^2 of habitat associated with the temporary installation of the tailrace cofferdam was also to be impacted.

In order to carry out the redevelopment, an authorization was obtained through Fisheries and Oceans Canada (DFO) for the harmful alteration, disruption and destruction (HADD) of habitat (DFO 2006). As a condition of the HADD Authorization (No. 05-HPAC-PA7-000-000188), BC Hydro was required to compensate for fish habitat and productivity losses through the construction of approximately 3,000 m^2 of off-channel habitat in a permanent side channel. BC hydro elected to exceed these requirements and created 5,290 m^2 of compensation habitat (McPherson et al., 2010). The side channel was constructed in the fall of 2008. This study focuses on the effectiveness monitoring of fish and fish habitat in the side channel over the first five years of its operation. Monitoring was completed for Year 1 in 2009-2010 (McPherson and Robinson 2010), for Year 2 in 2010-2011 (McPherson and Robinson 2011), and for Year 3 in 2011-2012 (Interior Reforestation Ltd. 2012). This report presents Year 4 findings.

1.1 Mainstem Fish Values Prior to Redevelopment

The main objective of this monitoring project was to assess whether the goal of no net loss of productive capacity of the Bull River after the redevelopment has been achieved. To assess this, the fisheries values prior to development were summarized.

The diversion reach, located between the tailrace pool and the dam, includes an upper and a lower habitat section. These sections are separated by a natural bedrock fall approximately 800 m downstream of the dam, which forms a barrier that restricts upstream fish access between the two sections. The main habitat of concern for productivity losses is a pool-riffle sequence with a mid-channel bar that connects the generating station tailrace and pool with the deep bedrock pool at the base of the upstream fish barrier. Streambed in this section of the Bull River is dominated by large cobbles, boulder, rubble, and bedrock. It provides low abundances of Kokanee (*Oncorhynchus nerka*) spawning habitat and potential spawning and summer rearing habitat for Westslope Cutthroat Trout (*Oncorhynchus clarki lewisi*) , Mountain Whitefish (*Prosopium williamsoni*), Longnose Dace (*Rhinichthys cataractae*), Largescale Sucker (*Catostomus macrocheilus*), Torrent Sculpin (*Cottus rhotheus*), Slimy Sculpin (*Catostomus cognatus*), and possibly Bull Trout (*Salvelinus confluentus*). In the upstream section (canyon), habitat provides connectivity to over-wintering pools for isolated Westslope Cutthroat Trout (Cutthroat Trout; *Oncorhynchus clarkii lewisi*) and mountain whitefish entrained over the dam (Cope 2006). As a whole, habitat in the diversion reach was not considered high quality (Cope 2006).

The diversion reach was assessed for its primary and secondary productivity (i.e., periphyton and benthic invertebrates) (Cope 2006) and continues to be monitored as under the WUP (Perrin and Bennett, 2011). It was recognized that provision of a minimum flow would be a risk-averse strategy to ensure ecological connectivity while mitigating lost summer aquatic productivity in the diversion reach (BC Hydro 2008a).

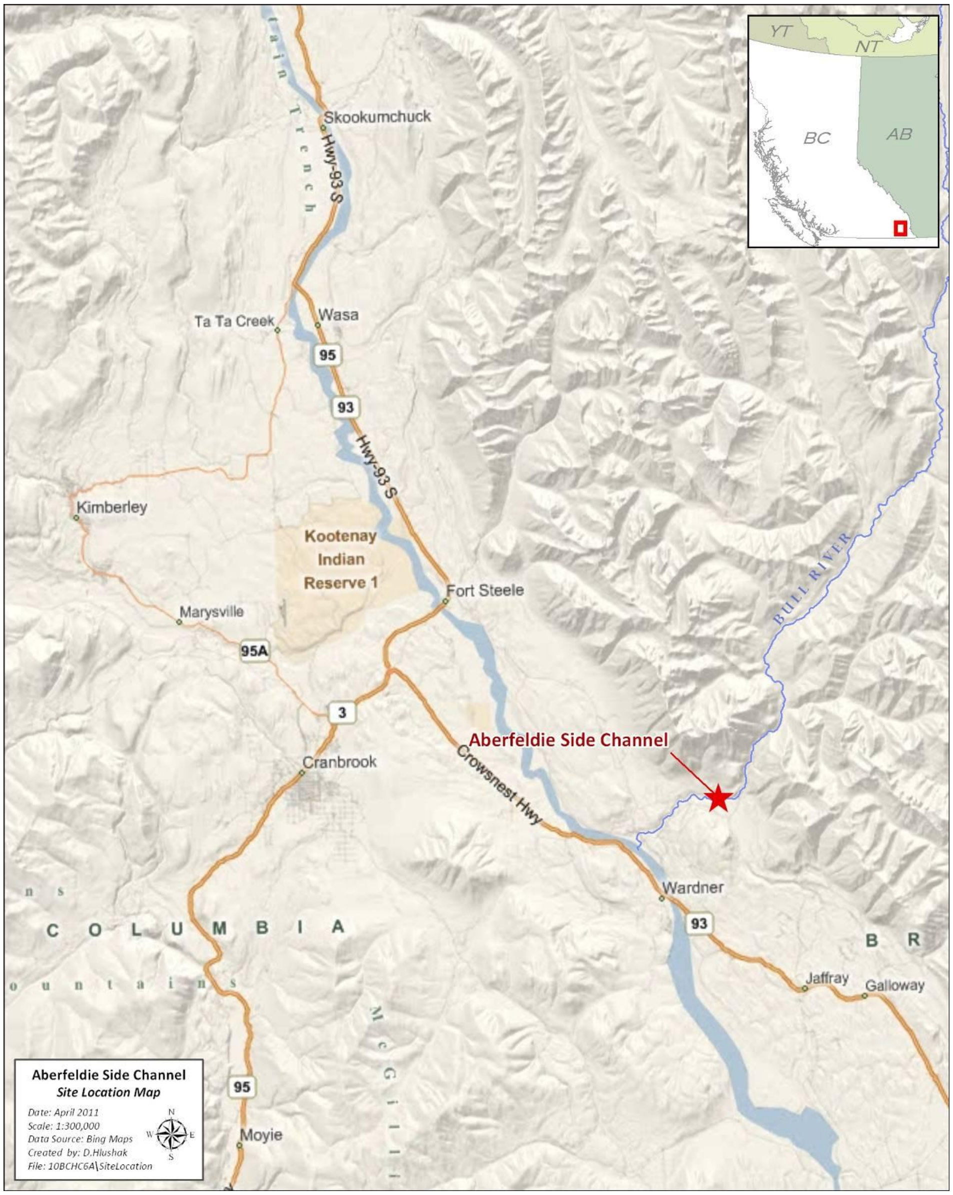

Figure 1 Site location map, Aberfeldie side channel.

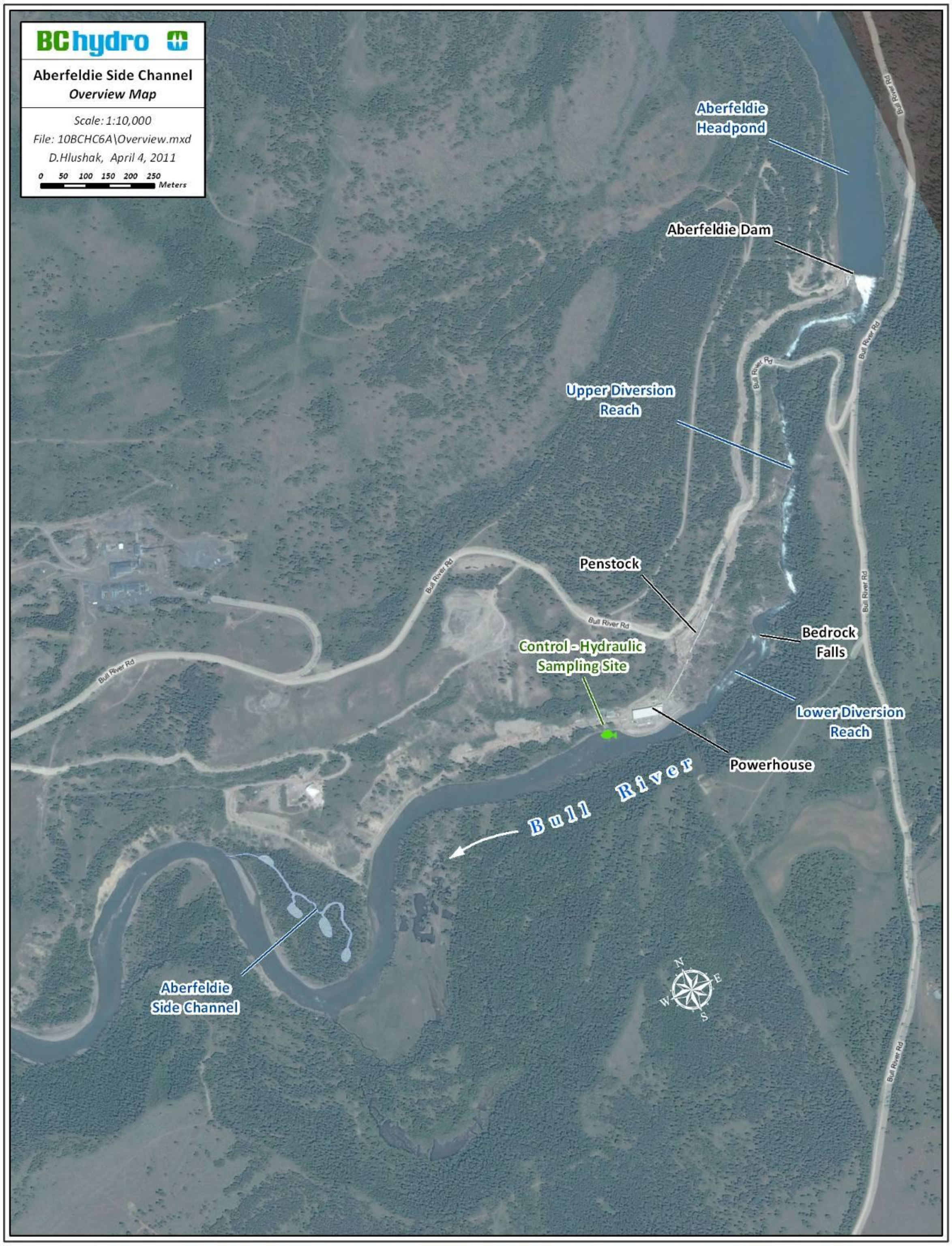

Figure 2 Layout of the Aberfeldie hydroelectric generating facility, diversion reach and side channel compensation habitat.

1.2 Channel Design

The Aberfeldie side channel design, completed by Reid et al. (2008), was finalized in the Terms of Reference document developed for the side channel's construction (BC Hydro 2008b). The side channel was built in the fall of 2008 and is located on the right bank of the Bull River, approximately 500 m downstream of the tailrace. This area is a floodplain segment of the Bull River bounded by the valley wall to the north and the river on all other aspects. The channel was designed to intercept shallow groundwater flow from the river and groundwater flow from the upslope area to the north (Reid et al. 2008). The site was selected because of its proximity to the impact area and ability to provide replacement habitat for the potentially impacted mainstem reaches, its low potential maintenance requirements, and potential to retrofit a surface water intake in future years, if required (Reid et al. 2008).

The groundwater channel was designed to enhance primary and secondary productivity (as per the 2011 Fish Authorization) and provide fish and benthic habitat (as per the ToR) solution. In terms of fish habitat, it was intended to provide a variety of hydraulic conditions required to support various life history stages, namely the spawning and rearing of cutthroat trout, Kokanee (non-native to the area), and possibly Bull Trout, as well as the rearing requirements for mountain whitefish (Table 1). It was also recognized that the channel might also be used by non-native Rainbow Trout (*O. mykiss*) and Eastern Brook Trout (*S. fontinalis*).

Table 1 Potential fish habitat use of the Aberfeldie side channel from Reid et al. 2008.

Species	Scientific Name	Life History Stage	Duration
Westslope Cutthroat Trout	*Oncorhynchus clarkii lewisi*	spawning, fry, juvenile and adult	year-round
Kokanee	*Oncorhynchus nerka*	spawning, fry	2 months post swim-up
Bull Trout	*Salvelinus malma*	spawning, fry, juvenile	year-round until >300 mm fork length
Mountain Whitefish	*Prosopium williamsoni*	juvenile and adult	year-round, but primarily juvenile
Rainbow Trout [a]	*Oncorhynchus. mykiss*	spawning, fry, juvenile and adult	year-round, but primarily juvenile
Eastern Brook Trout [a]	*Salvelinus. fontinalis*	spawning, fry, juvenile and adult	year-round

[a] potential non-native species

On May 21, 2009, a Fish Habitat Assessment Procedure (FHAP) was completed on the entire side channel (McPherson and Robinson 2010). Since this FHAP was completed during the first year of the side channel's operation and prior to spring freshet events, it is considered an as-built survey of the area. The FHAP determined the channel to be 586 m long with a wetted area of 5290 m^2. Flows determined from a permanent gauging station (weir; Appendix 1) ranged from 0.01 to 0.04 m^3/s in 2009/10 (McPherson and Robinson 2010).

The side channel has three reaches (Appendix 1). Reach 1 comprises the main length of the channel (478 m), while Reach 2 (54 m) and Reach 3 (53 m) are each made up of a short glide and large alcove pool extending off from the main reach. The side channel has four large pools (totalling 3726 m^2), 12 glides (totalling 1436 m^2), 5 riffles (totalling 94 m^2), and 4 cascades (34.8 m^2). Overview details of these habitats as provided by McPherson and Robinson (2010; unless otherwise cited), are as follows:

Pools made up 70% of the total area of the channel and were constructed to provide refuge (for all seasons), rearing, and adult holding areas, as well as low velocity and deep water areas for other aquatic organisms (e.g., algae, invertebrates, etc.) (Reid *et al.* 2008). Between 50 and

75% of the pool area were covered by wood. There were four ponds (two inline and two alcove), with maximum depths averaging 1.4 m ± 0.4 m).

Glides comprised 27% of the total habitat area in the side channel. Glides were intended to support the majority of benthic production and stream rearing for the channel, as well as some isolated spawning in areas where suitable hydraulics and bed materials exist (Reid *et al.* 2008). Large woody debris (LWD) was the main type of habitat cover, covering approximately 40% of the area of glides. Glides had low gradients ranging from 1% to 2% and consequently produce low water velocities (mean 0.10 to 0.01 m/s).

Seven of the glides had spawning platforms constructed at their most downstream end, where the glide transitioned to a riffle or cascade. Pebble surveys completed on three of the spawning platforms indicated mean pebble diameter to be 48.3 ± 34.1 mm. The median size of substrates (D_{50}) was 45 mm, a pebble diameter larger than that required for smaller salmonids found in the Bull River. Based on known body lengths, the appropriate D_{50} for Kokanee was estimated to be 20 mm, and for Westslope Cutthroat Trout the D_{50} was estimated to range from 15 to 35 mm. As-built spawning platform details differed from the design specifications (Reid *et al.* 2008), which required velocities of 0.3 to 0.5 m/s over 25 mm washed gravel, suitable for cutthroat trout and Kokanee spawning.

Riffle and cascade habitat combined made up 2.5% of the total area of the side channel. These habitats were intended to provide aeration, connectivity, benthic production, fish rearing areas, and grade/water level control (Reid *et al.* 2008). Riffle gradients had a mean of 3.4 ± 1.1 %, and cascade gradients had a mean of 15.5 ± 6.6 %.

1.3 Scope

BC Hydro and Power Authority (BC Hydro) retained the services of Vast Resource Solutions Inc. (Vast; formerly Interior Reforestation Co. Ltd.) in 2009 to develop and implement a 5-year (2009-2013) fish and fish habitat effectiveness monitoring program for the Aberfeldie side channel. This report summarizes data collected in 2012/2013, the fourth year of monitoring. The overall goal of this study is to assess the status of the newly constructed side channel in providing fish habitat. This study will also identify areas that may require changes or additional efforts.

This study is one of five ongoing effectiveness monitoring components currently being undertaken through BC Hydro to determine the effectiveness of the Aberfeldie redevelopment compensation works in meeting the federal fisheries goal of no-net-loss. Other environmental components being assessed but not covered in this report include:

- Baseline productivity monitoring (ABFMON-1)
- Primary and secondary productivity monitoring (ABFMON-5 Task 2A)
- Riparian vegetation monitoring (ABFMON-5 Task 2C)
- Habitat impact monitoring (ABFMON-3)
- Winter flow effectiveness monitoring (ABFMON-4)

The results of these combined effectiveness monitoring studies will be used to answer the following **Management Questions** (BC Hydro 2008a):

- Does the productive capacity realized in the constructed habitat, in combination with the productive capacity of the diversion reach at the 2 m^3/s summer minimum flow achieve the Aberfeldie Redevelopment project compensation goal of no-net-loss of productive capacity?

- Is there a lower summer minimum flow discharge that, in combination with the productive capacity of the compensation habitat, could achieve the Aberfeldie Redevelopment project compensation goal of no-net-loss of productive capacity?

1.4 Monitoring Hypotheses

The hypotheses associated with these management questions were outlined in the BC Hydro Aberfeldie Water Use Plan - monitoring program terms of reference (BC Hydro 2008a). The hypotheses relate to the primary productivity of the constructed side channel habitat and the diversion reach during the summer 2.0 m^3/s productivity flow release. If the side channel compensation is successful, there will be no difference between the productivity **prior** to redevelopment (diversion reach only) and the productivity **after** redevelopment (combined productivity of the diversion reach under the post redevelopment 2 m^3/s minimum summer flow release and the side channel habitat). Testing of these hypotheses will require results from programs ABFMON-1 (Baseline Productivity Monitoring), ABFMON-5 Task 2A (Primary and Secondary Productivity Monitoring), ABFMON-5 Task 2B (Effectiveness Monitoring Fish Habitat Works), ABFMON-5 Task 2C (Riparian vegetation monitoring). The hypotheses relate to primary productivity (periphyton and benthic invertebrate results) not fish productivity and thus are not addressed in this report.

1.5 Objectives

The objectives of this study are to qualitatively and quantitatively describe the fish community and fish habitat in the side channel and to monitor the structural integrity of the compensation habitat. Seven major components were developed to achieve the objectives of the program:

Fish and Fish Habitat Assessment Procedure (FHAP; Year 1): The FHAP is a detailed description of habitat types (and habitat units) and their locations to provide a baseline of habitat features. Details from the FHAP can be used to perform spatial analyses of fish and fish habitat and to document changes in fish-habitat associations and habitat quality over time. The FHAP data were used to relate fish species and life-history stage to types of habitat and to evaluate fish habitat conditions for target fish species. These findings will be monitored over time to identify changes to fish-habitat associations and habitat quality.

Water Quality and Water Level Data (Years 1 – 5): In order to evaluate suitability of habitat conditions, water quality and quantity must be assessed. Water quality data are to be collected once per season at benchmark sites established by BC Hydro. Water level measurements at the established weir are to be collected during every site visit to determine whether or not channel flows are meeting fish habitat requirements. In Year 4, intra-gravel dissolved oxygen was monitored in the side channel (glide habitat unit 1-12) and a comparable location in the mainstem of the Bull River (control hydraulic sampling site; Figure 2) to evaluate conditions for egg incubation of target fish species.

Structural Stability Survey (Years 1 - 5). The purpose of the survey is to assess whether: 1) the outlet protection groyne is preventing the outlet from infilling by promoting scour at the toe of the downstream side which is within the side channel outlet; 2) the berm on the right downstream boundary is protecting the side channel from the tributary gully and ravelling slope; 3) the berm on the left downstream boundary is protecting the side channel from Bull River floods; and 4) the Bull River bank at the upstream end of the channel is stable. The presence of cattle, beaver and any other impacts on stability are also to be reviewed.

Spring Spawning Survey (Years 1, 2, 4 and 5): The purpose of this survey is to qualitatively describe the fish community by visually assessing the side channel for spring spawning activity by documenting the number of observed spawning fish (i.e., Western Cutthroat Trout and Rainbow Trout) and redds. These data are also to be used to estimate the numbers of fish utilizing the side channel for spring spawning and the types of habitat being used.

Juvenile Habitat Use (Years 1, 2, 4 and 5): The purpose of this survey is to quantitatively describe the fish community by conducting presence/absence sampling using electrofishing and trapping techniques in the summer to determine habitat use by juvenile fish species.

Fall Spawning Survey (Years 1, 3 and 4): The purpose of this survey is to qualitatively describe the fish community by visually assessing the side channel for fall spawning activity by documenting the number of observed spawning fish (e.g., Kokanee, Bull Trout) and/or their redds. These data are to be used to estimate the numbers of fish utilizing the side channel for fall spawning and the types of habitat (habitat units) being used.

Overwintering Review (Years 1, 3 and 4): In order to evaluate suitability of habitat conditions, availability of essential overwintering habitat must be assessed. Overwintering habitat was assessed by conducting a one day review of fish use in the side channel during the winter to determine overwintering habitat availability and quality. The overwintering review is a qualitative assessment of fish use.

2 Methods

Year 4 monitoring involved the completion of seasonal water quality assessments, spring spawning, juvenile habitat use, fall spawning surveys, structural stability assessments, and an overwintering assessment (Table 2).

Table 2 Fish habitat effectiveness monitoring activities completed during Year 4 in the Aberfeldie side channel.

Activity	Date
Seasonal water quality assessment	17-Jun-12 30-Jul-12 23-Sep-12 14-Feb-13
Intra-gravel DO monitoring	30-Sep-12 to 14-Feb-13
Spring spawning assessment	28-May-12 08-Jun-12 17-Jun-12 22-Jun-12
Juvenile habitat use	July 30-31, 2012, August 23-24, 2012
Fall spawning survey	15-Sep-12 23-Sep-12 30-Sep-12 09-Oct-12
Structural stability assessment Overwintering assessment	09-Oct-12 14-Feb-12

2.1 Water Quality and Quantity Measurements

Water Quality

Water quality data were collected from eight sites during each season (n=32). The sites included one mainstem (run habitat) location and seven locations (glide, cascade, and pool habitats) within the side channel (Appendix 1). Data for the following water quality variables were collected: temperature (°Celsius), specific conductivity (µS/cm), salinity (ppt), pH, dissolved oxygen (DO; mg/L), percent DO and redox potential (mV). A YSI meter (Model 556 MPS) was used to measure these water quality variables from the water column in each habitat unit (HU) designated for collection of water quality data (i.e., WQ5/Bull River Mainstem, WQ4/pool HU 1-07, WQ 3/glide HU 1-12, WQ2/pool HU 2-02, WQ1/cascade HU 1-13, WQ6/pool HU 3-02, WQ7/glide HU 1-18, WQ8/pool HU 1-21). The manufacturer specifications can be found in Appendix 7.

Standard procedures for water quality data collection were followed. The YSI meter was calibrated prior to each day's use, to ensure accuracy. Calibration for specific conductivity, turbidity and pH measurements were completed in the lab, while DO was calibrated in the field in order to account for local barometric pressure conditions. During data collection, care was taken to minimize sediment suspension by carefully placing the probe at sampling locations with minimal disturbance to the substrate in locations upstream of crew activity. At each sites water quality parameters were measured at the bottom of the water column just above the substrate

Factorial ANOVA was performed to assess the effects of project year, season, habitat, and their interactions (factors) on water quality variables (dependent variables). Water quality data from all years of the study were pooled for each habitat unit and were compared with federal and provincial criteria and to suitable fish habitat conditions. All statistical analyses were performed with SPSS 16.0 statistical software. Assumptions of linearity, normality and independence were assessed prior to analyses.

Unless otherwise noted, mean values ± standard error (SE) are reported.

Water Quantity

Water Survey of Canada was contracted to design and install a staff gauge/weir during the side channel construction. Water levels were recorded at the weir during each site visit. The water level data were used to estimate discharge using the site specific rating curve provided by BC Hydro (S. Wilson, BCH, *pers. comm*.).

Water Velocity

Water velocity and depth were measured at spawning platforms located in glide habitats. Data were recorded in habitat units (HUs) 1-08, 1-12, 1-14, 1-16, 1-18, and 1-20 during the spring spawning, juvenile habitat use, and fall spawning assessments (Appendix 6). Water velocity and depth at two additional habitat units, HUs 1-03 (glide) and 1-06 (riffle) were recorded on July 30, 2013 and September 23, 2013 for comparison. ANOVA was conducted to compare water velocity among habitat units.

Intra-gravel Dissolved Oxygen Monitoring

Two HOBO U-26 dissolved oxygen (DO) data loggers were used to measure intra-gravel DO on the constructed side channel and on the Bull River mainstem. The data loggers were calibrated using a 0 mg/L DO solution of sodium sulphate and deployed on September 30th, 2013 during the Kokanee run. Each unit was placed in protective wire mesh tubes and secured to a heavy anchor using steel cable (Figure 3). The loggers were buried horizontally in the spawning substrate at a depth of approximately 15 to 20 cm, which is representative of the typical egg burial depth by *Oncorhynchus nerka* as reported in DeVries (1997) and Steen and Guinn (1999).

One of the DO loggers was placed at the spawning platform located at the downstream end of glide habitat unit 1-12 (HU 1-12). This site was selected based on water quality data from previous monitoring years, which indicated that surface water DO concentration at this location is consistently higher than at any other constructed spawning platform in the side channel. This finding was supported by the high number of Kokanee spawners observed at this particular location in Year 1 and 3 fall spawning assessments compared to other habitat units. The second DO logger was placed on the Bull River mainstem at the same location used to collect reference data during the Year 2 incubation success study. This site is located in a secondary channel, on the right downstream bank, immediately downstream of the powerhouse tailrace.

Intra-gravel DO was recorded during the entire Kokanee incubation period from September 30 to February 13, 2013. The recorded data were downloaded monthly to mitigate the risk of data loss in the event that the DO loggers were damaged.

During each site visit, additional intra-gravel DO data were collected using a YSI 556 multi-parameter water quality meter and a metal syringe to extract hyporheic water samples as described in Beblow and Guimond (2010) (Figure 4). The YSI 556 unit was calibrated during each site visit following the manufacturer's standard procedures. Three repeated measurements were taken in the vicinity of the buried DO loggers to enable QA/QC and comparison of the results obtained through the two techniques. Additional measurements were taken at two other spawning platforms in the side channel to assess the range of intra-gravel DO conditions available throughout the constructed habitat.

Figure 3 HOBO U-26 dissolved oxygen logger in protective wire mesh tube secured to anchor**.**

Figure 4 Extraction of hyporheic water sample from intra-gravel using syringe.

2.2 Structural Stability and Physical Parameters

Observations of channel stability were made throughout the monitoring period, and a full review of the side channel structural stability features was conducted on July 30, 2012. This date followed spring freshet and summer high flows, which is typically the period with the greatest potential to impact the channel stability. The features reviewed included:

- Stability and erosion of the berm on the left downstream boundary of the channel, running the extent of the riverside boundary;

- Effectiveness of the berm on the right downstream bank to protect the channel from the adjacent eroding slope; and
- Channel connectivity to the Bull River, including stability of the outlet protection groyne and erosion and/or scour at the channel entrance; and
- Erosion and stability of the bank along the Bull River at the upstream end of the off-channel habitat.

Other physical alterations to the channel (e.g., cattle usage of the area or beaver related activity) were also documented throughout the duration of the project.

2.3 Spring Spawning Survey

Spring spawning surveys were conducted by a two-person crew on May 31, June 8, and June 17, 2010. Hydrometric data from the Water Survey of Canada Station 08NG002 (Environment Canada 2011) located on the Bull River downstream of the side channel were used as a guide for timing spawning surveys. The sampling dates occurred during the descending limb of the hydrograph (Figure 5), which corresponds with a peak period for cutthroat spawning (Schmetterling 2000).

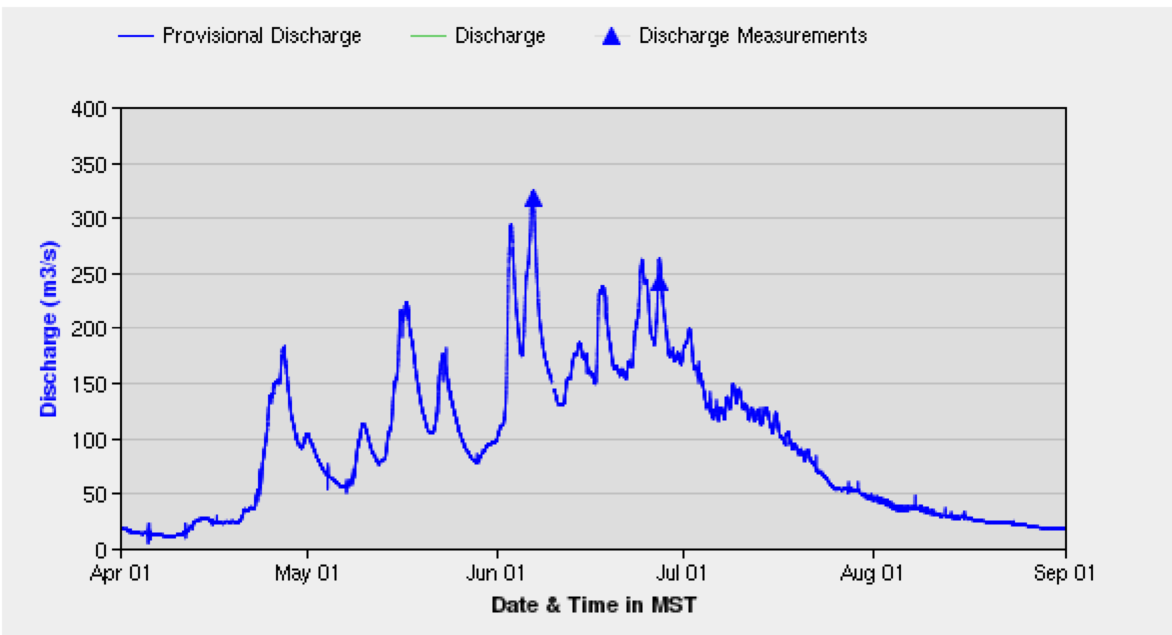

Figure 5 Bull River discharge and water levels from April 2012 to September 2012 and weekly sampling period for spring spawning fish (Environment Canada, 08NG002 Hydrometric Station, located at the Bull River near Wardner).

Spring spawning surveys were undertaken to identify if there were any spawning adults or associated redds in the side channel. Cutthroat Trout and Rainbow Trout were the species most likely to spawn in the side channel during the spring. A shore based survey technique was used, with observers viewing the stream from elevated positions along the channel bank. This method limited disturbances to potential spawning pairs.

Surveyors for the spawning assessment and all other fish sampling activities wore polarized glasses for optimal viewing through the water column. The spawning surveys were conducted by a two-person crew. The survey was initiated at the downstream extent of the side channel (at the channel's outlet to the Bull River) and progressed up the channel. The surveyors walked at the same pace, one on each side of the channel looking for redds and for fish. Adults were enumerated when observed. Crew members surveyed for indications of redds, such as cleaned areas, excavated pits with a mound on the downstream end, and sorted substrate with pit material being somewhat larger than the tail material. We expected to find redds in hydraulic transition areas such as glide/riffle or pool/riffle habitats, which provide optimal spawning locations due to hyporheic exchange (McPhail, 2007). Pools were also surveyed for the presence of fish or redds (e.g., along shoals and at outlets).

2.4 Juvenile Habitat Use

Juvenile habitat use was assessed over two periods in Year 4, once from July 30-31 and again from August 23-24. Site selection and sampling methods used in Years 1 and 2 were repeated, to allow for comparison of results among study years.

Given that daily temperature was not monitored for the Aberfeldie side channel after 2010, we determined appropriate sampling dates for the juvenile habitat use assessments using dates from previous years. Sampling dates from Years 1 and 2 were based on appropriate time periods for egg hatching and embryo development using accumulated temperature unit (ATU) calculations. Cutthroat Trout and Rainbow Trout spawn between mid-May and mid-June and require 475 to 500 ATUs for egg emergence (O. Schoenberger, *pers. comm*.). Year 1 and 2 ATUs were calculated using temperature data provided by BC Hydro for several theoretical development periods to ensure that appropriate time had elapsed for eggs to hatch and fry to emerge from the gravels (McPherson and Robinson, 2010, 2011). Dates of the Year 4 juvenile habitat use assessments were chosen to ensure a suitable length of time for fry emergence from gravels for enumeration in surveys.

Sampling of juvenile habitat was completed using two methods, depending on habitat-type:

1) **Riffle/glide habitats** (HUs 1-10 to 1-13, 1-18 to 1-20): electrofishing of enclosed sites; and,
2) **Pool habitats** (HUs 1-07 and 1-21): fyke traps and minnow traps set in enclosed sites.

Crews blocked off the upstream and downstream ends of the sites with mesh nets secured to the streambed prior to sampling to enclose sites.

Riffle/Glide Habitats

Two riffle/glide sections were sampled using electrofishing techniques. Each site is representative of riffle, glide, and cascade habitats in upper (above the weir) and lower (below the weir) portions of the channel that each extended approximately 100 m and excluded the deep pools. The lower site, EF-1, included HU 1-10 through to HU 1-13 (three glides and three riffles/cascades), and had a total length of 108 m (*See* Appendix 1). The upper electrofishing site, EF-2, included HU 1-18 to the upper end of HU 1-20 (two glides and one cascade) and had a total length of 116 m.

A Smith-Root LR-24 backpack electrofisher was used for closed sampling of the riffle/glide sections (set at a voltage of 300 volts and frequency of 65 hertz). Consistent with sampling in previous years, the three-pass depletion technique (Zippin 1958) was used. The following steps were applied to complete the three-pass depletion method sampling:

- Downstream and upstream stop nets were installed to prevent immigration and/or emigration in or out of the site;
- Starting at the downstream end of a closed site, all available fish habitat was sampled in a single pass within the enclosed site;

- Fishes caught were measured (fork length, mm) and weighed (g). Captured fishes were not released until after all passes had been completed;
- Up to two additional passes were immediately completed using the same technique. Sampling ended if no fish were captured after the first and second passes. A minimum of two passes were conducted for verification purposes. Prior to conducting each pass, crews allowed fine suspended sediments to subside, to allow for maximum visibility.

Pool Habitats

The two inline pool habitats, HU 1-07 and HU 1-21, were sampled with fyke and minnow traps. Each pool had one fyke trap and one minnow trap that were baited and set at a minimum depth of 1.0 m. Soak time was up to two 24 hour sampling periods per site. No fish were captured following the first 24 hours so traps and nets were removed.

Fish Handling and Data

Standard fish handling techniques were used to minimize fish stress and mortality. Captured fish were placed in a bucket containing stream water and measurements were recorded as quickly as possible. Fish were provided recovery time before being returned to the side channel.

Cutthroat Trout and Rainbow Trout were the juvenile species most likely to be utilizing the side channel. Since Cutthroat and Rainbow Trout juveniles can be hard to distinguish from one another, Vast was prepared to voucher up to five fish samples requiring laboratory verification of species.

Fish capture data were entered into the provincial Field Data Information System (FDIS) data entry tool as a requirement of Fish Collection Permit No. CB12-79194 obtained from the BC Ministry of Environment (BC MoE) prior to the commencement of the project.

Fish Population Density Estimates

Assessment of summer juvenile habitat use is scheduled to be conducted in Years 1, 2, 4, and 5 at reference sampling locations established in Year 1. Comparisons of Year 1, 2, and 4 population density and biomass estimates were made using three-pass removal data.

Assumptions the Closed Population Removal (Hayes *et al. 2007*) are:

- All fishes are equally vulnerable to capture throughout all passes;
- All captured fishes are unable to re-enter the population until all passes are complete;

Relative abundance (number/100 m^2) and biomass (g/100 m^2) of fish within each sample area were calculated using the mean wetted width and site length.

2.5 Fall Spawning Survey

The timing of the Fall Spawning Survey was based on local observations and historical data of spawning events in the Bull River. A two-person crew completed the fall spawning surveys of all habitat units on September 15, 23, 30, October 9, and 12, 2012. Species likely to spawn in the side channel during this period were primarily Kokanee, Eastern Brook Trout, and Bull Trout. Surveys were conducted from shore to view the in-stream environment from elevated positions along the channel bank. This method reduces disturbance to potential spawning pairs. Two different approaches were used for spawning surveys depending on the fish species being surveyed. Bull Trout surveys were based on counts of redds, while Kokanee and Eastern Brook Trout surveys were based on counts of individuals. Bull Trout construct large, well-defined redds, which can be counted easily to estimate the number of spawning individuals. Conversely, Kokanee and Eastern Brook Trout spawn in dense groups during which redd construction may overlap and be indistinguishable from one another. Hence, counts of individuals are a more accurate survey method for Kokanee and Eastern Brook Trout than counts of indistinct redds, which could lead to under-estimation of spawning individuals.

Surveyors wore polarized glasses to minimize glare on the water surface during spawning assessments. Surveys were initiated at the downstream end of the side channel (at the channel's outlet to the Bull River) and continued in an upstream direction. During the surveys, surveyors walked slowly along the bank on either side of the channel. The surveyors looked for redds or for fish. Given the clarity of the water and the shallow depth of the channel, spawning individuals were easily enumerated and fish counts can be considered highly accurate.

Fish mortality in the side channel was also assessed. This review included enumerating kelts in each habitat unit and periodically dissecting fish to identify the reproductive status of females and to determine whether eggs had been successfully deposited.

To assess spawning habitat preferences of fish, the numbers of spawning fish were compared among habitat units. The number of fish per square meter (fish density) was calculated for each habitat unit in order to account for the varying size of each unit.

$$\text{Nb of Fish per m}^2 = \frac{\text{Nb of fish in Habitat Unit}}{\text{Surface Area of Habitat Unit (m}^2\text{)}}$$

Weighted number of individuals was compared among Years 1, 3, and 4 with ANOVA for each habitat type and unit. These tests will characterize trends in preference of fish for certain habitat types or habitat units. Results will help understand spawning habitat use in the side channel and may provide information upon which to base future operating decisions.

Multivariate tests were conducted to assess the influence of water quality predictor variables on spawning data. Associations between water quality variables (e.g., temperature, discharge) and spawning data (i.e., number of spawning individuals/redds) during a particular spawning year were evaluated.

Spawner Enumeration

The area-under-the-curve (AUC) method was used to convert the periodic counts of spawning Kokanee in the side channel to an estimate of escapement. Escapement, in this case, is the number of spawning Kokanee that accessed the Aberfeldie side channel in 2012. Several studies have discussed methods for estimating salmon escapement based on the area-under-the-curve method (e.g., Irvine *et. al.* 1992, English *et al*. 1992, Bue *et al*. 1998, Szerlong and Rundio 2007). These studies employed various sampling methods, but the common feature of all studies was the practice of determining the quotient of the AUC and the mean residence time (RT) of fish in the survey area to estimate escapement. J. Irvine, Fisheries and Oceans Canada, (*pers. comm.*) was consulted on how to best analyse Kokanee spawner data, given the methods employed for this project. The approaches detailed below were recommended.

The RT refers to the average time that fish spend in a given area. For the purposes of this study, RT refers to the average time mature Kokanee spend in the Aberfeldie side channel prior to death. Determination of RT is stream specific and can vary from year to year based on physical conditions (e.g., stressors such as temperature may decrease RT) (English *et al.* 1992).

For this study, RT was approximated to range from 7 to 10 days (mean = 8.5 days) based on Aberfeldie field observations and Kokanee data collected by BC MoE at the Redfish side channel in West Kootenay (J. Bell, *pers. comm*.). However, based on migration distance alone, the residence time is likely higher at the Redfish channel since it is within 500 m of Kootenay Lake, while the Aberfeldie side channel is 12 km upstream of the Bull River. Given that the RT of Aberfeldie Kokanee is presumed to be lower than that of Redfish Kokanee, our RT estimate is likely high, which consequently may lead to an under-estimation of escapement (see below).

The numbers of spawning Kokanee observed on each field visit were plotted on an x-y scatterplot. A 2nd-order polynomial regression was used to estimate the shape of the curve and extrapolate the start and end dates of the run. The AUC was determined by calculating the integral of $y(x)$ between the start and end dates of the run:

$$AUC = \int_{Start}^{End} y(x)dx$$

Escapement was estimated by dividing the AUC (fish*days) by the mean RT of 8.5 days. As discussed above, this calculated escapement is likely an underestimate given that the RT is based on Redfish Kokanee, which is likely higher than that of Aberfeldie Kokanee.

2.6 Overwintering Assessment

The overwintering assessment was initially conducted on February 14, 2012. The weather leading up to this assessment was warmer than that suggested in the monitoring terms of reference (BC Hydro 2008a), which outlines that the maximum air temperature should preferably be -7.5 ^{o}C or colder for five days prior to the assessment. Mean temperature was -4.1 ^{o}C over the five day period at the Bull River prior to the assessment (Environment Canada 2012). On the day of the assessment, mean temperature was -3.5 ^{o}C.

Seasonal water quality data (from the 8 sites) were also collected during the overwintering assessment (Appendix 3). Along with water quality data, the winter assessment also included details on water levels, ice depth in pools, temperature, and DO-profiles beneath the ice. A qualitative assessment of the channel was also conducted that characterized outlet connection to the mainstem, extent of ice coverage, and quality of winter refuge for fish.

2.7 Photo Documentation

Field monitoring activities for this project were photographed and indexed (Appendix 2). The index and photos have been provided in chronological order.

3 Results

3.1 Water Quality

Field data collected during the seasonal water quality assessments are provided in Appendix 3.

Variation in water quality values between year, season, and habitats were tested for statistical significance using factorial ANOVA. Results of these tests are summarized in **Error! Reference source not found.** and discussed in the sections below.

The results from the factorial ANOVA indicated that the factor, season, and the interaction factor, year-season, were consistently significant across all water quality variables, except for specific conductance and dissolved oxygen (**Error! Reference source not found.**). To investigate the influence of the season and year-season factors further, we conducted one-way ANOVAs for the influence of the factor year on water quality variables for each habitat type and season. The results of the one-way ANOVAs are presented in Table 3.

Temperature, oxygen, and pH were the only water quality parameters with guidelines by the Canadian (CCME 2007) and British Columbia (BC MoE 2006) governments. Based on these guidelines, the recorded data show that the conditions in the Aberfeldie side channel in 2012 were sufficient to meet the requirements for rearing and reproduction of fish species.

Table 3 F-values from one-way ANOVAs examining the effects of year on water quality variables for each habitat type and season for Year 4 of the Aberfeldie side channel study. Asterisks indicate significant effects at the Holm modified Bonferroni corrected level (*p < 0.007, **p < 0.001). Degrees of freedom and direction of significant differences are shown in parentheses. 'Y1' = study period 2009-2010; 'Y2' = study period 2010-2011; 'Y3' = study period 2011-2012; 'Y4' = study period 2012-2013.

Dependent Variables ($df_{denominator}$)			**Source of variation ($df_{numerator}$)**
WQ Variable	Habitat Type-Season		Year (2)
Temp (^{o}C)	Pool	Fall (15)	33.140** (Y1<Y2, Y1<Y3, Y1<Y4)
		Winter (15)	ns
		Spring (15)	ns
		Summer (15)	ns
	Glide	Fall (7)	55.666* (Y1<Y2, Y1<Y3, Y1<Y4)
		Winter (7)	36.772* (Y2<Y1, Y2<Y3, Y2<Y4)
		Spring (7)	ns
		Summer (7)	ns
pH	Pool	Fall (15)	11.850** (Y1<Y2, Y3<Y2, Y4<Y2)
		Winter (15)	ns
		Spring (15)	ns
		Summer (15)	ns
	Glide	Fall (7)	ns
		Winter (7)	89.72** (Y1<Y2, Y1<Y3, Y4<Y2)
		Spring (7)	ns
		Summer (7)	ns
Dissolved Oxygen (mg/L)	Pool	Fall (15)	ns
		Winter (15)	ns
		Spring (15)	ns
		Summer (15)	10.117* (Y1<Y4, Y2<Y4, Y3<Y4)
	Glide	Fall (7)	ns
		Winter (7)	ns
		Spring (7)	ns
		Summer (7)	ns
% Dissolved Oxygen	Pool	Fall (15)	ns
		Winter (15)	ns
		Spring (15)	ns
		Summer (15)	8.779* (Y1<Y4, Y2<Y4, Y3<Y4)
	Glide	Fall (7)	ns
		Winter (7)	56.294** (Y1<Y3, Y2<Y3, Y4<Y3)
		Spring (7)	ns
		Summer (7)	ns
Specific Conductance (µS/cm)	Pool	Fall (15)	ns
		Winter (15)	ns
		Spring (15)	ns
		Summer (15)	ns
	Glide	Fall (7)	ns
		Winter (7)	61.100** (Y4<Y1, Y4<Y2, Y4<Y3)
		Spring (7)	59.868** (Y1<Y2, Y1<Y3, Y4<Y2, Y4<Y3)
		Summer (7)	ns
Salinity (ppt)	Pool	Fall (15)	ns
		Winter (15)	ns
		Spring (15)	ns
		Summer (15)	ns
	Glide	Fall (7)	ns

Dependent Variables ($df_{denominator}$)			**Source of variation ($df_{numerator}$)**
WQ Variable	Habitat Type-Season		Year (2)
		Winter (7)	42.378* (Y4<Y1, Y4<Y2, Y4<Y3)
		Spring (7)	45.130** (Y1<Y2, Y1<Y3, Y4<Y2, Y4<Y3)
		Summer (7)	ns
Redox (mV)	Pool	Fall (15)	699.980** (Y1<Y4, Y2<Y4, Y3<Y4)
		Winter (15)	12.967** (Y1<Y2, Y1<Y4)
		Spring (15)	ns
		Summer (15)	21.951** (Y1<Y4, Y2<Y4, Y3<Y4)
	Glide	Fall (7)	606.410** (Y1<Y4, Y2<Y4, Y3<Y4)
		Winter (7)	ns
		Spring (7)	ns
		Summer (7)	ns

Water temperature

There were significant differences in temperature for season, habitat, and project year-season interaction (**Error! Reference source not found.**; all p <0.007). All habitat units of the side channel consistently had higher temperatures than the Bull River mainstem over all seasons and years (Figure 6). As expected, summer temperatures were significantly higher than other seasons (p<0.001) while winter temperatures were significantly lower than other seasons (p<0.001).

For both pools and glides, there were significant differences in fall temperature among study years. Fall temperatures in Year 1 were lower than temperatures in Years 2, 3, and 4. Glide temperatures were also significantly different among years during winter; Year 2 temperatures were lower than Year 1, 3, and 4 temperatures (Table 3).

In spring 2012, during the Westlope Cutthroat breeding season, mean water temperatures exceeded the optimal cutthroat spawning range in all habitat units (Figure 7). Side channel temperatures were within the optimal range for Cutthroat Trout rearing (7.0-16.0 ^{o}C; BC MoE 2001) or Kokanee spawning (12.0 ^{o}C; BC MoE 2001).

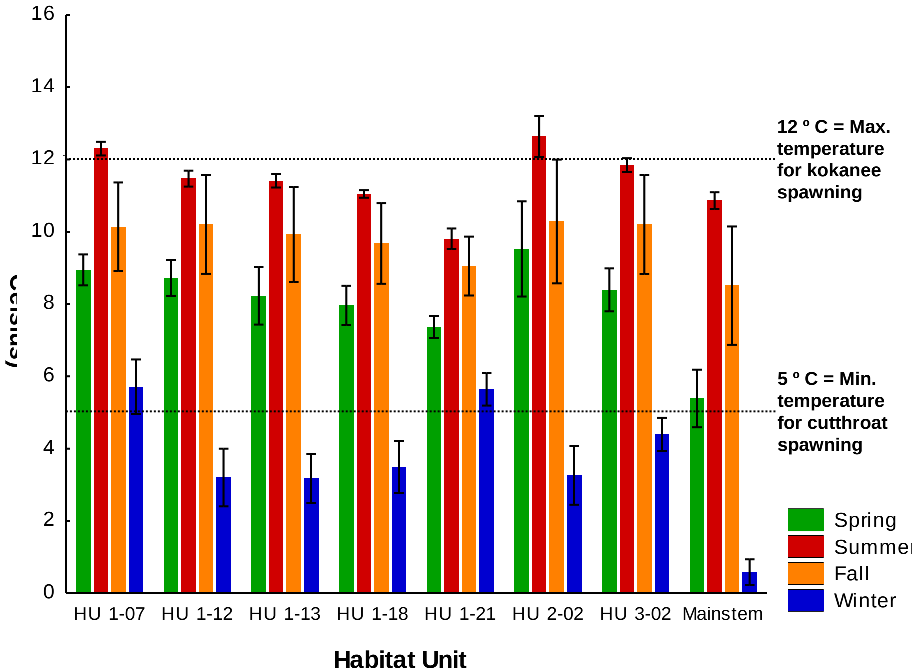

Figure 6 Mean water temperature (°Celsius) at habitat units sampled for water quality assessments of the Aberfeldie side channel. Dashed lines mark the maximum temperature for kokanee spawning (12° C) and maximum temperature for cutthroat spawning (5°C), respectively (BC MoE, 2001). Error bars represent ± standard error (SE).

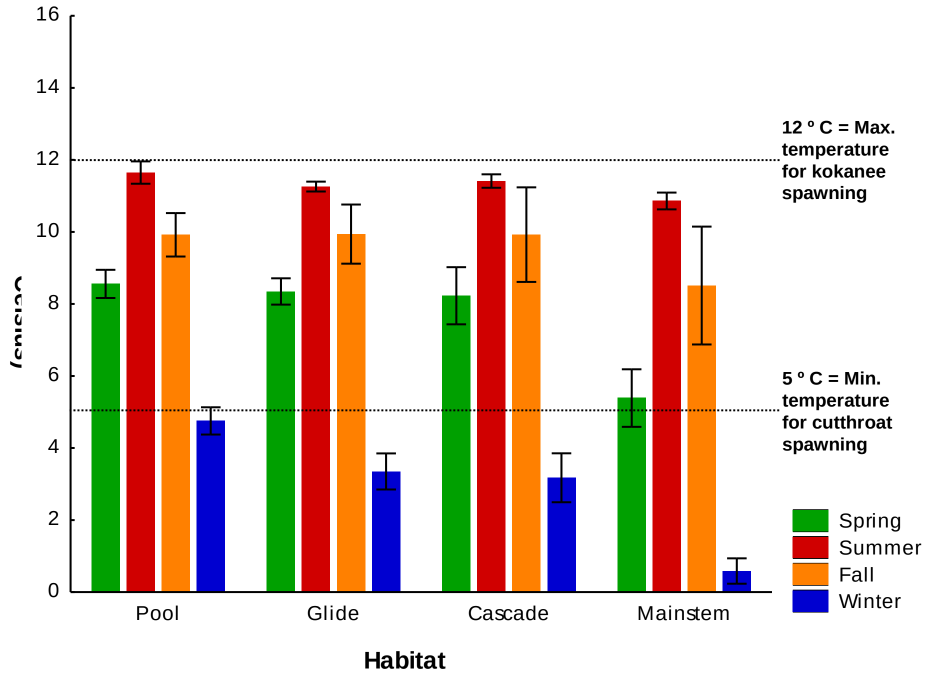

Figure 7 Mean water temperature (° Celsius) at habitats (pool, glide, cascade, and Bull River mainstem) sampled for water quality assessments of the Aberfeldie side channel. Dashed lines mark the maximum temperature for kokanee spawning (12° C) and maximum temperature for cutthroat spawning (5° C), respectively (BC MoE, 2001). Error bars represent ± standard error (SE).

pH

There were significant differences in pH by project year, season, and project year-season interaction (**Error! Reference source not found.**; all p <0.007). Mean pH during Year 2 was significantly higher than pH during other study years (p<0.001). Mean pH during summer was significantly lower than mean pH during fall (p<0.007).

There were significant differences in pH during the fall for pools and during the winter for glides. In pools during the fall, Year 2 pH was higher than pH levels for Years 1, 3, and 4. Winter glide pH was lowest in Year 1 and highest in Year 2 (Table 3)

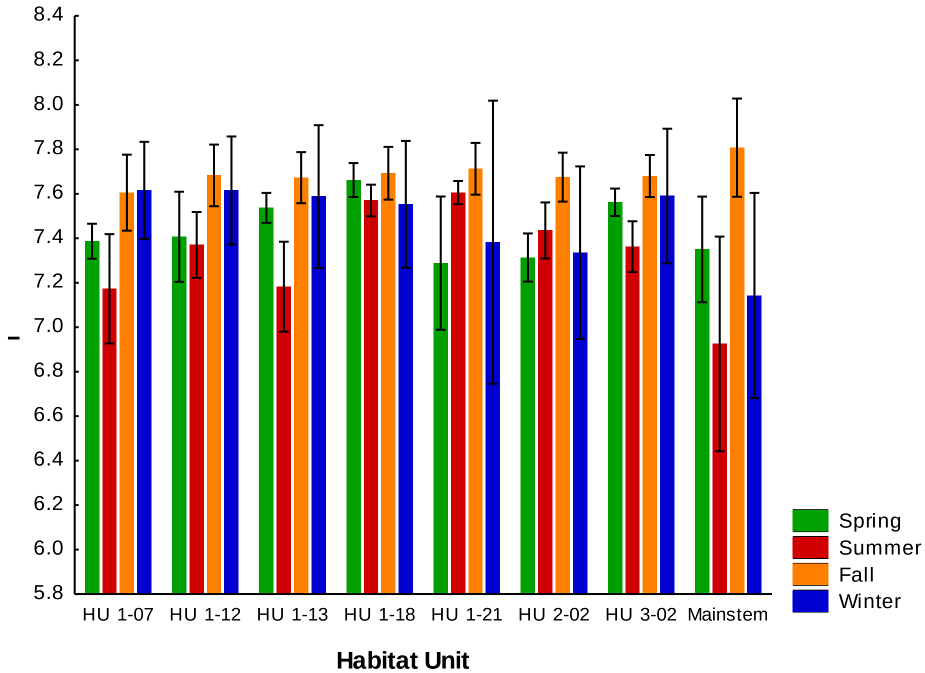

Figure 8 Mean pH at habitat units sampled for water quality assessments of the Aberfeldie side channel. Error bars represent ± standard error (SE).

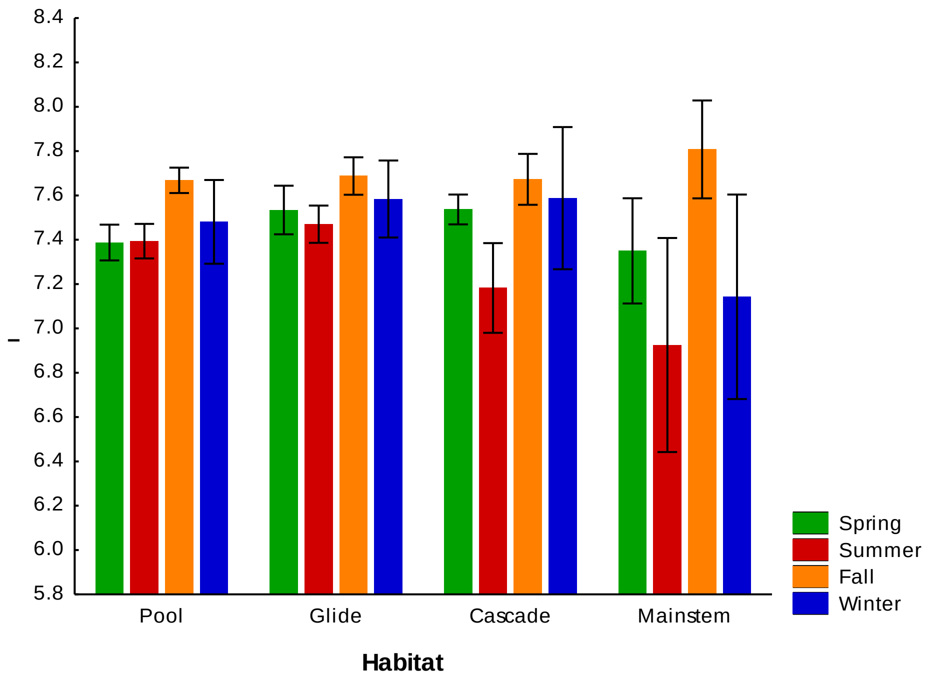

Figure 9 Mean pH of habitats (pool, glide, cascade, and Bull River mainstem) sampled for water quality assessments of the Aberfeldie side channel. Error bars represent ± standard error (SE).

Dissolved oxygen (DO)

There were significant differences in dissolved oxygen concentration (DO) and % DO by project year, season, habitat, and project year-season interaction (**Error! Reference source not found.**; all p <0.001). All habitat units of the side channel consistently had lower DO than the Bull River mainstem over all seasons and years (Figure 10, Figure 11, Figure 12, and Figure 13). Mean DO was highest during spring (p<0.001) and in the mainstem (p<0.001), whereas it was lowest in pools (p<0.001) (Tukey's HSD tests).

Dissolved oxygen levels were significantly different among summer project years in pool habitats. Summer pool DO was highest in Year 4 as compared to Years 1, 2, and 3 DO levels (p<0.007). As well, DO levels in winter glide habitats were significantly higher in Year 3 than in Years 1, 2, and 4 (p<0.007). There were no significant differences between DO levels during other seasons.

The BC MoE water quality guidelines recommend at least 5 mg/L DO concentration to support aquatic life and at least 9 mg/L to support buried embryos and alevins life stages. The HUs that reached the minimum DO level required for successful development of buried embryos/alevins (9 mg/L) were glide HUs 1-12, 1-13, 1-18, and pool HUs 1-21 and 3-02 during spring. Although DO concentrations measured in spring exceeded the minimum requirement for aquatic life of 5 mg/L in all habitat units, only habitat units 1-12 (the same HU where the intra-gravel DO was measured) and 1-13 (two adjacent glides) consistently met this minimum requirement during all four seasons. Measured DO concentrations were particularly low in HU 1-21 and 3-02 (two most upstream pools) with summer levels as low as 2.93 mg/L. Comparatively, DO concentration in the Bull River mainstem exceeded 9 mg/L during all seasons.

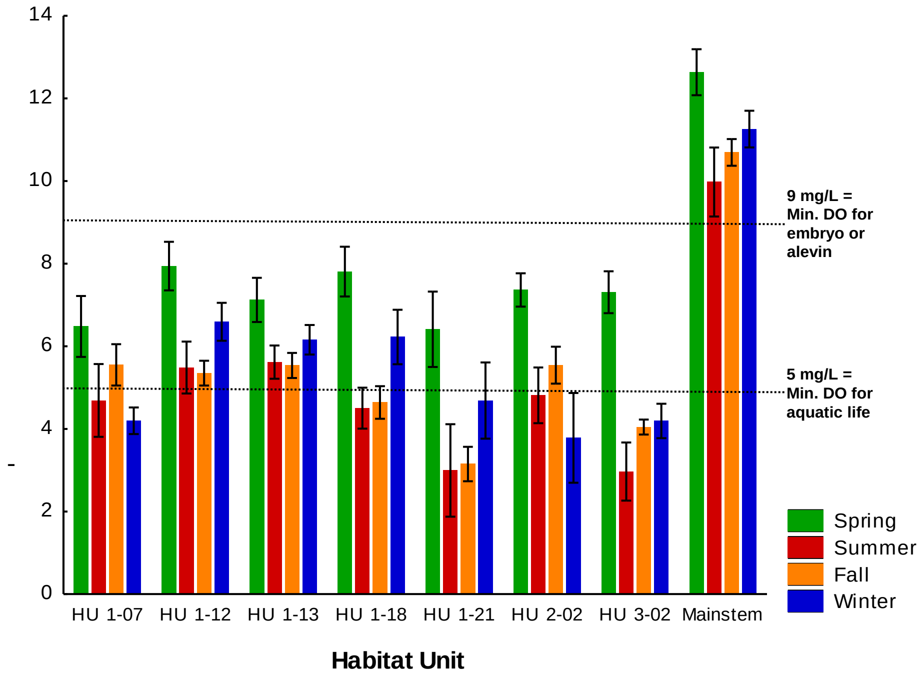

Figure 10 Mean dissolved oxygen concentration (mg/L) at habitat units sampled for water quality assessments of the Aberfeldie side channel and Bull River mainstem. Dashed lines indicate the minimum dissolved oxygen concentration required for embryo and alevin rearing (9 mg/L) and minimum dissolved oxygen concentration required for aquatic life (5 mg/L) (BC MoE, 2001). Error bars represent ± standard error (SE).

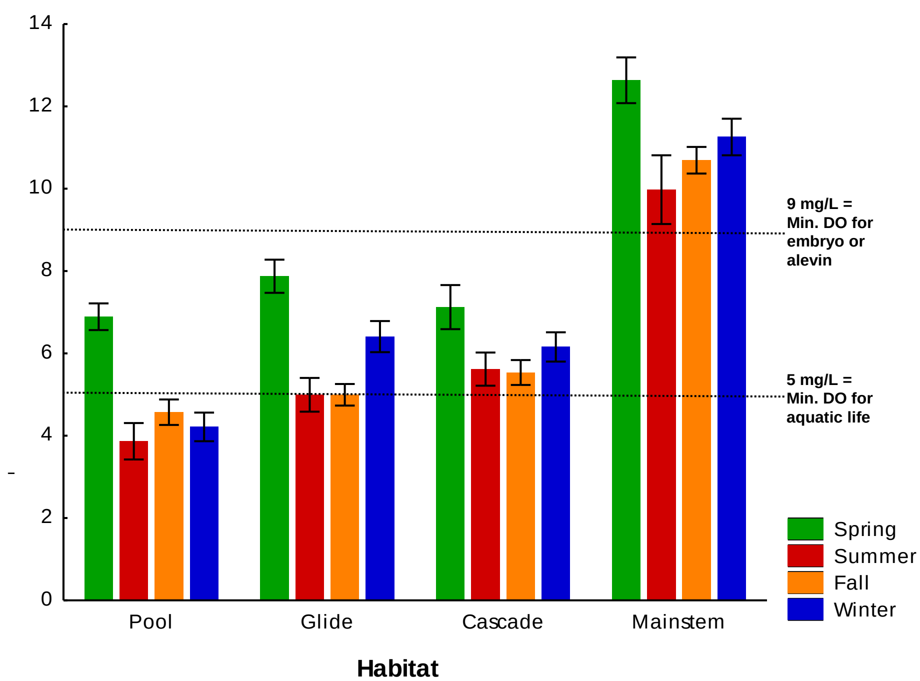

Figure 11 Mean dissolved oxygen concentration (mg/L) at habitat types sampled for water quality assessments of the Aberfeldie side channel and Bull River mainstem. Dashed lines indicate the minimum dissolved oxygen concentration required for embryo and alevin rearing (9 mg/L) and

minimum dissolved oxygen concentration required for aquatic life (5 mg/L) (BC MoE, 2001). Error bars represent ± standard error (SE).

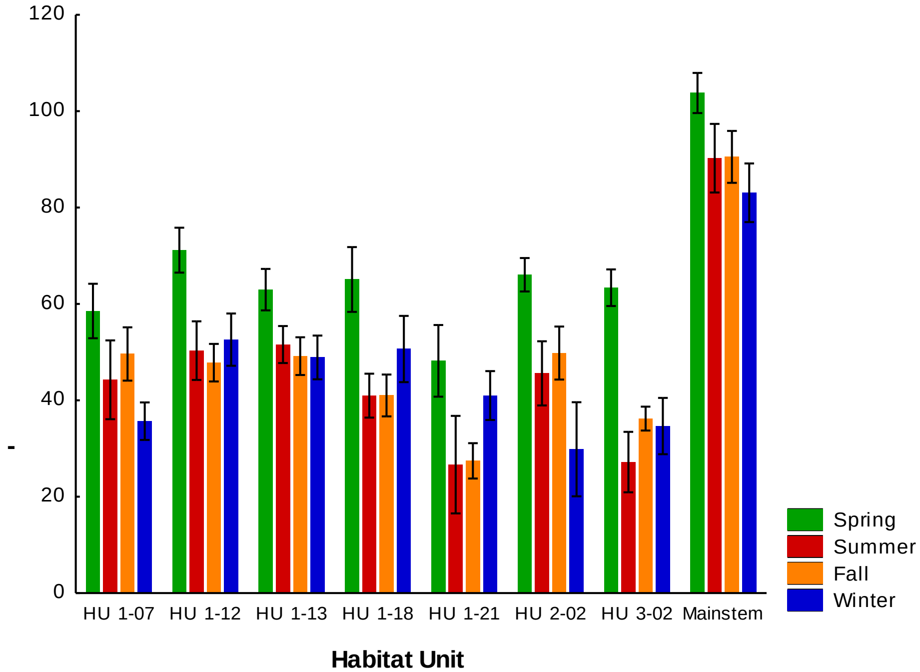

Figure 12 Mean dissolved oxygen saturation (%) at habitat units sampled for water quality assessments of the Aberfeldie side channel and Bull River mainstem. Error bars represent ± standard error (SE).

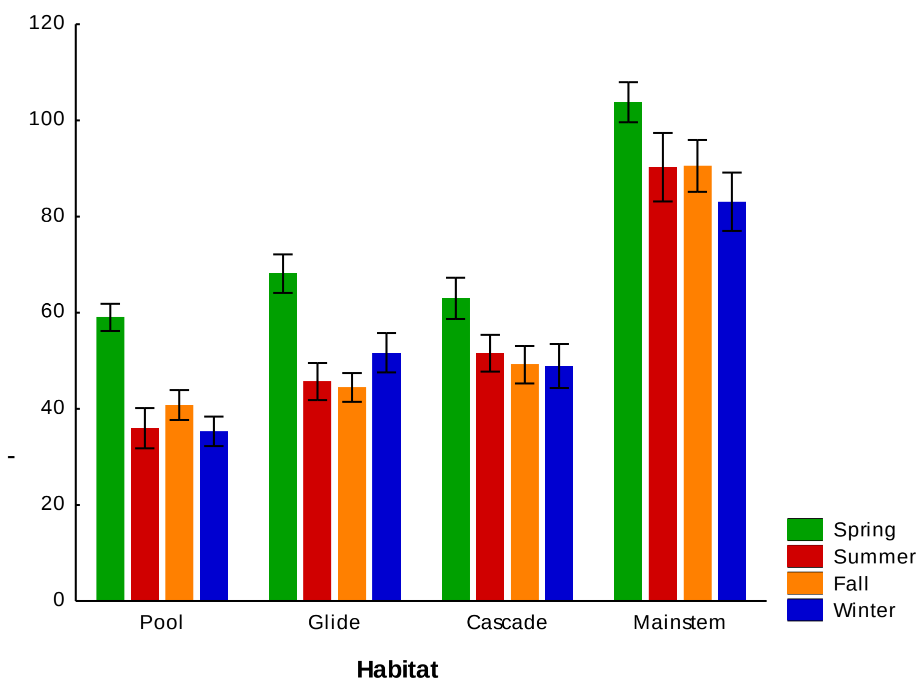

Figure 13 Mean dissolved oxygen saturation (%) at habitat types (pool, glide, cascade, and Bull River mainstem) sampled for water quality assessments of the Aberfeldie side channel. Error bars represent ± standard error (SE).

Specific Conductance

There were significant differences in specific conductance by project year, habitat, and project year-season interaction (**Error! Reference source not found.**; all p <0.007). All habitat units of the side channel consistently had higher specific conductance than the Bull River mainstem over all seasons and years, except during fall and winter (Figure 14). Habitat unit 1-07 (Pool) had significantly higher specific conductance than all other habitat units, except pool habitat unit 2-02 (p<0.007; Figure 14). Pool habitats also had significantly higher specific conductance than other habitats (p<0.002; Figure 15).

Specific conductance was significantly different among spring and winter project years for glide habitats. Spring glide specific conductance was higher in Years 2 and 3 than in Years 1 and 4 (p<0.001). As well, winter glide specific conductance was lowest in Year 4 as compared to all other years (p<0.007).

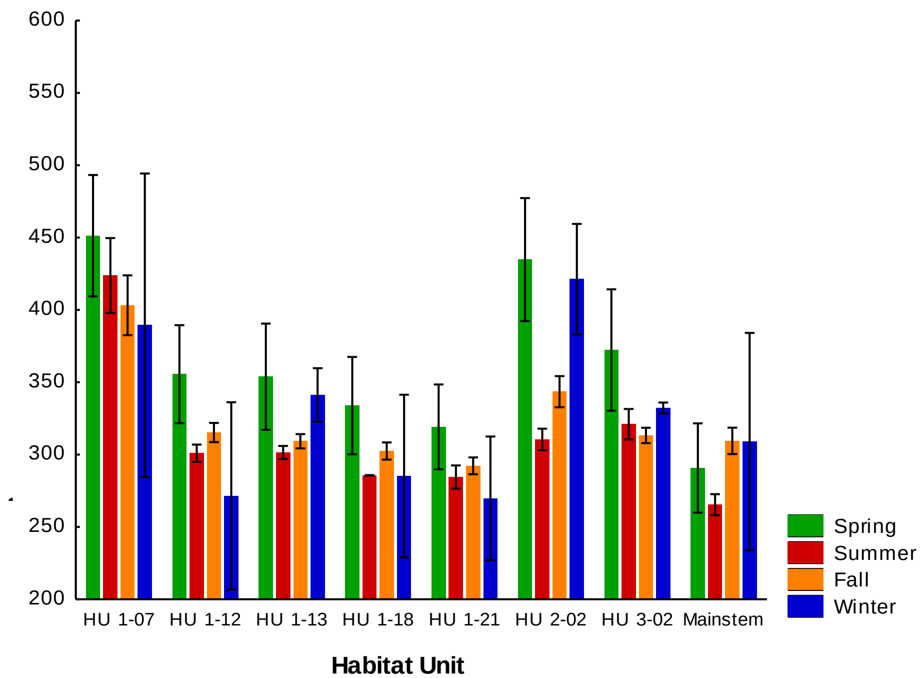

Figure 14 Mean specific conductance (µS/cm) at of habitat units sampled for water quality assessments of the Aberfeldie side channel and Bull River mainstem. Error bars represent ± standard error (SE).

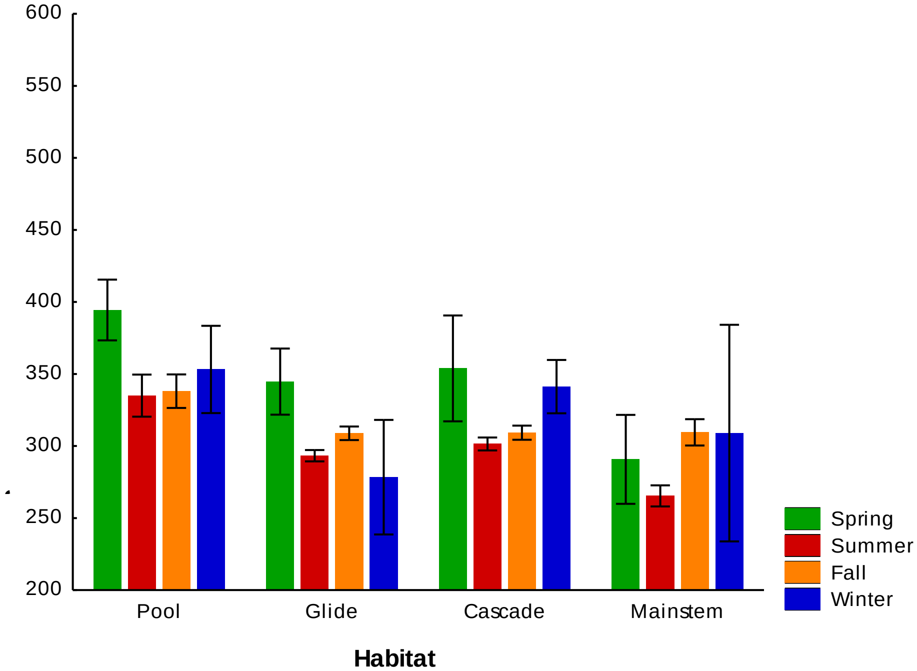

Figure 15 Mean specific conductance (µS/cm) of habitats (pool, glide, cascade, and Bull River mainstem) sampled for water quality assessments of the Aberfeldie side channe and Bull River mainstem. Error bars represent ± standard error (SE).

Salinity

There were significant differences in salinity by season, habitat and project year-season interaction (Table 1; all p <0.007). All habitat units of the side channel had higher salinity than the Bull River mainstem during spring and summer (Figure 16). Similarly to the trends for specific conductance, habitat unit 1-07 (Pool) had significantly higher salinity than most other habitat units (p<0.007; Figure 13), except for Pools 2-02 and 3-02. Pool habitats also had significantly higher salinity than the mainstem (p<0.001; Figure 17).

Salinity levels were significantly different among project years during winter and spring in glide habitats. Year 4 winter glide salinity was significantly lower than winter glide salinity during Years 1, 2, and 3 (p<0.007; Table 3). Spring glide salinity was higher during Years 2 and 3 than during Years 1 and 4 (p<0.007; Table 3).

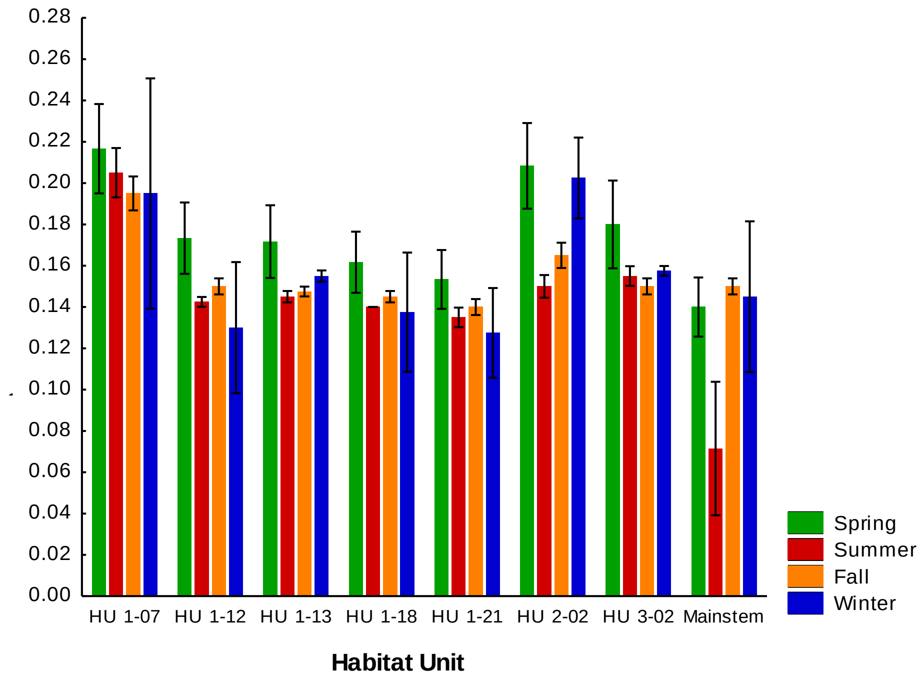

Figure 16 Mean salinity (ppt) of habitat units sampled for water quality assessments of the Aberfeldie side channel and Bull River mainstem. Error bars represent ± standard error (SE).

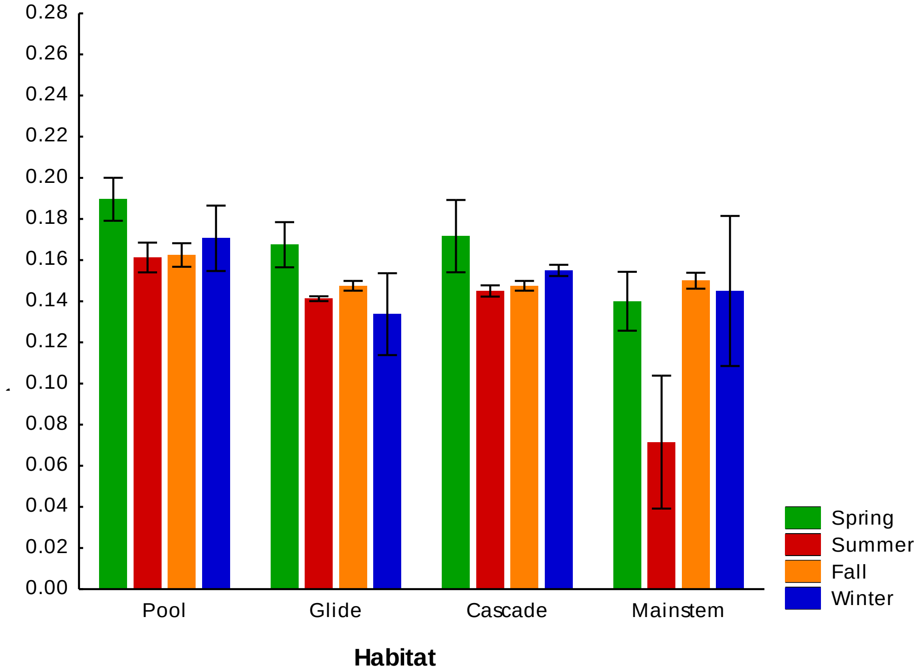

Figure 17 Mean salinity (ppt) of habitats (pool, glide, cascade, and Bull River mainstem) sampled for water quality assessments of the Aberfeldie side channel**.** Error bars represent ± standard error (SE).

Redox Potential

There were significant differences in redox potential by project year, season, and project year-season interaction (**Error! Reference source not found.**; all p <0.007). Redox potential was significantly higher in Year 4 than other study years (p<0.001). Redox potential during winter was significantly higher than other seasons (p<0.001; Figure 18 and Figure 19).

For pools, there were significant differences in fall, winter, and summer redox levels among study years. Pool redox values during fall and summer were highest during Year 4 compared to other study years (p<0.001). Winter pool redox values during Year 1 was lower than winter pool redox values during Year 2 and 4 (p<0.007). Glide redox values during fall highest during Year 4 compared to other study years (p<0.001).

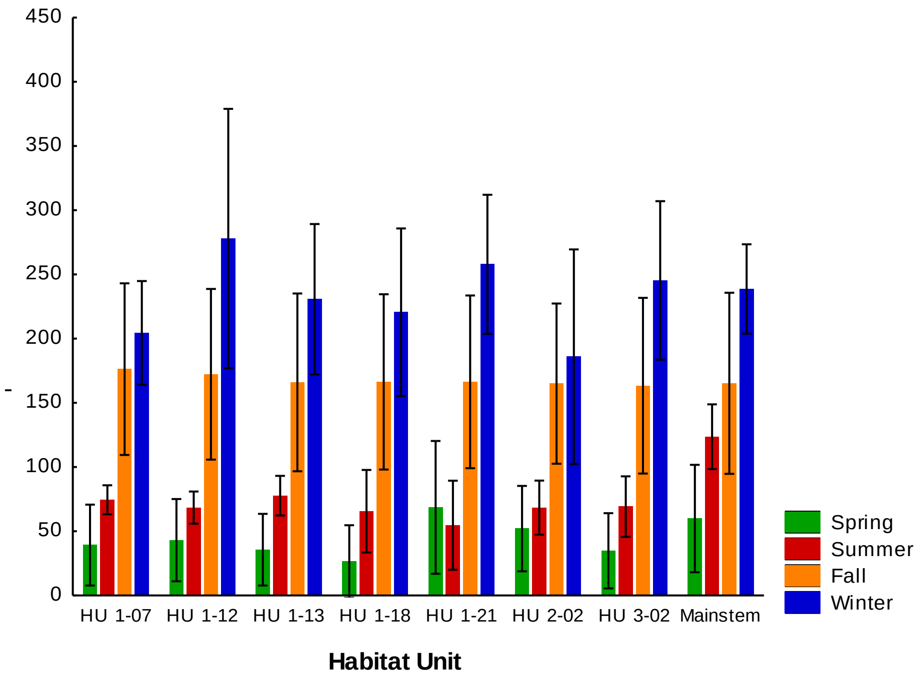

Figure 18 Mean redox potential (mV) at habitat units sampled for water quality assessments of the Aberfeldie side channel and Bull River mainstem. Error bars represent ± standard error (SE).

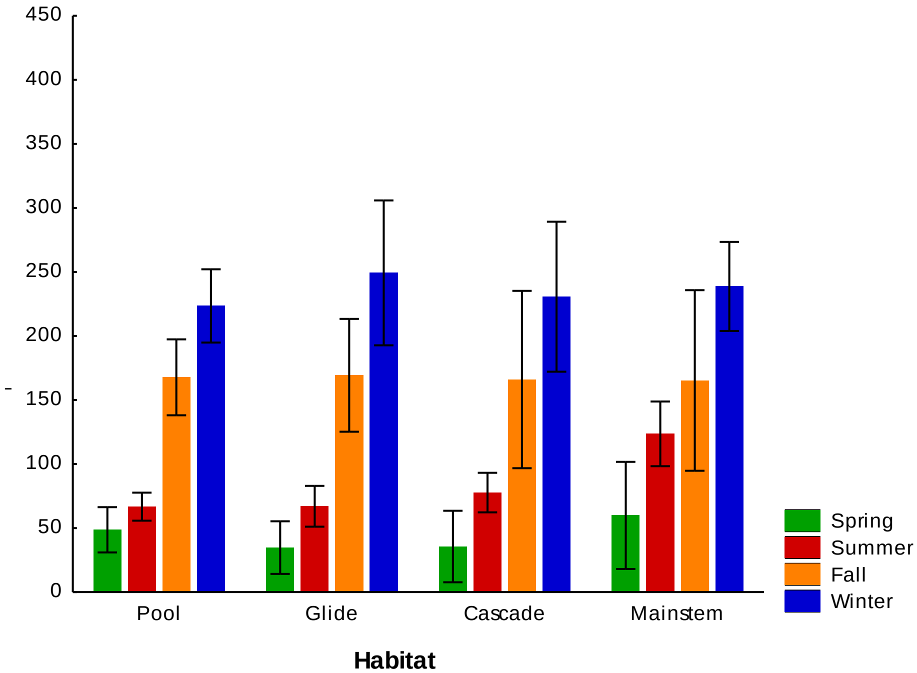

Figure 19 Mean redox potential (mV) of habitats (pool, glide, cascade, and Bull River mainstem) sampled for water quality assessments of the Aberfeldie side channel. Error bars represent ± standard error (SE).

Algae

Similarly to Year 1, 2, and 3 of the monitoring program, algae growth was observed in the Aberfeldie side channel (Figure 20). Algae were also observed on gravel and water surfaces in glide HUs 1-10, 1-12, 1-14, 1-16, and 1-20 and pool HUs 1-07, 2-02, 3-02, and 1-21. *Chara* spp. mats were also observed in HU 1-21, which had the most abundant algae growth. Water clarity was poor in pool HU 1-07 but improved later in the season

Figure 20 Algal growth on water surface and bottom surface in HU 1-21 Pool (May 28, 2012). Chara was also observed growing on the pool bottom**.**

Water Quantity and Water Velocity

There was no significant difference in discharge of the Aberfeldie side channel among project years ($p<0.05$). Figure 21 shows discharge trends measured in Years 1, 2, 3, and 4 of the monitoring program. During Year 4, discharge ranged from a low winter discharge of 0.001 m^3/s measured on January 19, 2012, to a spring peak of 0.04 m^3/s on June 17, 2012. Discharge gradually decreased through the summer, reaching a low of 0.006 m^3/s on September 23, 2012. Through the fall and winter, levels dropped to a low of 0.005 m^3/s, measured during the overwintering assessment on February 14, 2012. These observations are consistent with the fluctuations of the Bull River mainstem discharge measured during the same period (Environment Canada 2012; Figure 22). Mean discharge in Year 4 was 0.019 ± 0.01482 m^3/s. Water levels recorded at the hydrometric weir and calculated discharges are provided in Appendix 4 F-values from factorial ANOVAs examining the effects of project year, season, habitat, and their interaction on water quality variables (temperature, pH, dissolved oxygen, specific conductivity, salinity, and redox) for Year 4 of the Aberfeldie study. Asterisks indicate significant effects at the Holm modified Bonferroni level: *$p < 0.007$. Degrees of freedom are shown in parentheses

Dependent Variables ($df_{denominator}$)	**Source of variation ($df_{numerator}$)**						
Water Quality Variables	Year (2)	Season (3)	Habitat (3)	Year Season (6)	Year Habitat (4)	Season Habitat (6)	Year Season Habitat (12)
Temp (°C)	2.95	137.12*	11.43*	9.05*	0.14	1.44	0.16
pH	13.04*	6.53*	1.29	4.41*	0.66	1.01	1.93

Dissolved Oxygen (mg/L)	3.50*	15.18*	100.53*	2.74*	0.21	1.05	0.54
% Dissolved Oxygen	5.93*	12.54*	88.78*	4.68*	0.32	0.80	0.52
Specific Conductance (µS/cm)	6.56*	4.10	5.38*	3.81*	0.20	0.56	0.37
Salinity (ppt)	3.75	7.12*	7.93*	4.59*	0.37	1.12	0.57
Redox (mV)	14.34*	35.67*	0.33	11.85*	0.36	0.25	0.38

Appendix 5.

Appendix 6 summarizes water velocity and depth recorded from each habitat unit. Mean water velocity across all glide habitats was 0.10 (± 0.075 SD) m/s. There was a highly significant difference in water velocity among habitat units ($p<0.01$). The mean water velocity of habitat unit 1-20 (0.22 ± 0.053 SD m/s) was significantly higher ($p<0.01$) than all other habitat units. The channel morphology of the Aberfeldie side channel was originally designed to ensure a minimum water velocity of 0.3 to 0.5 m/s on constructed spawning platforms to support spawning and egg development (Reid *et al.*, 2008). None of the spawning platforms meet the minimum water velocity requirement.

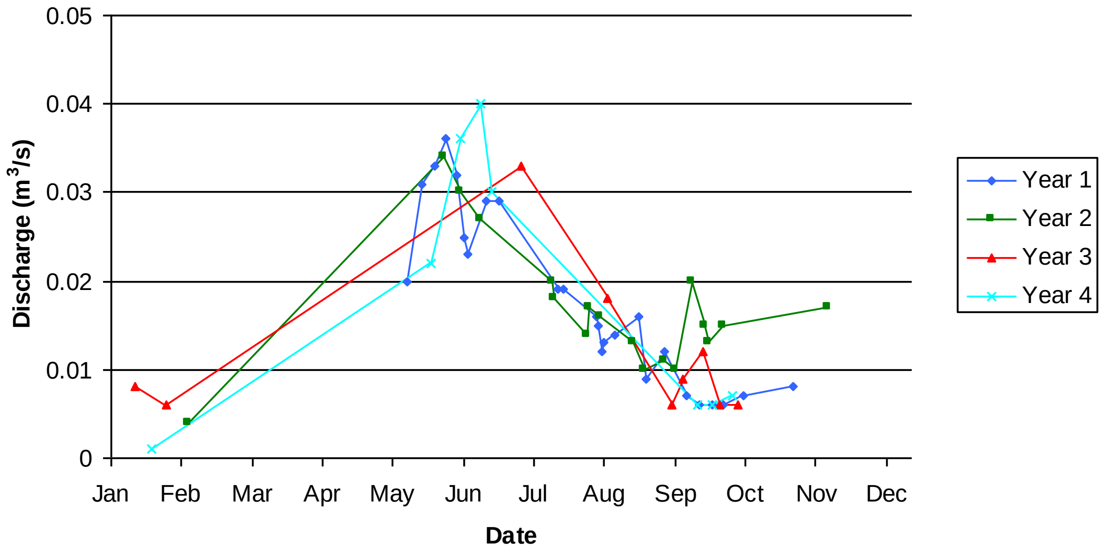

Figure 21 Aberfeldie side channel discharge (m^3/s) measured at the weir during Year 1 (2009) to Year 4 (2012) site inspections.

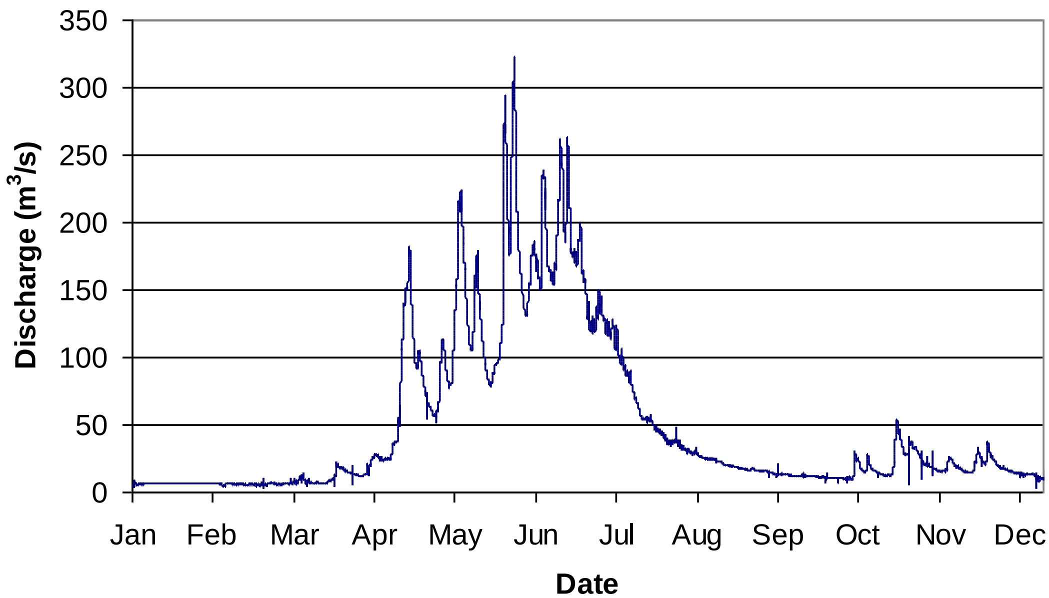

Figure 22 Bull River hourly discharge (m3/s) from January 1, 2012 to December 31, 2012 (from Environment Canada 2013, 08NG002 Hydrometric Station, located at the Bull River near Wardner).

Intra-gravel Dissolved Oxygen Monitoring

The intra-gravel DO and temperature monitoring data are presented in Figure 23 and Figure 24.

Intra-gravel conditions at the spawning platform HU 1-12 in the constructed channel exhibited consistently lower DO and higher temperature than at comparable habitat on the Bull River mainstem.

During the monitoring period, intra-gravel DO varied between 3.80 and 10.17 mg/L at HU1-12 in the side channel and between 8.77 and 15.35 mg/L in the mainstem. The BC MoE water quality guidelines are a minimum of 5 ml/L DO concentration for support of aquatic life and a minimum of 9 mg/L DO concentration for support of embryo and alevin life stages.

As expected, we observed a clear positive correlation between intra-gravel DO and water temperature in both the mainstem and the side channel. This was illustrated by a regular increase in DO concentration throughout the monitoring period as winter conditions established. The Bull River water level also appeared to influence intra-gravel DO at both monitoring sites. Peaks in intra-gravel DO concentration were repeatedly observed 3 to 4 days following a peak in mainstem discharge. The origin of this 3-4 days delay is unclear.

DO measurements from hyporheic water samples collected in the vicinity of the buried loggers were relatively consistent with the logger's data although some variations were observed. These variations were likely inherent to the low repeatability of the sampling syringe technique (i.e., off-gassing during sample extraction, introduction of sediment in sample, etc.). Overall, the hyporheic sample data validate the measurements of the buried logger method.

The DO levels of hyporheic samples collected downstream of the buried logger (spawning platform HU 1-6) in December and February (represented by blue dots on Figure 23) were relatively similar to those at HU 1-12. However, hyporheic samples collected upstream (represented by orange dots on Figure 23) had consistently lower DO concentration than at HU 1-12. These results confirm previous observations of decreasing DO conditions in the upstream sections of the constructed channel.

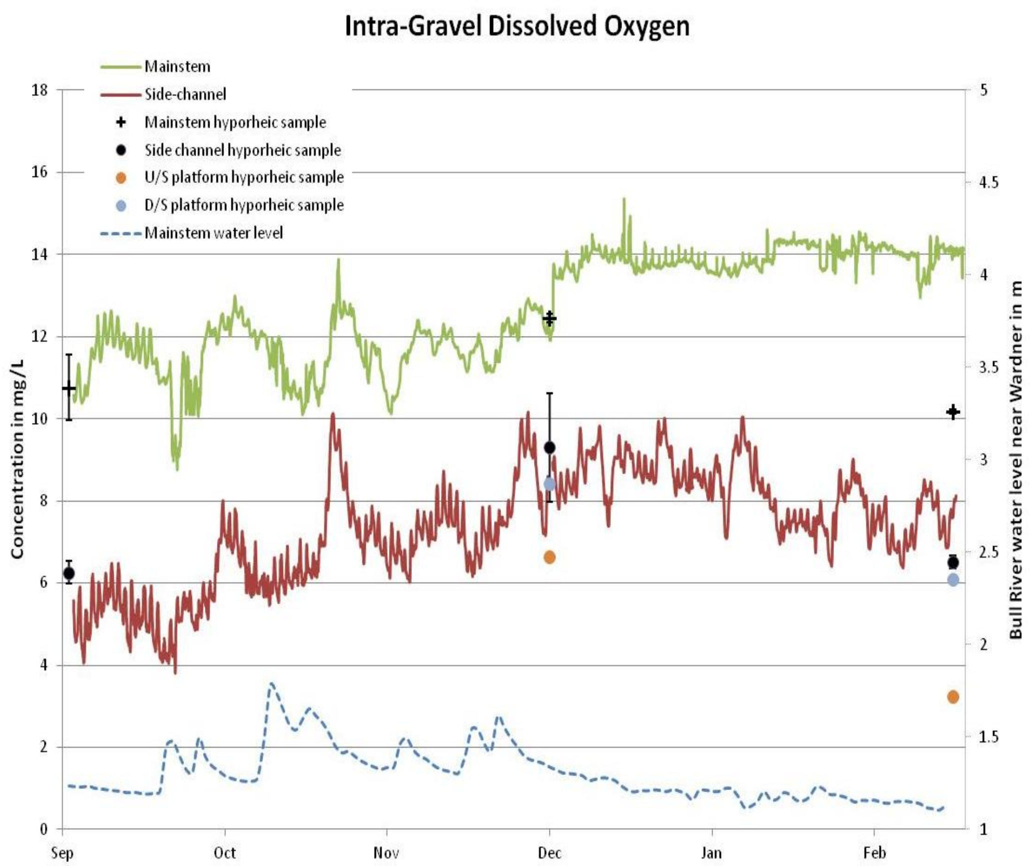

Figure 23 Intra-gravel DO concentrations and Bull River water levels during the Year 4 monitoring period.

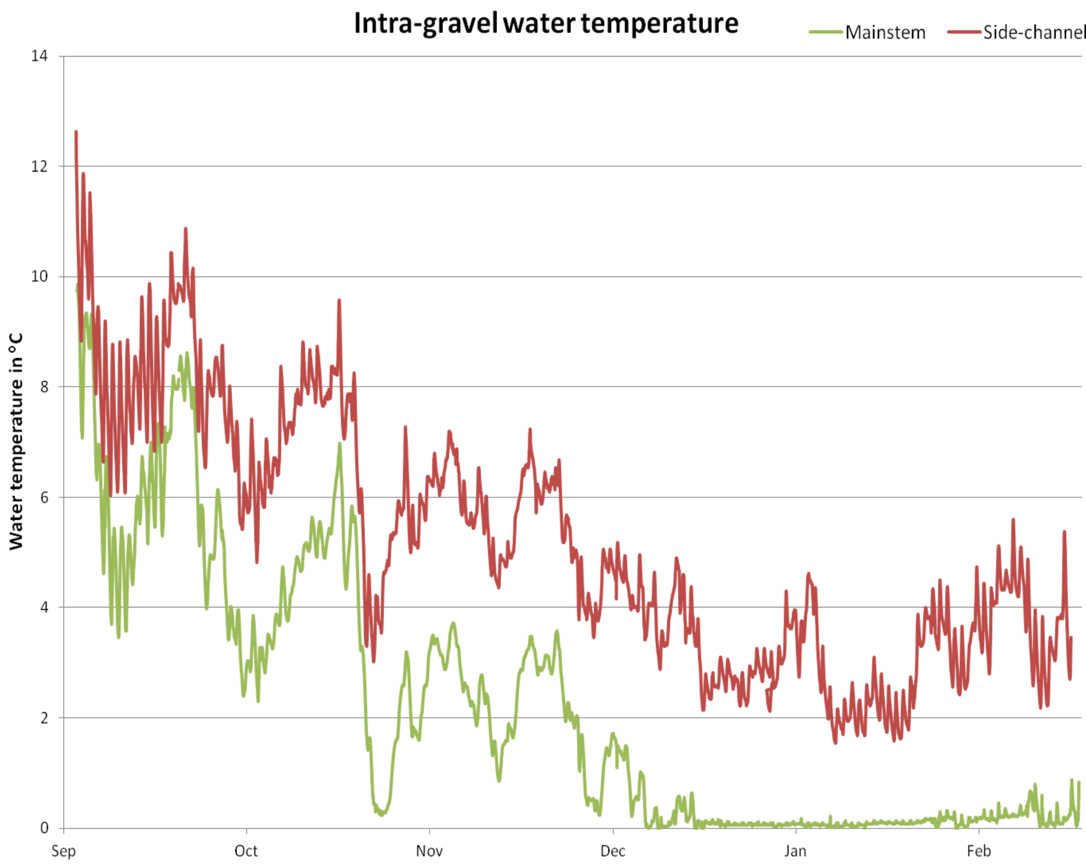

Figure 24 Intra-gravel water temperature during Year 4 monitoring period

3.2 Structural Stability and Physical Parameters

While general observations of channel stability were made throughout the monitoring period, a focussed structural stability assessment on features within the side channel was conducted on July 30, 2012. This assessment followed the high spring discharge period on the Bull River (peak estimated at 323 m^3/s on June 6, 2012), which would have contributed to any erosional or stability impacts.

Outlet protection groyne

The outlet protection groyne is located at the side channel outlet on the lateral bar of the Bull River. The groyne was constructed to minimize the risk of the side channel outlet becoming disconnected from the Bull River (Reid *et al.* 2008). It is intended to promote scour at the toe and thus protect the outlet from infilling (Reid *et al.* 2008).

The groyne was observed under varying flow conditions, with high spring and low summer flow depicted in Figure 25 and Figure 26, respectively. During the spring high flows, considerable amounts of sediment were deposited along the groyne that covered gravels. The water flowed through the rip rap substrate and sediment was deposited that was not removed by scour. Although the outlet of the channel was maintained, the sediment accumulation created a continuous pool-like habitat along HUs 1-01 to 1-06 (no riffle or glide habitat). During peak flows, the groyne was submerged (observed during spring assessments conducted on June 8 and 17, 2012). As reported previously, some minor scour was evident along the upstream side of the groyne, but there was no undercutting that would lead to stability concerns.

During low flow conditions, the water depth in glide habitat at the downstream section of the side channel (HU 1-01 to 1-06) reached a minimum of 0.1 m (Figure 25). As previously reported, accumulation of fine sediment was observed in this section; however, the side channel outlet remained open and accessible to the mainstem during all seasons (Figure 26 and Figure 27).

Figure 25 Aberfeldie side **c**hannel outlet and groyne under spring high flow conditions (June 17, 2012).

Figure 26 Sediment accumulation through rip rap at groyne after spring high flows (July 30, 2012).

Figure 27 Upstream (left photo) and downstream (right photo) views of groyne and sediment accumulation during overwintering assessment (February 14, 2013). Side channel is open to the Bull River mainstem.

Right downstream berm, near channel outlet

The secondary berm, located on the right downstream side of the channel, alongside the first pool (HU 1-7), was built to contain and deflect potential sediment inputs from a tributary gully (Reid *et al.* 2008) and from the existing unstable slope. As reported in previous years, the 2012 assessment confirmed that the berm is adequately protecting the side channel from the inputs of any materials from these sources. However, increased erosion was observed along the bank directly below the berm. During the winter assessment visit, fine sediment was observed running off the berm's slope and entering the side channel at this particular location (Figure 28).

Figure 28 Erosion at right downstream berm near channel outlet (July 30, 2012).

Left downstream berm

The berm running the extent of the left downstream boundary of the side channel appeared to be stable and did not show any signs of erosion along the mid and downstream portions. The ground cover had a high clover component, which is valuable to wildlife as forage. Few of the willow and cottonwood plantings along the berm have survived.

Bull River Bank Stability at Upstream End of Channel

As noted in previous surveys, the mainstem's hydraulic forces (on the outside meander bend) near the upstream end of the berm have caused some bank erosion, as evidenced by undercutting on the river side of the berm. This does not appear to pose an immediate threat as the side channel is set well back from the river at this location and the undercutting had not increased noticeably since 2009.

Figure 29 Berm on left downstream boundary of the Aberfeldie side channel (July 30, 2012).

Figure 30 Bull River Bank at upstream end of the Aberfeldie side channel.

Cattle activity

Cattle activity was first reported in the side channel area in 2009 and appeared to have been addressed in 2010. In 2011, new evidence of cattle activity was observed during the fall visit. Evidence of cattle activity was observed on Sept. 15, 2012 during the fall spawning assessment but no subsequent evidence of cattle has been observed since then. Cattle activity in the side channel area is of particular concern as animals crossing the channel significantly increase bank erosion and contribute to the in-filling of the channel.

Beaver activity

No beaver activity has been noted at the side channel since Year 2 of the monitoring program. We will continue to monitor for any beaver activity in the side channel, particularly those areas repeatedly visited by beavers in the past, such as the crests of riffles (HU1-11, HU 1-13, and HU 1-15), and the upstream end of the weir. Any materials related to dam construction by beavers will be documented and removed to ensure adequate water flow and accessibility of the side channel by fish.

Slope Stability and Re-vegetation

A review of riparian vegetation establishment and its effectiveness in providing stability was outside of this project's scope. However, some general observations related to slope stability and re-vegetation were noted throughout the project. Of key importance, mentioned in the Year 3 report, the banks of the side channel did not appear to be adequately stabilized. The banks are generally steep, and are composed of unconsolidated substrates with a high proportion of fines (e.g., sand and silt). In several locations, there was evidence of sloughing of the banks into the channel caused by natural erosion and animal activities (Figure 31 and Figure 32). This sloughing is particularly significant at glide HUs 1-14, 1-18, and 1-20. Bank re-vegetation and bioengineering work have not been effective in stabilizing the slopes. Sedimentation has also been noted around the periphery of pools (Vast, 2012), which are utilized by Kokanee for spawning. An increased number of trees have fallen across the side channel in Year 4 illustrating the ongoing degradation of the bank stability.

Figure 31 Erosion along slope of glide habitat unit 1-18 (upstream view) of the Aberfeldie side channel (June 17, 2012).

Figure 32 Sedimentation at glide habitat unit 1-14 (left upstream boundary) of the Aberfeldie side channel (May 28, 2012).

3.3 Spring Spawning Assessment

Visibility for the shore-based spring spawning surveys was very good. The relatively narrow channel width (average width of habitat units excluding pools was 3.5 m) and lack of vegetation allowed for unobstructed views of the instream habitat. No adult fish or evidence of redds were observed during the Year 4 spring spawning assessment.

Kokanee fry observations

Although spring field investigations failed to identify evidence of spring spawning, the assessment confirmed the use of the side channel by juvenile fish species, such as Kokanee. Numerous Kokanee (identified by lack of band on dorsal fin) fry were observed in glide HUs 1-12, 1-14, and 2-01. A school of approximately 100 Kokanee fry was observed in HU 1-14 and in fewer numbers in other glide habitats on May 28, 2013. Fry were also observed on June 8, 2012 in glide habitats. The fry were approximately 2 – 3 cm long, and had parr marks. These observations of fry suggest that Kokanee eggs laid during fall spawning had successfully incubated over the winter in the side channel.

Wildlife observations

The side channel area was an active area for birds and ungulates during the spring spawning assessment. Numerous Killdeer (*Charadrius vociferous*) and Cedar Waxwing (*Bombycilla cedrorum*) were observed flying and nesting in the side channel area. Evidence of wildlife crossing the channels was observed by erosion of channel banks and subsequent inputs of sediment along channel banks in glide HUs 1-14, 1-18, and 1-20. Moose droppings were observed near the Mainstem.

3.4 Juvenile Habitat Use

Electrofishing and fyke/minnow trapping data for two sampling periods (July 30 and August 23, 2012) are summarized in Table 4. A total of 17 fishes (3 young-of-year Kokanee, 12 young-of-year Westslope Cutthroat, and 2 - 1+ year Westslope Cutthroat) were captured on July 30 while 11 fishes (1 – 1+ year Rainbow Trout, 8 young-of-year Westslope Cutthroat, and 2- 1+ year Westslope Cutthroat) were captured on August 23 in site EF1 after three passes on each day. The finding of the young-of-the-year Kokanee in the side channel was unusual as they typically migrate to lakes once they emerge (McPhail, 2007). Ages of Westslope Cutthroat are based on aging of scales collected from a 77 mm and a 135 mm individual. No fish were caught in sites EF2, TR1, or TR2 on either sampling day. Table 5 summarizes relative abundance and biomass data from juvenile enumeration for all study years. Figure 33 and Figure 34 compare density and relative biomass, respectively, of fishes among study years. Over the duration of the monitoring program, there has been an increase in density and biomass of Westslope Cutthroat (WCT).

Table 4 Juvenile habitat use assessment fish data from the Aberfeldie side channel. Sample sites EF1 (HUs 1-08 glide, 1-09 cascade, 1-10 glide, 1-11 riffle, 1-12 glide, and 1-13 cascade) and EF2 (HUs 1-18 glide, 1-19 cascade, and 1-20 glide) were sampled by electrofishing techniques and samples sites TR1 (HU 1-07 pool) and TR2 (HU 1-21 pool) were sampled using fyke nets and minnow traps. Fish species are denoted by 'WCT' = Westslope Cutthroat; 'KO' = Kokanee; 'RB' = Rainbow Trout, and 'NFC' = No fish caught.

Date	Sample Site	Sampling Method	Species	Fork Length (mm)	Weight (g)
30-Jul-12	EF 1	Electrofishing Pass 1	WCT	66	3.5
			WCT	130	25.0
			WCT	83	6.2
			WCT	127	27.4
			WCT	72	4.1
			WCT	74	3.9
			WCT	66	3.2
			KO	56	1.5
		Electrofishing Pass 2	WCT	63	3.0
			WCT	63	2.6
		Electrofishing Pass 3	KO	55	2.2
			WCT	60	2.2
			KO	44	0.8
			WCT	80	5.4
			WCT	59	2.2
			WCT	37	3.2
			WCT	72	3.8
	EF 2	Electrofishing Pass 1	NFC	n/a	n/a
	TR1	Fyke trap, Minnow Trap, 24 hours	NFC	n/a	n/a
	TR2	Fyke trap, Minnow Trap, 24 hours	NFC	n/a	n/a
23-Aug-12	EF 1	Electrofishing Pass 1	RB	131	31.4
			WCT	77	5.1
			WCT	63	3.4
		Electrofishing Pass 2	WCT	135	32.7
			WCT	83	6.2
			WCT	78	6.2
			WCT	102	11.6
			WCT	76	4.5
			WCT	76	6.8
		Electrofishing Pass 3	WCT	88	9.0
			WCT	70	4.7
	EF 2	Electrofishing Pass 1	NFC	n/a	n/a
	TR1	Fyke trap, Minnow Trap, 24 hours	NFC	n/a	n/a
	TR2	Fyke trap, Minnow Trap, 24 hours	NFC	n/a	n/a

Table 5 Summary of relative abundance and biomass of fish species captured for juvenile habitat use assessment study years 1, 2, and 4. Sample sites EF1 (HUs 1-08 glide, 1-09 cascade, 1-10

glide, 1-11 riffle, 1-12 glide, and 1-13 cascade) and EF2 (HUs 1-18 glide, 1-19 cascade, and 1-20 glide) were sampled by electrofishing techniques and samples sites TR1 (HU 1-07 pool) and TR2 (HU 1-21 pool) were sampled using fyke nets and minnow traps. Fish species are denoted by 'WCT'=Westslope Cutthroat; 'KO'=Kokanee; 'RB'=Rainbow Trout, and 'NFC'=No fish caught.

Sample Site	Site Length (m)	Site Mean Width (m)	Site Area (m^2)	Study Year	Species	Relative Abundance (per 100 m^2)	Biomass (g per 100 m^2)
EF1	108.0	2.7	291.6	Year 4	KO	1.03	1.54
					RB	0.34	10.77
					WCT	8.23	63.75
				Year 2	KO	1.10	1.75
					RB	1.03	32.64
					CRH	0.34	0.69
				Year 1	WCT	0.01	0.548
EF2	116.0	3.5	406.0	Year 4	NFC	0	0
				Year 2	NFC	0	0
				Year 1	NFC	0	0
TR1	47.6	12.6	599.8	Year 4	NFC	0	0
				Year 2	NFC	0	0
				Year 1	RB	0.002	0.088
TR2	54.6	25.4	1386.8	Year 4	NFC	0	0
				Year 2	KO	0.07	0.14
				Year 1	NFC	0	0

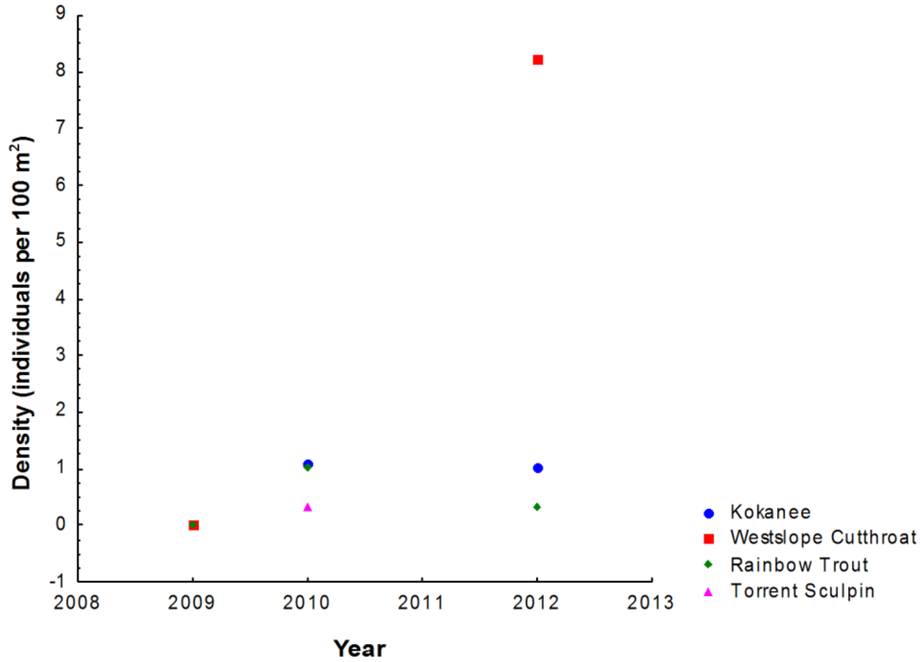

Figure 33 Comparison of fish density (number of individuals per 100 m^2) among study years. Study Year 1 (2009), Year 2 (2010), and Year 4 (2012).

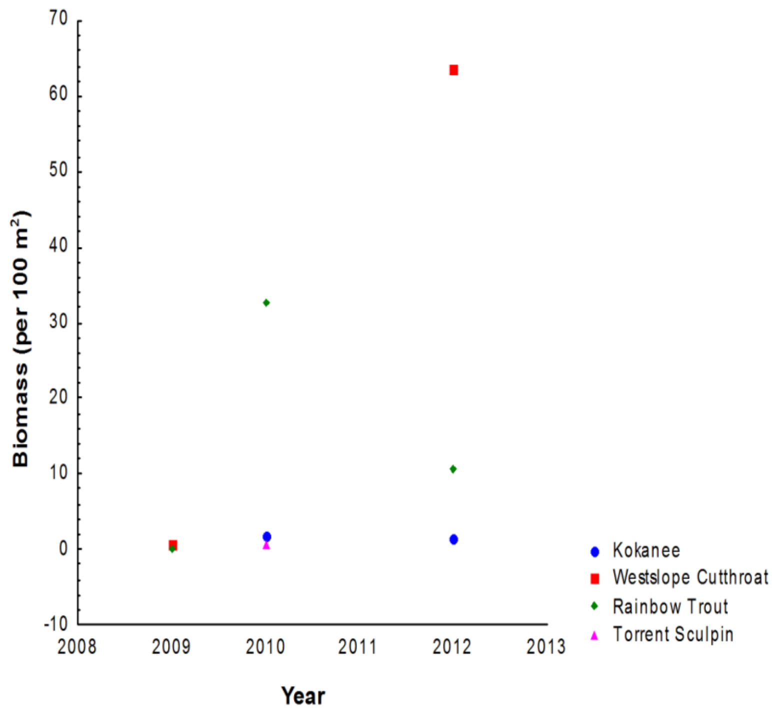

Figure 34 Comparison of fish relative biomass (per 100 m^2) among study years. Study Year 1 (2009), Year 2 (2010), and Year 4 (2012).

3.5 Fall Spawning Assessment

All fall spawning assessments were conducted under optimal survey conditions, when ideal water levels and turbidity allowed for excellent views of the instream habitat and accurate two-person counts from the banks. As in previous years, only Kokanee spawners were observed; no Brook Trout nor Bull Trout were seen. Depths at the outlet were very shallow throughout the spawning period, with measurements as low as 0.07 m in glide habitats (HU 1-12 and 1-20; Sept 23, 2012) at the downstream end of the channel. This did not appear to prevent Kokanee migration from the Bull River mainstem into the side channel.

Weekly Fish Counts and Habitat Use

Surveys were conducted on September 15, 23, 30, and October 9, for a total of four visits. The highest number of spawners observed in the side channel was 1,854 Kokanee on September 30, 2012 (Table 6).

Table 6 2012 Kokanee spawner counts in each habitat unit (HU) in the Aberfeldie side channel.

Habitat Unit	Habitat Type	HU Length (m)	Kokanee Spawner Counts					Mortality Count (12 Oct)
			15-Sep	23-Sep	30-Sep	09-Oct	Total	
1-1	Glide	21.1	0	1	5	9	14	0
1-2	Riffle	5.7	0	0	2	0	2	0
1-3	Glide	11.8	0	0	0	0	0	1
1-4	Riffle	4.1	0	0	0	0	0	0
1-5	Glide	19.7	0	0	0	0	0	0
1-6	Riffle	8.3	0	0	0	0	0	0
1-7	Pool	47.6	54	120	184	73	431	13
1-8	Glide	7.2	0	3	1	0	4	0
1-9	Cascade	2	0	0	0	0	0	0
1-10	Glide	48.6	0	17	30	3	49	6
1-11	Riffle	5.9	0	0	2	0	2	0
1-12	Glide	41.3	27	230	320	83	660	17
1-13	Cascade	2.9	0	6	10	1	17	0
1-14	Glide	29.2	0	39	70	40	148	6
1-15	Riffle	4.8	0	4	6	0	10	0
1-16	Glide	43.2	40	97	150	32	318	9
1-17	Cascade	3.8	0	7	0	8	15	0
1-18	Glide	38.9	25	81	128	37	271	6
1-19	Cascade	5.3	0	2	7	2	11	0
1-20	Glide	72.3	6	186	250	61	502	6
1-21	Pool	54.6	51	210	256	156	673	7
2-1	Glide	12.5	7	45	41	19	111	3
2-2	Pool	41.9	17	122	101	48	288	3
3-1	Glide	8	7	44	43	12	106	0
3-2	Pool	44.8	58	238	253	107	656	20
		Total	292	1449	1854	689	4283	97

Based on total counts, Kokanee appeared to be associated with glide and pool habitats. However, given that each habitat type is not equally represented in the side channel, numbers of fish per square meter (density) had to be calculated to better assess habitat preferences relative to areas of each habitat unit. Given that cascade habitat units are limited in size compared to other habitat types, fish counts in cascade habitat units were not included in the following analyses to avoid skewing results. In fact, Kokanee abundance was particularly high at cascade habitat unit 1-13 compared to other habitat units. This can be explained by the presence of the hydrometric weir in HU 1-13. Although the weir is not a migration barrier, it creates a bottle-neck in the channel. Kokanee were observed congregating downstream of the weir before leaping over the narrow passage.

There were significant differences in Kokanee density (fish/m^2) by habitat type and habitat unit (both $p<0.001$; Figure 35 and Figure 36). There was no significant difference in Kokanee density among study years. Kokanee had the highest density in glide habitats compared to other habitat types ($p<0.001$; Figure 35). Fish density was highest in glide HU 1-12 and 3-01 ($p<0.001$; Figure 36). Similar observations were made in previous years of the study.

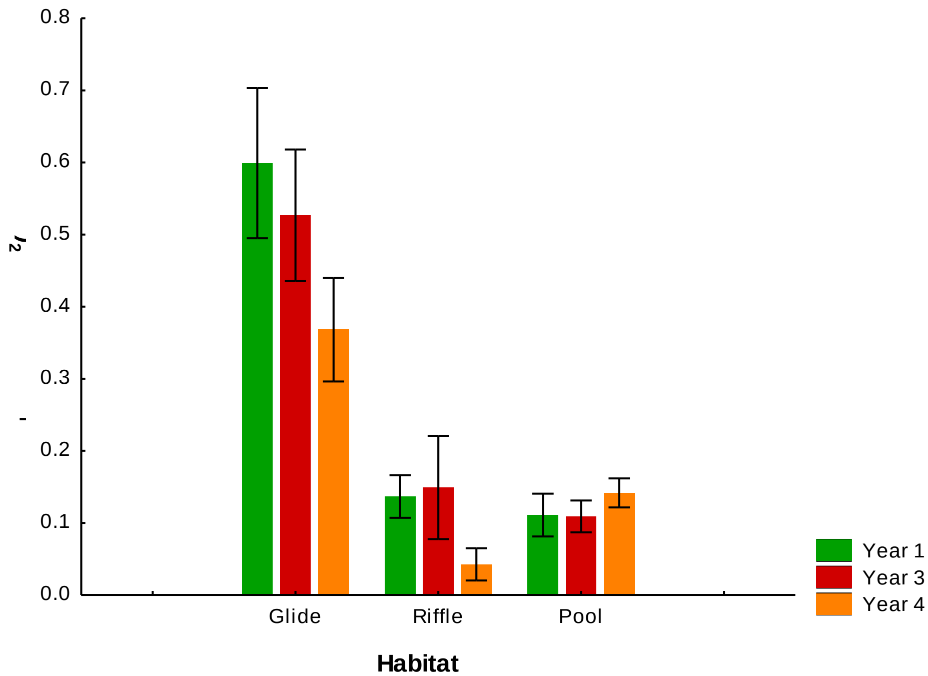

Figure 35 Density of Kokanee (fish/m^2) at each habitat type for 2009, 2011, and 2012 fall spawning assessments of the Aberfeldie side channel. Bars represent SE.

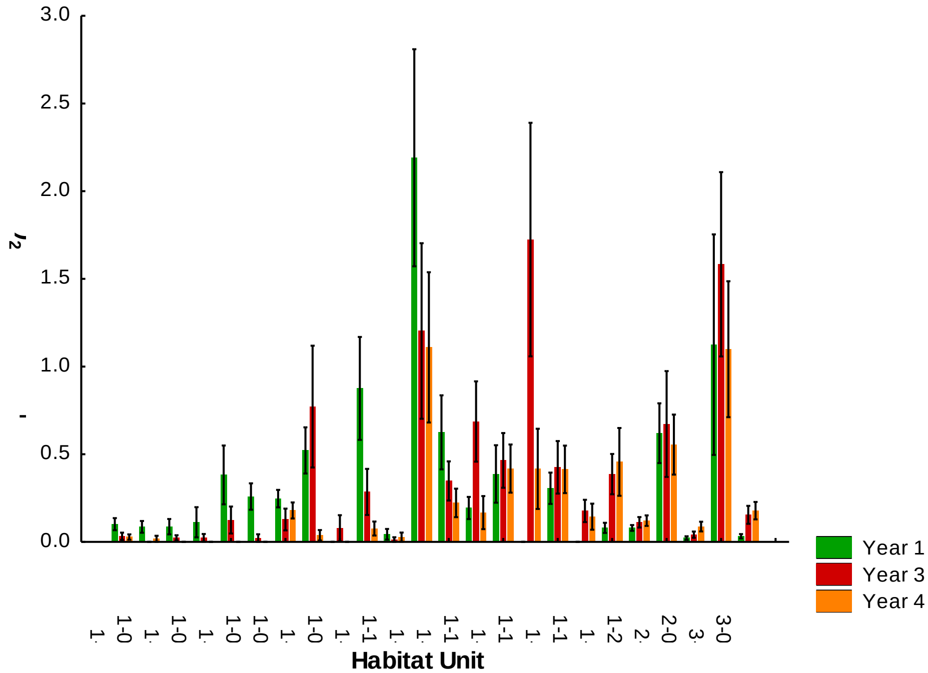

Figure 36 Density of Kokanee (fish/m^2) at habitat units for 2009, 2011, and 2012 fall spawning assessments of the Aberfeldie side channel. Bars represent SE.

As reported in previous years, anecdotal observations were made of Kokanee congregating in the upper and lower portion of glides, in the tail-outs of pools, and along pool margins. Fish are likely attracted to these areas by more favourable conditions such as higher water velocity and possible water upwelling. Kokanee are known to have higher spawning success in upwelling areas even if the area has a high proportion of fine sediments (Garret *et al,* 1998).

Kokanee were observed in greatest numbers at the spawning platforms located at the junction between Reach 1 and 2 and between Reach 1 and 3. At these two locations fish were observed interacting with one another but no obvious redd building or active spawning was noted. In pool habitats, fish were sparser but numerous spawning pairs were seen protecting redds or swimming along the pool margins. No active spawning was directly observed (which likely happened at night). It appeared that most redds were constructed on the pool margins in substrate from the eroding banks. Kokanee were generally not observed in areas with extensive woody debris in the Aberfeldie side channel.

Kokanee Escapement Estimates for the Side Channel

The Kokanee escapement was estimated using the Area Under the Curve method (AUC) described in English *et al.*, 1992. The weekly fish count data were plotted and extrapolated to start on September 15 and end on October 9. The curve estimated by 2nd-order polynomial regression (Figure 37) had the following equation:

$$y(x) = -8.94x^2 + 502.04x - 5259.7 \quad \text{(with } R^2 = 0.9842\text{)} \quad \text{(Equation 1)}$$

For the x-intercepts, when

$$y(x) = 0; \; x1 = 42.20 \text{ and } x_2 = 13.94$$

Hence, the AUC was estimated to be

$$\sum_{16.70}^{45.88} y(x) = 33619.8 \text{ fish.days}$$

Using the mean residence time (RT) of 8.5 days established from field observations and previous studies, escapement was calculated as,

$$\text{Escapement} = \frac{AUC}{RT} = \frac{33619.8}{8.5} = 3955 \text{ individuals}$$

The escapement range for the 7-10 days RT estimates is 3362 - 4803 Kokanee.

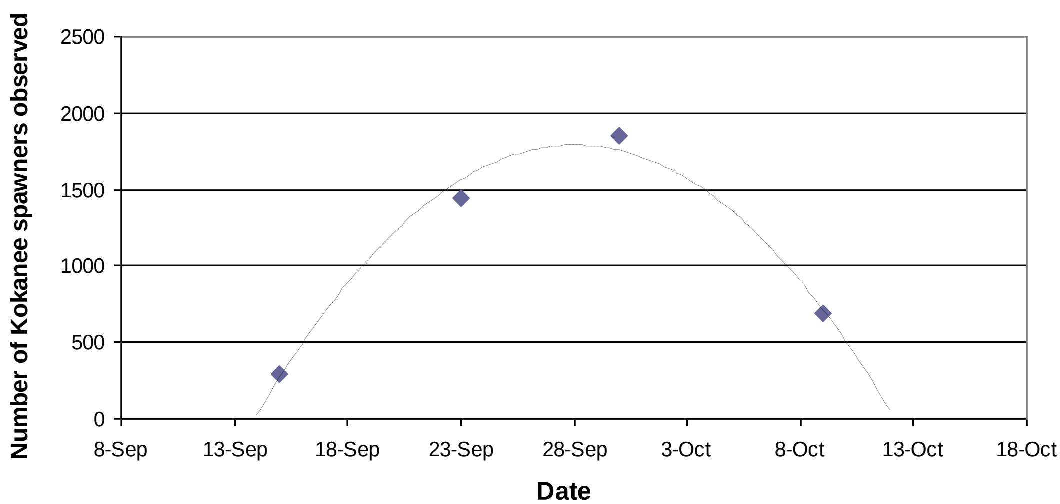

Figure 37 Number of 2012 spawning Kokanee over time, plotted to estimate the total number of spawners that utilized the side channel (i.e., escapement). Equation 1 provides the 2nd-order polynomial regression of the curve.

3.6 Overwintering Assessment

Winter water quality

Seasonal water quality data collected during the overwintering assessment are reported in Section 3.1 and provided in Appendix 3.

The mean water temperature measured in the side channel during winter assessments (4.7^{o} C ± 1.6) was significantly higher than the temperature measured in the Bull River mainstem (1.05 ^{o}C). The mean DO concentrations measured in the side channel was 4.7 mg/L ± 1.76 and 10.8 mg/l measured in the Bull River mainstem. Dissolved oxygen concentrations measured in pool habitats were particularly low (3.6 mg/L ± 1.62) and did not meet the minimum requirements to support aquatic life. Dissolved oxygen concentration in glide habitats (6.2 mg/L ± 0.16) was higher than in pool habitats but below the minimum requirement for the development of embryo and alevins. Variations in water quality parameters were observed at glide HU 1-12 (WQ 3); warm water was located at the bottom with colder water at the surface with high pH – likely due to upwelling. Water quality measurements were taken at the bottom of pool HU 2-02 (WQ 2), which had high specific conductance (345 µS/cm versus mean 216.3 µS/cm for the side channel) and salinity (0.25 ppt versus 0.10 ppt for the side channel). Algae growth was noted in pool HU 1-21.

Overwintering habitat

The outlet of the side channel, although shallow, remained open during winter, allowing fish to move in and out of the channel. A thin layer of ice (approximately 1 cm deep) covered the channel margins, but did not restrict fish movements. The ice thickness on the surface of pool HU 2-02 was approximately 20 cm. Very little ice was observed at pool HU 3-02. At the time of the survey (February 14, 2012), the engineered undercut banks were above water level and therefore were not available to fish as overwintering habitat. Deeper glide sections and pool habitat with LWD (Figure 38) constitute the most suitable overwintering habitat in the side channel. However, as noted in previous years, the low DO conditions occurring in pool habitat further limited overwintering habitat availability. Despite these harsh conditions, Kokanee fry were observed in pool habitat unit 1-21 during the overwintering assessment, as well as on March 03, 2012.

Figure 38 Logs in pool habitat unit 1-07 provides habitat and cover for overwintering fish (February 14, 2012).

4 Discussion

4.1 Water Quality

As reported in previous years, water quality conditions, particularly DO concentrations, in the Aberfeldie side channel rarely met the provincial requirements (BC MoE, 2006) for rearing and reproduction of the targeted fish species. A summary of key physical habitat conditions required for each of these target species is shown in Appendix 8.

Water temperatures recorded in the side channel were consistently higher than in the Bull River mainstem. In the spring, water temperatures were adequate for Westslope Cutthroat Trout (9-12 ^{o}C; BC MoE, 2001) and Rainbow Trout spawning (10.0-15.5 ^{o}C; BC MoE, 2001). In the summer, water temperatures were adequate but marginal in glide habitats for incubation of these two species (Westslope Cutthroat Trout: 9-12 ^{o}C; Rainbow Trout: 10-12 ^{o}C; BC MoE, 2001) and were too high for incubation in pool habitats. Fall water temperatures were adequate for Kokanee spawning (below 12 ^{o}C; McPhail, 2007) but exceeded the maximum temperature for Bull Trout spawning (9 ^{o}C; McPhail, 2007).

The pH measurements in the side channel were satisfactory and generally within the 6.5-9 range as recommended in BC MoE guidelines for the support of aquatic life. A small number of pH measurements recorded in Years 1 and 3 (n=5) were lower than the recommended 6.5 value. These measurements were collected in different habitat units, in different seasons, and in different years, and did not appear to be part of a trend. The lowest pH measurement recorded in Year 4 was 6.7.

Water column dissolved oxygen levels in the side channel were consistently lower than in the Bull River mainstem. DO concentrations were generally higher in glide habitat than in pool habitat. While Year 4 summer DO concentration in pools was significantly higher than in previous monitoring years, pools remained the habitat type with the most limiting DO conditions. DO concentrations in pool habitat in fall and winter consistently fell below the minimum requirement for support of aquatic life (5 mg/L; BC MoE 2006). The minimum requirement for the development of embryo and juvenile (9 mg/L; BC MoE 2006) was never reached in any of the side channel's habitat units. In comparison, the average DO concentration in the Bull River mainstem was 11.1 (± 0.33) mg/L. The best DO conditions in the side channel were found in adjacent glide habitat units 1-12 (6.4 ± 0.43 mg/L) and 1-13 (6.1 ± 0.43 mg/L), which are located in the middle of the side channel. The most limiting DO conditions were found in the most upstream pool habitat units 1-21 (4.4 ± 0.43 mg/L) and 3-02 (4.8 ± 0.43 mg/L).

Intra-gravel conditions at the spawning platform HU 1-12 (7.36 ± 1.342 mg/L) in the constructed channel exhibited consistently lower DO and higher temperatures than at comparable habitat on the Bull River mainstem (12.69 ± 1.281 mg/L). Intra-gravel DO concentration in the side channel was influenced by water temperature and by the water levels of the Bull River. Although provincial water quality guidelines recommend a minimum of 5 mg/L DO in the water column to support embryo and alevin development, no guideline exists for intra-gravel DO. The relationship between surface water DO and DO concentration in interstitial spaces within the substrate is not linear and is correlated to a number of parameters, including water velocity, substrate permeability, and temperature. Few studies have investigated DO requirements at the embryo and alevin stages in *Oncorhynchus nerka*. Cope and MacDonald (1998) indicated that Sockeye Salmon rarely spawn in habitat where intra-gravel DO concentration is lower than 3 mg/L. Based on this single reference, it appears that intra-gravel DO conditions at the spawning platform HU 1-12 of the constructed side channel satisfy this minimum requirement. However, given that DO conditions decrease upstream of the side channel, the DO of upstream habitat units may not fulfil this requirement.

Specific conductance and salinity measurements collected during Year 4 in the side channel were generally higher than in the Bull River mainstem. Comparing year-to-year data, it was noted that habitat unit 1-07 (most downstream pool) had significantly higher conductivity and salinity than all other habitat units. Water upwelling likely contributes to the ion load increase in the side channel. Specific conductance is commonly higher in groundwater than in rainwater, snowmelt, or glacial melt water because of its longer contact time with rock and/or soils.

Redox potential measurements appeared consistent with variations of the redox potential measured in the Bull River mainstem. Conditions are typically reducing in spring, summer, and fall (E_h ~ 0-100mV) while more oxidizing conditions prevail in winter (E_h ~ 100-450 mV). Summer redox potential in the side channel appeared lower than in the mainstem, which is likely a result of the low DO concentration and high water temperatures occurring in the side channel during summer. Low redox potential results in an increased bioavailability of phosphate ions, which in turn, contributes to algae blooms and the onset of eutrophic conditions (Lampert and Sommer, 2007). Algal growth was observed in the side channel.

4.2 Water Quantity and Water Velocity

Fluctuations of the side channel discharge were consistent with the discharge of the Bull River mainstem. There was no significant difference in side channel discharge among study years of the monitoring program.

Low water velocities measured in glide habitats and on spawning platforms (mean 0.10 ± 0.075 m/s) are of particular concern. During the design stage of the Aberfeldie side channel, a minimum water velocity of 0.3 to 0.5 m/s was recommended by Reid *et al.* (2008) to support spawning and egg development in the side channel. Improvements to water flow through the side channel glide habitats are recommended.

4.3 Spring Spawning Assessment

To date, no evidence (e.g. redds, paired up fish etc.) of spawning has been observed in the Aberfeldie side channel during the spring assessment.

4.4 Juvenile Habitat Use

A total of 28 fishes were captured in the side channel during the Year 4 assessment. Westslope Cutthroat were the most abundant fish species recorded in the constructed habitats with highest density (8.23/100 m^2) and biomass (63.75 g/100 m^2). Other fish species observed in Year 4 included Kokanee and Rainbow Trout.

A total of four fish species have been observed utilizing the Aberfeldie side channel since the beginning of the monitoring program: Kokanee, Rainbow Trout, Westslope Cutthroat, and Torrent Sculpin. Utilization of the side channel by fish appears to have increased over time based on the increase in fish species and number of individuals observed. The gauging station weir is likely a physical barrier for juvenile upstream movement at all discharge levels since only a single young-of-year Kokanee was captured upstream of the weir throughout the monitoring study.

When comparing year-to-year data, more fishes were captured in glide habitats than in pool habitats. Although this result is consistent with the poor water quality conditions observed in pool habitat, it may also be inherent to the difference in effectiveness of the techniques used to sample each habitat types. Only two fish have been collected in pools since the beginning of the monitoring program.

4.5 Fall spawning assessment

As in previous years, Kokanee were the only fish species utilizing the Aberfeldie side channel for spawning during the fall. Although this period also corresponds to the Bull Trout spawning season, low water levels associated with low flow velocity, large substrate size, low DO concentrations, and water temperatures greater than 9º C likely prevented gravid Bull Trout from selecting the side channel as a suitable spawning site. Large numbers of spawning Bull Trout were observed in the Bull River mainstem in the vicinity of the side channel (VAST, 2012).

An estimated 3,955 Kokanee entered the side channel for spawning in Year 4 compared to 4,300 in Year 3 and 4,050 in Year 1 of the monitoring program. These estimates were calculated based on a mean residence time of 8.5 days. The actual residence time of Kokanee in the side channel is unknown. Fish count data revealed that spawning Kokanee preferred glide habitat. More specifically, large numbers of Kokanee were observed on spawning platforms located at the junctions between Reach 1 and Reach 2 and between Reach 1 and Reach 3. These observations are consistent with observations made in Years 1 and 3 of the monitoring program. Spawning activity was observed in both glide and pool habitat. In pool habitats, most redds were located in the peripheral area of the pools (as opposed to the centre of the pool) as observed in previous years. In glide habitat, Kokanee preferred sediments entering the channel from erosion of the banks as spawning substrate and avoided large gravel on spawning platforms. Dissection of a sub-sample of dead individuals (n=15) confirmed that the majority had successfully spawned (n=12; 80%). The large majority of observed Kokanee returned to the Bull River since only 97 dead individuals were collected in the side channel. It is unknown whether the individuals who returned to the mainstem had successfully spawned. Dig tests confirmed that eggs had been deposited in the channel substrate. Despite limiting water quality conditions, Kokanee eyed eggs, alevins, and fry were observed in the side channel later in the season indicating successful spawning.

4.6 Overwintering assessment

The side channel remained physically accessible to fishes in winter during Year 4. However, as in previous years, overwintering habitat availability within the side channel was limited by low DO concentrations in pools (below the minimum requirement to support aquatic life), glides (below the minimum requirement for the development of embryo and alevins), and low water levels in glide habitats. Ice cover over pool HU 2-02 may have limited DO exchange with air given that DO concentration was lowest at this site during the winter. Ice cover was minimal over other areas of the side channel. Deeper glide sections with LWD (HUs upstream of weir) and the upper water layer of pool habitats constitute the most suitable overwintering habitat in the side channel.

4.7 Structural stability and physical parameters

The structural stability monitoring confirmed that the outer structure of the Aberfeldie side channel functions as intended. The groyne at the downstream end of the channel offers suitable protection to the outlet during high spring flows although high amounts of sediment were deposited through the rip rap after high flows. Increased erosion has been observed at the right downstream berm during Year 4 with fine sediment entering the side channel from the berm's slope.

As reported in previous years, monitoring of the inner channel structure revealed important stability concerns. Evidence of bank erosion was present throughout the side channel (Figures 31, 32), likely caused by the steep slope of the banks (*pers. Comm.* S. Vokey, P. Eng., Vast Resource Solutions Inc.). Bank erosion is aggravated by precipitation and animal activity in the side channel area (i.e., wildlife and cattle). Bioengineering and re-vegetation efforts have not been effective in reinforcing banks and preventing erosion of unstable hill slopes, particularly of the right downstream side of the channel. Sediment input from bank erosion may directly affect fish spawning habitat availability through the settling of fines in spawning gravel interstitial spaces and the reduction of the channel effective width.

5 Conclusion and Recommendations

The objective of this monitoring program (ABFMON-5 Task 2B), in combination with ABFMON-5 Tasks 2A and 2C, is to provide qualitative and quantitative assessments to verify whether the side channel meets the requirement Fisheries Act Authorization (05-HPAC-PA7-00188) for the Aberfeldie Upgrade Project of no net loss of fisheries productive capacity. In the case that the side channel does not function to off-set the observed habitat reduction associated with post-upgrade flow changes in the diversion reach, results from the monitoring program will provide information upon which to base future operating decisions. After five years, the results from the WUP monitoring programs will be used to determine acceptability of the recommended flow regime (BC Hydro 2008a).

5.1 Water Quality

In Year 4 of the monitoring program (as in previous years of the study), low water column DO concentrations in combination with low water velocity remained the factors most limiting the fish habitat quality in the Aberfeldie side channel. Intra-gravel DO monitoring at glide HU 1-12 revealed that although intra-gravel conditions were marginal at this location, they were sufficient for successful incubation of Kokanee eggs. This site was selected based on water quality monitoring data indicating that surface water DO concentrations at this location is higher than at all other spawning platforms in the side channel. In Year 5, we propose that additional intra-gravel DO monitoring be conducted at an upstream habitat unit where water column DO conditions are more limiting (e.g., glide HU 1-18 or 1-20). This assessment will provide an indication of the range of intra-gravel DO conditions available in the constructed habitat. While intra-gravel DO concentrations were marginal at glide HU 1-12, conditions may not be sufficient at other spawning platforms and improvements may be necessary.

5.2 Physical Habitat Quality

The structural stability assessment indicated the continual erosion of side channel banks resulting in inputs of fine sediment in the side channel and reduction of the effective width of the side channel. These factors have affected the availability of physical habitat in the constructed channel. We recommend that these banks be stabilized with the input of a revegation specialist in coordination with the finding from ABFMON5 Task 2c.

5.3 Fish Utilization and Fish Productivity

Although large numbers of Kokanee utilize the 5,290 m^2 of available constructed habitat for spawning, usage by other target fish species (Westslope Cutthroat and Rainbow Trout) was still minimal in Year 4. No spawning of target species other than Kokanee was observed in the side channel. Only a small number of juvenile fish utilized rearing habitat. The fish productivity achieved through the constructed habitat is limited.

6 Closure

Vast Resource Solutions Inc. trusts that this report satisfies the requirements of the Terms of Reference. Should BC Hydro have any comments, please contact us at your convenience.

Vast Resource Solutions Inc.

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Ben Meunier, MSc
Fisheries Biologist

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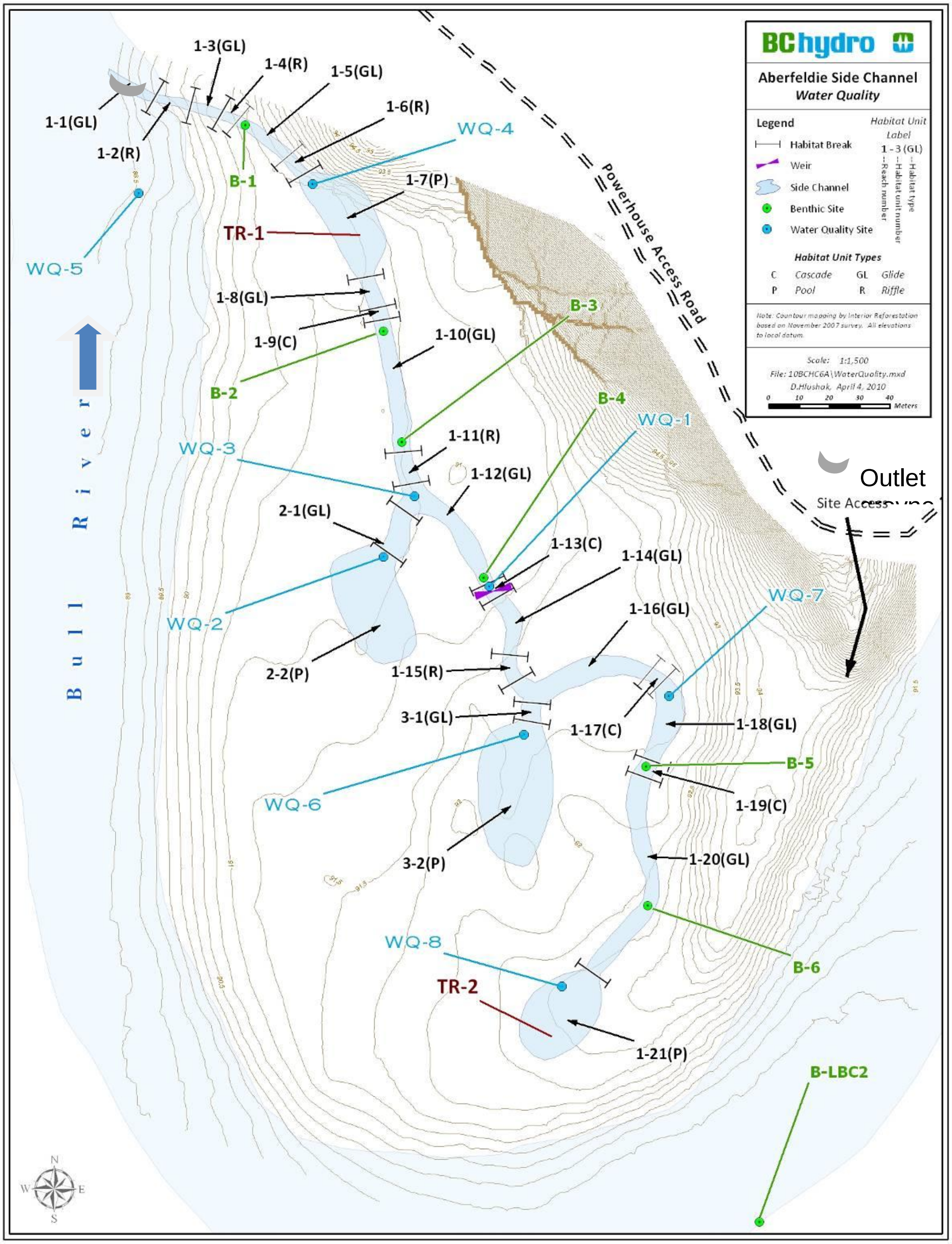
8 Appendices

Appendix 1 Map of Habitat Units and Water Quality Sites (Seasonal and Benthic)



Appendix 2 Documentation and Photo Index

Task	Date	Image #	Caption
Spring Spawning Assessment	28-May	DSCN1406	Partially decomposing deer leg HU 1-14GL
Spring Spawning Assessment	28-May	DSCN1410	Sedimentation and erosion at HU 1-14GL; evidence of wildlife crossing
Spring Spawning Assessment	28-May	DSCN1413	Sedimentation and erosion at HU 1-14GL; evidence of wildlife crossing; ~50 kokanee (no band on dorsal fin) fry feeding
Spring Spawning Assessment	28-May	DSCN1415	Sedimentation and erosion at HU 1-14GL; evidence of wildlife crossing; ~50 kokanee (no band on dorsal fin) fry feeding
Spring Spawning Assessment	28-May	DSCN1420	Fallen tree at pool HU 1-07
Spring Spawning Assessment	28-May	DSCN1421	Sedimentation and erosion at HU 1-14GL; evidence of wildlife crossing
Spring Spawning Assessment	28-May	DSCN1424	Abundant algae on gravel/cobble surfaces and water surface at HU 1-12GL
Spring Spawning Assessment	28-May	DSCN1425	Cleaned cobble along LWD in HU 1-10GL; d/s end has much less algae; no fry
Spring Spawning Assessment	28-May	DSCN1428	Algal blooms on sed and water surface in HU 1-07P; black decomposed material throughout middle of pool
Spring Spawning Assessment	28-May	DSCN1429	Algal blooms on sed and water surface in HU 1-07P; black decomposed material throughout middle of pool
Spring Spawning Assessment	28-May	DSCN1430	HUs 1-01 to HU 1-06R
Spring Spawning Assessment	28-May	DSCN1432	Downstream view of groyne; riffle HU 1-02 submerged; no riffles
Spring Spawning Assessment	28-May	DSCN1434	Mainstem with submerged gravel bar
Spring Spawning Assessment	28-May	DSCN1438	HUs 1-01 to HU 1-06R
Spring Spawning Assessment	28-May	DSCN1439	HU 2-02P better clarity than 1-07P (no black abyss); algae form brown mats on surface and covering much of surface along banks; upwelling cause of clarity and less algae in Hus 2-02 and 3-02 pools?
Spring Spawning Assessment	28-May	DSCN1440	Abundant green algae and *Chara* mats in pool HU 1-07; most abundant algae compared to other pool habitats
Spring Spawning Assessment	28-May	DSCN1441	Bank at upstream end of side channel
Spring Spawning Assessment	08-Jun	DSCN1483	normal WQ5 monitoring location submerged
Spring Spawning Assessment	08-Jun	DSCN1484	groyne partially submerged; note silt deposition
Spring Spawning Assessment	08-Jun	DSCN1485	silt accumulation through rip rap
Spring Spawning Assessment	08-Jun	DSCN1486	log swept into groyne; rip rap on right downstream side intact
Spring Spawning Assessment	08-Jun	DSCN1516	mayfly emerging from exuviae (molting) on water surface
Spring Spawning Assessment	08-Jun	DSCN1524	Duck nest near at base of fallen tree near pool

			HU 1-07
Spring Spawning Assessment	08-Jun	DSCN1526	Fallen tree at pool HU 1-07
Spring Spawning Assessment	08-Jun	DSCN1532	WCT found stuck in panels of weir
Spring Spawning Assessment	08-Jun	DSCN1542	Limnephilid caddisflies on surface of gravels/cobble in glide HU 1-18 where water is still; cases made from wood and needles
Spring Spawning Assessment	08-Jun	DSCN1552	Limnephilid caddisflies on surface of gravels/cobble in glide HU 1-18 where water is still; cases made from wood and needles
Spring Spawning Assessment	08-Jun	DSCN1554	Killdeer nest
Spring Spawning Assessment	08-Jun	DSCN1557	Cedar Waxwings active pool HU 1-21
Spring Spawning Assessment	08-Jun	DSCN1566	Bull River high flows at upstream end of side channel
Spring Spawning Assessment	08-Jun	DSCN1568	Bull River high flows at upstream end of side channel
Spring Spawning Assessment	17-Jun	DSCN1582	partially submerged groyne; water higher than June 8 assessment
Spring Spawning Assessment	17-Jun	DSCN1584	upstream view of glide HU 1-18; note sedimentation along banks due to erosion in area that would provide good spawning habitat; good cobbles but sediment in interstitial spaces decreases quality
Spring Spawning Assessment	17-Jun	DSCN1585	Bull River high flows at upstream end of side channel
Juvenile Habitat Use Assessment	30-Jul	100-0021	Pool HU 3-1 net
Juvenile Habitat Use Assessment	30-Jul	100-0023	Pool HU 3-1 algae and eroding banks; silt accumulation in pool
Juvenile Habitat Use Assessment	30-Jul	100-0025	Pool HU 3-1 algae and eroding banks; silt accumulation in pool
Juvenile Habitat Use Assessment	30-Jul	100-0026	Pool HU 3-1 algae and eroding banks; silt accumulation in pool
Juvenile Habitat Use Assessment	30-Jul	100-0027	Groyne toward Bull River
Juvenile Habitat Use Assessment	30-Jul	100-0028	Downstream view of groyne
Juvenile Habitat Use Assessment	30-Jul	100-0029	Downstream view of groyne
Juvenile Habitat Use Assessment	30-Jul	100-0030	Eroding along bank near HU 1-04 on right downstream side
Juvenile Habitat Use Assessment	30-Jul	100-0031	Eroding along bank near HU 1-04 on right downstream side
Juvenile Habitat Use Assessment	30-Jul	100-0033	Upstream view of left downstream berm of side channel
Juvenile Habitat Use Assessment	30-Jul	100-0036	Downstream view of left downstream berm of side channel
Juvenile Habitat Use Assessment	30-Jul	100-0040	Downstream view of left downstream berm of side channel
Juvenile Habitat Use Assessment	30-Jul	100-0041	Upstream view of left downstream berm of side channel
Juvenile Habitat Use Assessment	31-Jul	P7310045	Electrofishing site EF1
Fall Spawning Assessment	23-Sep	DSCN2310	Kokanee congregating in glide HU 1-12

Fall Spawning Assessment	23-Sep	DSCN2326	Kokanee eggs in gravel of glide HU 1-12
Fall Spawning Assessment	23-Sep	DSCN2336	Underwater views of congregating Kokanee
Fall Spawning Assessment	23-Sep	DSCN2339	Underwater views of congregating Kokanee
Fall Spawning Assessment	23-Sep	DSCN2353	Underwater views of congregating Kokanee
Fall Spawning Assessment	23-Sep	DSCN2374	Underwater views of congregating Kokanee
Fall Spawning Assessment	23-Sep	DSCN2375	Underwater views of congregating Kokanee
Fall Spawning Assessment	23-Sep	DSCN2379	Underwater views of congregating Kokanee
Fall Spawning Assessment	30-Sep	DSCN2590	Kokanee congregating in glide HU 1-12
Fall Spawning Assessment	30-Sep	DSCN2591	Location of DO logger in glide HU 1-12
Fall Spawning Assessment	30-Sep	DSCN2593	Syringe used to extract water sample from intragravel
Fall Spawning Assessment	30-Sep	DSCN2594	Placement of syringe in intragravel space
Fall Spawning Assessment	30-Sep	DSCN2595	Extracting water from intragravel space with syringe
Fall Spawning Assessment	30-Sep	DSCN2597	Extracting water from intragravel space with syringe
Fall Spawning Assessment	30-Sep	DSCN2598	WQ measurement of water extracted from intragravel with YSI
Fall Spawning Assessment	30-Sep	DSCN2600	Location of DO logger in mainstem of Bull River
DO Data Download	13-Dec	DSCN4191	Eyed Kokanee egg found at glide HU 1-18 (WQ7)
DO Data Download	13-Dec	DSCN4194	Bear dig at bank of glide HU 1-18 (WQ7); sediment disturbed by bear entered channel
Overwintering Assessment	14-Feb	P2143256	Upstream view of groyne and Bull River mainstem; note sediment accumulation from high flows through rip rap
Overwintering Assessment	14-Feb	P2143257	Downstream view of groyne opening to Bull River mainstem; note sediment accumulation from high flows through rip rap
Overwintering Assessment	14-Feb	P2143258	Pool HU 1-07
Overwintering Assessment	14-Feb	P2143259	Glide HU 1-10
Overwintering Assessment	14-Feb	P2143260	Pool HU 2-02
Overwintering Assessment	14-Feb	P2143265	Pool HU 3-02
Overwintering Assessment	14-Feb	P2143266	Pool HU 1-21 and algal growth
Overwintering Assessment	14-Feb	P2143267	Pool HU 1-21 and algal growth
Overwintering Assessment	14-Feb	P2143269	Larval Kokanee found at pool HU 1-21
Overwintering Assessment	14-Feb	P2143271	DO logger in case

Appendix 3 Year 4 (2012-2013) Seasonal Water Quality Data

Season	Date (m/d/y)	Site	Habitat Type	Temp (^oC)	Sp. Cond. (µS/cm)	Salinity (ppt)	pH	DO (mg/L)	%DO	Redox Potential (mV)
Spring	6/8/12	WQ 1	Cascade	8.73	288	0.14	7.78	9.42	81.2	-54.0
Spring	6/17/12	WQ 1	Cascade	8.86	286	0.14	7.53	8.24	71.1	-39.1
Spring	6/8/12	WQ 2	Pool	11.02	524	0.25	7.43	8.53	77.6	-39.9
Spring	6/17/12	WQ 2	Pool	10.81	357	0.17	7.59	8.48	76.5	-26.0
Spring	6/8/12	WQ 3	Glide	8.86	288	0.14	7.69	9.60	83.0	-66.5
Spring	6/17/12	WQ 3	Glide	9.43	298	0.14	7.59	8.41	73.6	-32.5
Spring	6/8/12	WQ 4	Pool	8.42	323	0.15	7.34	8.87	75.6	-47.7
Spring	6/17/12	WQ 4	Pool	9.42	301	0.14	7.64	8.43	73.7	-57.5
Spring	6/8/12	WQ 5	Mainstem	5.45	248	0.11	7.7	9.55	75.7	-34.1
Spring	6/17/12	WQ 5	Mainstem	6.48	204	0.10	7.67	12.70	103.4	-26
Spring	6/8/12	WQ 6	Pool	8.65	297	0.14	7.74	9.10	78.1	-53.2
Spring	6/17/12	WQ 6	Pool	8.48	294	0.14	7.54	8.05	68.7	-44.0
Spring	6/8/12	WQ 7	Glide	8.15	265	0.13	7.93	9.98	84.6	-78.4
Spring	6/17/12	WQ 7	Glide	8.39	271	0.14	7.60	8.16	69.5	-41.8
Spring	6/8/12	WQ 8	Pool	6.16	271	0.13	7.73	9.54	77.1	-35.1
Spring	6/17/12	WQ 8	Pool	6.88	257	0.12	7.60	7.93	65.4	-39.1
Summer	7/30/12	WQ 1	Cascade	11.95	304	0.15	7.74	6.70	62.2	126.1
Summer	7/30/12	WQ 2	Pool	13.58	325	0.16	7.82	6.92	66.5	134.8
Summer	7/30/12	WQ 3	Glide	12.15	289	0.14	7.82	7.09	66.6	106.9
Summer	7/30/12	WQ 4	Pool	12.15	350	0.17	7.93	7.47	70.1	109.9
Summer	7/30/12	WQ 5	Mainstem	10.51	246	0.12	8.02	11.98	107.5	155.2
Summer	7/30/12	WQ 6	Pool	11.53	310	0.15	7.72	5.19	47.0	143.3
Summer	7/30/12	WQ 7	Glide	11.16	285	0.14	7.76	5.97	54.6	166.8
Summer	7/30/12	WQ 8	Pool	10.48	268	0.13	7.76	6.47	58.1	161.9
Fall	9/23/12	WQ 1	Cascade	10.51	336	0.16	7.74	10.91	98.1	387.0
Fall	9/23/12	WQ 2	Pool	11.46	38	0.19	7.63	6.13	55.5	387.0
Fall	9/23/12	WQ 3	Glide	12.04	332	0.16	7.61	6.20	57.7	382.0
Fall	9/23/12	WQ 4	Pool	13.12	373	0.18	7.63	5.66	53.5	362.0
Fall	9/23/12	WQ 5	Mainstem	11.74	321	0.15	7.50	6.22	57.4	384.0
Fall	9/23/12	WQ 6	Pool	12.21	323	0.16	7.58	4.51	42.1	387.4
Fall	9/23/12	WQ 7	Glide	11.31	316	0.15	7.53	5.56	50.6	381.4
Fall	9/23/12	WQ 8	Pool	10.23	305	0.15	7.54	2.93	26.1	387.4
Winter	2/14/13	WQ 1	Cascade	3.1	318	0.15	7.89	6.00	44.7	250.1
Winter	2/14/13	WQ 2	Pool	5.01	510	0.25	7.88	1.725	13.55	247.85
Winter	2/14/13	WQ 3	Glide	3.26	40	0.03	7.52	6.31	47.2	253.3
Winter	2/14/13	WQ 4	Pool	7.43	71	0.03	8.03	3.44	28.6	240.5
Winter	2/14/13	WQ 5	Mainstem	0.05	73	0.03	6.70	10.75	73.7	256.6
Winter	2/14/13	WQ 6	Pool	4.32	324	0.15	7.69	3.73	28.9	314.0
Winter	2/14/13	WQ 7	Glide	3.34	113	0.05	7.34	6.09	45.7	295.4
Winter	2/14/13	WQ 8	Pool	6.13	138	0.06	8.62	5.68	45.8	260.3

Appendix 4 F-values from factorial ANOVAs examining the effects of project year, season, habitat, and their interaction on water quality variables (temperature, pH, dissolved oxygen, specific conductivity, salinity, and redox) for Year 4 of the Aberfeldie study. Asterisks indicate significant effects at the Holm modified Bonferroni level: *p < 0.007. Degrees of freedom are shown in parentheses

Dependent Variables ($df_{denominator}$)	**Source of variation ($df_{numerator}$)**						
Water Quality Variables	Year (2)	Season (3)	Habitat (3)	Year Season (6)	Year Habitat (4)	Season Habitat (6)	Year Season Habitat (12)
Temp (^{o}C)	2.95	137.12*	11.43*	9.05*	0.14	1.44	0.16
pH	13.04*	6.53*	1.29	4.41*	0.66	1.01	1.93
Dissolved Oxygen (mg/L)	3.50*	15.18*	100.53*	2.74*	0.21	1.05	0.54
% Dissolved Oxygen	5.93*	12.54*	88.78*	4.68*	0.32	0.80	0.52
Specific Conductance (µS/cm)	6.56*	4.10	5.38*	3.81*	0.20	0.56	0.37
Salinity (ppt)	3.75	7.12*	7.93*	4.59*	0.37	1.12	0.57
Redox (mV)	14.34*	35.67*	0.33	11.85*	0.36	0.25	0.38

Appendix 5 Year 4 (2012-2013) staff gauge water levels and calculated discharge

Date	Stage (m)	Discharge* (m^3/s)
25-May-12	0.074	0.022
8-Jun-12	0.102	0.036
17-Jun-12	0.11	0.04
22-Jun-12	0.09	0.03
23-Sep-12	0.03	0.006
30-Sep-12	0.03	0.006
9-Oct-12	0.034	0.007
14-Feb-13	0.028	0.005

***Discharge calculated from BC Hydro discharge rating curve over the 2.0 ft rectangular weir.**

Appendix 6 Year 4 (2012-2013) water velocity and depth at spawning platforms

Date	Habitat Unit	Habitat Type	Mean Velocity	Depth
8-Jun-12	HU 1-08	Glide	0.07	0.25
8-Jun-12	HU 1-12	Glide	0.04	0.28
8-Jun-12	HU 1-14	Glide	0.1	0.22
8-Jun-12	HU 1-16	Glide	0.07	0.18
8-Jun-12	HU 1-18	Glide	0.07	0.16
8-Jun-12	HU 1-20	Glide	0.29	0.11
17-Jun-12	HU 1-08	Glide	0.02	0.55
17-Jun-12	HU 1-12	Glide	0.06	0.225
17-Jun-12	HU 1-14	Glide	0.06	0.3
17-Jun-12	HU 1-16	Glide	0.11	0.15
17-Jun-12	HU 1-18	Glide	0.07	0.16
17-Jun-12	HU 1-20	Glide	0.25	0.11
22-Jun-12	HU 1-06	Riffle	0.07	0.37
22-Jun-12	HU 1-08	Glide	0.13	0.18
22-Jun-12	HU 1-12	Glide	0.08	0.16
22-Jun-12	HU 1-14	Glide	0.09	0.24
22-Jun-12	HU 1-16	Glide	0.08	0.18
22-Jun-12	HU 1-18	Glide	0.09	0.16
22-Jun-12	HU 1-20	Glide	0.19	0.1
30-Jul-12	HU 1-03	Glide	0.31	0.13
30-Jul-12	HU 1-06	Riffle	0.22	0.21
30-Jul-12	HU 1-08	Glide	0.10	0.21
30-Jul-12	HU 1-12	Glide	0.08	0.17
30-Jul-12	HU 1-14	Glide	0.01	0.42
30-Jul-12	HU 1-16	Glide	0.06	0.15
30-Jul-12	HU 1-18	Glide	0.04	0.18
30-Jul-12	HU 1-20	Glide	0.22	0.11
23-Sep-12	HU 1-03	Glide	0.10	0.17
23-Sep-12	HU 1-06	Riffle	0.22	0.10
23-Sep-12	HU 1-08	Glide	0.03	0.16
23-Sep-12	HU 1-12	Glide	0.12	0.07
23-Sep-12	HU 1-14	Glide	0.11	0.08
23-Sep-12	HU 1-16	Glide	0.01	0.19
23-Sep-12	HU 1-18	Glide	0.10	0.10
23-Sep-12	HU 1-20	Glide	0.15	0.07

Appendix 7 Manufacturer specification for YSI 5563MPS water quality meter

5563 MPS Sensor Specifications

Dissolved Oxygen (% saturation)	Sensor Type	Steady state polarographic
	Range	0 to 500% air saturation
	Accuracy	0 to 200% air saturation, ± 2% of the reading or ±2% air saturation, whichever is greater; 200 to 500% air saturation, ± 6% of the reading
	Resolution	0.1% air saturation
Dissolved Oxygen (mg/L)	Sensor Type	Steady state polarographic
	Range	0 to 50 mg/L
	Accuracy	0 to 20 mg/L, ± 2% of the reading or ±0.2 mg/L, whichever is greater; 20 to 50 mg/L, ± 6% of the reading
	Resolution	0.01 mg/L
Temperature	Sensor Type	YSI Temperature Precision™ thermistor
	Range	-5 to 45°C
	Accuracy	± 0.15°C
	Resolution	0.1°C
Conductivity	Sensor Type	4-electrode cell with autoranging
	Range	0 to 200 mS/cm
	Accuracy	± 0.5% of reading or ± 0.001 mS/cm; whichever is greater (4-meter cable) ± 1.0% of reading or ± 0.001 mS/cm; whichever is greater (20-meter cable)
	Resolution	0.001 mS/cm to 0.1 mS/cm (range-dependent)
Salinity	Sensor Type	Calculated from conductivity and temperature
	Range	0 to 70 ppt
	Accuracy	± 1.0% of reading or ±0.1 ppt, whichever is greater
	Resolution	0.01 ppt
pH (optional)	Sensor Type	Glass combination electrode
	Range	0 to 14 units
	Accuracy	±0.2 units
	Resolution	0.01 units
ORP (optional)	Sensor Type	Platinum button
	Range	-999 to +999 mV
	Accuracy	± 20 mV
	Resolution	0.1 mV
Total Dissolved Solids (TDS)	Sensor Type	Calculated from conductivity (variable constant, default 0.65)
	Range	0 to 100 g/L
	Resolution	4 digits
Barometer (optional)	Range	500 to 800 mm Hg
	Accuracy	± 3 mm Hg within ± 10°C temperature range from calibration point
	Resolution	0.1 mm Hg

Appendix 8 Physical habitat requirements for potential spawners in the Aberfeldie side channel (McPhail 2007, unless otherwise noted)

Species	Spawning		Fry	Juvenile	Adult
	Water velocity (m/s)	Substrate diam. (mm)			
Westslope Cutthroat Trout	0.56 (avg.) [1] 0.3 to 0.4 [2]	2 - 50 [2]	Shallow water (<0.20 m) quiet (0.07 to 0.10 m/s) stream edges. Substrate and wood for hiding	Summer: deep water, velocity 0.14 m/s - 0.39 ; Winter [3]: wood cover or large gravel/cobbles, velocity = 0.10 m/s.	Low velocity areas (<0.22 m/s) in pools with some overhead cover (e.g., LWD or large boulders). Winter: groundwater ponds[4]; or deeper pools, with groundwater [5]
Bull Trout	Groundwater is important; 0.2 - 0.6 [6] 0.39 – 0.45 [7]	D_{50}> 40 [6] 34 - 39 [7]	Shallow (<0.05 m deep) stream edges; in and around gravel (20-100 mm) interspersed with boulders & low velocity areas (<0.2 m/s) incl. side channels	Pools and deep side channels. Associated with cover (pools, wood or substrate). Low velocity areas (0.23 m/s) [8]	
Mountain Whitefish	Not critical[9]	Not critical[9]	Shallow (<0.50 m), quiet water over sand or silt. [9]	Assoc. with glides and runs, deeper waters with large substrates (25-40 cm), and moderate flow (0.25 – 0.6 m/s) [9]	Pools or among large organic debris; 79 cm avg. depth; velocity 0.30 – 0.80 m/s, and substrate D50 >25 cm[6].
Kokanee	0.15 to 0.85	10 - 25	Usually migrate to lake before starting to feed.		
Rainbow Trout	0.3-0.9[10]	Depends on female size	Initially shallow, small substrates and low flow (<0.01 m/s) [11]; cover is important [12]	Riffles and runs, <0.25 m deep, cobble-boulder substrates and avg. flow of 0.2-0.4 m/s [13].	Generally deeper faster water than juveniles. Overhead cover is important. Large pools used in winter[11]
Eastern Brook Trout	Variable ranging from 0.03 to 0.9[14].	Depends on female size (30 to 80 mm) [15].	Shallow edge habitats over coarse gravel and cobble substrates [14].	Low velocities, cover and depth are important [16].	Prefer low velocity (0.1 m/s) [17]. Cover is important.

References:
1) Schmetterling (2000)
2) Shepard *et al.* (1984)
3) Bonneau and Scarnecchia (1998)
4) Allen (1987)
5) Brown and Mackay (1995)
6) Bustard (1996)
7) Baxter *et al.* (1997)
8) Spangler and Scarnecchia (2000)
9) Northcote and Ennis (1998)
9 10) Raleigh *et al.* (1994)
10 11) Muhlfeld *et al.* (2001)

Appendix 9 Digital Copy of Report (including photos as jpegs for 2012 – 2013)