Aberfeldie Project Water Use Plan

Effectiveness Monitoring Fish Habitat Works

Year 3 Reporting

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Final Report

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Aberfeldie Side Channel
Effectiveness Monitoring of Fish Habitat Works (Year 3)

Project ABFMON 5 (Contract Q9-9260)

Year 3 Study Report

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Cover Photo

Spawning Kokanee leaping over hydrometric weir at Aberfeldie side channel (Habitat Unit 1-13), September 17, 2011.

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. This study monitored the fish and fish habitat effectiveness of the side channel in its third year of establishment and forms Year 3 of a 5-year monitoring program. Year 3 monitoring included: 1) a review of structural stability of the channel; 2) the collection of seasonal water quality and quantity data; 3) a fall spawning assessment; and, 4) 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 and Mountain Whitefish, may also use the side channel for rearing. Year 3 of the monitoring program revealed 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. DO levels (measured in the water column) marginally met the minimum requirement for the support of aquatic life in summer and fall (5mg/L) and never met the minimum requirements for successful development of embryo and alevins (9mg/L) (MOE, 2001). *Oncorhynchus nerka* embryos usually don't survive in locations where intragravel DO concentration is lower than 3mg/L (or approximately 6 to 7 mg/L in the water column) (Cope, 1996; MOE, 2001). Although the channel was initially designed to ensure sufficient 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 0.22 m/s. Despite sub-optimal conditions, an estimated 4,300 Kokanee entered the side channel for spawning, which is consistent with numbers of Kokanee spawners counted in Year 1 of the monitoring program. Kokanee fry were observed in the channel in March 2012 but the incubation success rate of deposited eggs is unknown. In winter, the channel outlet remained open but overwintering habitat availability was limited by low DO concentration in pools and low water levels in glides. Bank erosion was noted throughout the side channel and is the result of precipitation and animal activity (i.e., wildlife and cattle). Bank erosion led to fine sediments entering the channel, which, in the long run, could be detrimental to spawning habitat suitability.

In conclusion, Interior Reforestation recommends that a number of concerns be addressed by BC Hydro, including:

- Address DO and water velocity issues by remodelling the channel morphology and/or increasing water inflow from the Bull River.
- Investigate the residence time of spawning Kokanee and the incubation success of buried embryo in order to accurately assess and quantify the biological productive capacity achieved through the habitat compensation work.
- Revegetate and reslope the channels banks in order to prevent erosion and input of fine sediments in 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 create 3,600m2 of compensation habitat. 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) and for Year 2 in 2010-2011 (McPherson and Robinson 2011). This report presents Year 3 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 appropriately 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). 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 provide fish and benthic habitat. 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 4 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 (average 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 averaged 3.4 ± 1.1 %, and cascade gradients averaged 15.5 ± 6.6 %.

1.3 Scope

BC Hydro and Power Authority (BC Hydro) retained the services of Interior Reforestation Co. Ltd. (Interior Reforestation) 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 2011/2012, the third 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 any 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:

1) Baseline productivity monitoring (ABFMON-1)
2) Primary and secondary productivity monitoring (ABFMON-2)
3) Habitat impact monitoring (ABFMON-3)
4) 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):

1. 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?

2. 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) and ABFMON#2 (Primary and Secondary Productivity Monitoring). The hypotheses relate to primary productivity (periphyton and benthic invertebrate results) not fish productivity and thus are not addressed in this report.

The hypotheses are:

Periphyton

Ho_1: There is no difference between the peak biomass of periphyton in the diversion reach before redevelopment and in the combined off channel habitat and diversion reach of Bull River under the post redevelopment 2 m^3/s minimum summer flow release.

Ho_2: There is no difference between the total abundance and diversity of periphyton in the diversion reach before redevelopment and in the combined off channel habitat and diversion reach of Bull River under the post redevelopment 2 m^3/s minimum summer flow release.

Benthic invertebrates

Ho_3: There is no difference between the total abundance, biomass and diversity of benthic invertebrates in the diversion reach before redevelopment and in the combined off channel habitat and diversion reach of Bull River under the post redevelopment 2 m^3/s minimum summer flow release.

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:

1. **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 associate absence of fish with lack of habitat types or features. These findings will be monitored over time to identify any changes to fish-habitat associations and habitat quality.

2. **Water Quality and Water Level Data (Years 1 – 5):** In order to evaluate suitability of habitat conditions, water quality and water 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 (Appendix 1) are to be collected during every site visit in order to determine whether or not channel flows are meeting fish habitat requirements.

3. **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.

4. **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., 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.

5. **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.

6. **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.

7. **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 3 monitoring involved the completion of seasonal water quality assessments, fall spawning surveys, structural stability assessments, and an overwintering assessment (Table 2).

Table 2 Fish habitat effectiveness monitoring activities completed during Year 3 in the Aberfeldie side channel.

Activity	Date
Seasonal water quality assessment	July 5, 2011 August 13, 2011 September 12, 2011 February 28, 2012
Fall spawning survey	September 12, 2011 September 17, 2011 September 26, 2011 October 3, 2011 October 12, 2011
Structural stability assessment	October 3, 2011
Overwintering assessment	February 28, 2012

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 location and seven locations within the side channel (Appendix 1. – Map A). 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 collect data. The manufacturer specifications fcan be found in Appendix 5. In previous years, water quality data collected by Limnotek supplemented those collected by Interior; however, supplemental water quality data from Limnotek were not available for Year 3.

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 ± 95% 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*.).

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 October 3, 2011. 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:

1) Stability and erosion of the berm on the left downstream boundary of the channel, running the extent of the riverside boundary;
2) Effectiveness of the berm on the right downstream bank to protect the channel from the adjacent eroding slope; and
3) Channel connectivity to the Bull River, including stability of the outlet protection groyne and erosion and/or scour at the channel entrance; and
4) 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 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 12, 17, 26, October 3, and 12, 2011. 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. An additional day was added to the spawning survey given that peak mortality of Kokanee spawners had not been reached by Oct. 3, 2011.

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 during the assessment. This review included enumerating mortalities 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 between 2009 and 2011 using 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. Incorporation of data from Year 4 will allow for multivariate tests to assess the influence of water quality predictor variables. The Year 4 report will include assessments of the association between water quality variables, such as temperature and discharge, on spawning data (i.e., number of spawning individuals/redds) during a particular spawning year.

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 2011. 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 average 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.

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 average residence time (RT) of 8.5 days.

2.4 Overw intering Assessment

The overwintering assessment was initially conducted on January 19, 2012. The weather leading up to this assessment was very close to 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. Air temperatures averaged -7.0 ^{o}C at the Bull River over the five day period prior to assessment (Environment Canada 2011). On the day of the assessment, the temperature averaged -20.2 ^{o}C. Technical difficulties were encountered with the YSI probes due to the extreme temperature. A second assessment was deemed necessary and was conducted on February 28, 2012 after appropriate temperatures had been reached. The mean temperature was -8.9 ^{o}C.

Seasonal water quality data (from 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 characterize outlet connection to the mainstem, extent of ice coverage, and quality of winter refuge for fish.

2.5 Photo Documentation

Field monitoring activities for this project were photographed and indexed (Appendix 2.). The index and photos have been provided in chronological order and the image number has been coded to represent the year/month/date of sampling, to allow for easy cross reference of photos with the results (based on date or activity) and cataloguing over time. For instance, the first photo taken on July 5, 2011 was numbered as 110708_05.

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 Table 3 and discussed in the sections below.

The results from the factorial ANOVA indicated that the interaction factor of year-season was consistently significant across all water quality variables. To investigate the influence of the year-season interaction factor 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 4.

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 2011 were sufficient to meet the requirements for rearing and reproduction of fish species.

Table 3. 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). 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 (^oC)	9.05*	228.16*	22.79*	20.58*	0.29	2.91	0.46
pH	59.79*	11.02*	1.25	3.62*	2.85	2.46	4.42*
Dissolved Oxygen (mg/L)	1.65	18.36*	154.62*	4.12*	0.4	1.34	0.84
% Dissolved Oxygen	3.76	10.35*	116.55*	5.88*	0.53	0.91	0.64
Specific Conductance (µS/cm)	1.67	4.12	6.43*	4.03*	0.23	0.94	0.17
Salinity (ppt)	0.09	5.81*	8.13*	5.38*	0.72	1.42	0.77
Redox (mV)	0.04	51.00*	-	8.97*	1.26	0.84	2.28

Table 4. F-values from one-way ANOVAs examining the effects of year on water quality variables for each habitat type and season. 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.

Dependent Variables ($df_{denominator}$)			**Source of variation ($df_{numerator}$)**
WQ Variable	**Habitat Type-Season**		**Year (2)**
Temp (^oC)	Pool	Fall (9)	51.789** (2009<2010, 2009<2011)
		Winter (9)	ns
		Spring (9)	ns
		Summer (9)	ns
	Glide	Fall (6)	192.47** (2009<2010, 2009<2011)
		Winter (6)	95.145** (2011<2010, 2011<2012)
		Spring (6)	ns
		Summer (6)	ns
pH	Pool	Fall (9)	13.088* (2009<2010, 2011<2010)
		Winter (9)	ns
		Spring (9)	10.406* (2009<2010)
		Summer (9)	ns
	Glide	Fall (6)	18.222* (2009<2010, 2011<2010)
		Winter (6)	120.38** (2010<2011, 2010<2012, 2012<2011)
		Spring (6)	ns
		Summer (6)	ns
Dissolved Oxygen (mg/L)	Pool	Fall (9)	ns
		Winter (9)	ns
		Spring (9)	ns
		Summer (9)	ns
	Glide	Fall (6)	ns
		Winter (6)	22.044* (2010<2011, 2010<2012)
		Spring (6)	ns
		Summer (6)	ns

Dependent Variables ($df_{denominator}$)			**Source of variation ($df_{numerator}$)**
WQ Variable	**Habitat Type-Season**		**Year (2)**
% Dissolved Oxygen	Pool	Fall (9)	ns
		Winter (9)	ns
		Spring (9)	ns
		Summer (9)	ns
	Glide	Fall (6)	ns
		Winter (6)	54.591** (2010<2011, 2011<2012, 2010<2012)
		Spring (6)	ns
		Summer (6)	ns
Specific Conductance (µS/cm)	Pool	Fall (9)	ns
		Winter (9)	ns
		Spring (9)	ns
		Summer (9)	ns
	Glide	Fall (6)	ns
		Winter (6)	ns
		Spring (6)	ns
		Summer (6)	ns
Salinity (ppt)	Pool	Fall (9)	ns
		Winter (9)	ns
		Spring (9)	ns
		Summer (9)	ns
	Glide	Fall (6)	ns
		Winter (6)	ns
		Spring (6)	104.67** (2009<2011, 2010<2011)
		Summer (6)	ns
Redox (mV)	Pool	Fall (9)	ns
		Winter (9)	14.703* (2010<2011, 2012<2011)
		Spring (9)	27.024** (2009<2010, 2011<2009, 2011<2010)
		Summer (9)	53.316** (2009<2010, 2011<2010)
	Pool	Fall (9)	ns
		Winter (9)	22.981* (2010<2011, 2012<2011)
		Spring (9)	21.591* (2011<2009, 2011<2010)
		Summer (9)	92.362** (2009<2010, 2011<2010)

3.1.1 Water temperature

Factorial ANOVA results indicated that there were significant differences in temperature for factors project year, season, habitat, and project year-season interaction (Table 3; 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 3). 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 2009 were lower than temperatures in 2010 and 2011. Glide temperatures were also significantly different during winter; 2011 temperatures were lower than 2010 and 2012 temperatures (Table 4).

In the fall, during the Bull Trout breeding season, mean temperatures exceeded the optimal Bull Trout spawning range in all habitat units except habitat unit 1-21 (pool) (Figure 3). Temperatures did not exceed the optimal range for cutthroat trout rearing (7.0-16.0 ^{o} C; BC MoE 2001).

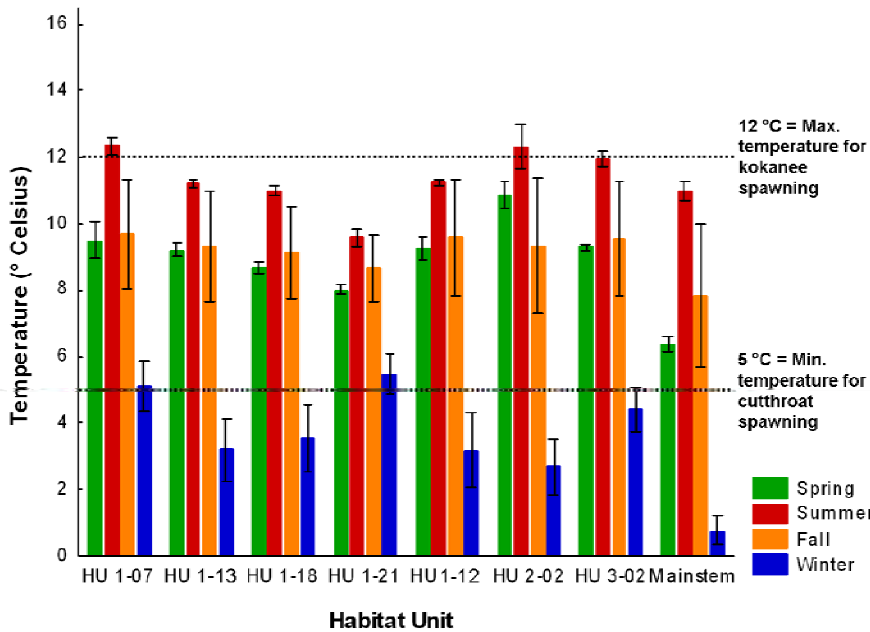

Figure 3. Mean water temperature (^{o} Celsius) at habitat units sampled for water quality assessments of the Aberfeldie side channel. Dashed lines mark the maximum temperature for cutthroat trout rearing (16^{o} C) and maximum temperature for Bull Trout spawning (9^{o} C), respectively (BC MoE, 2001).

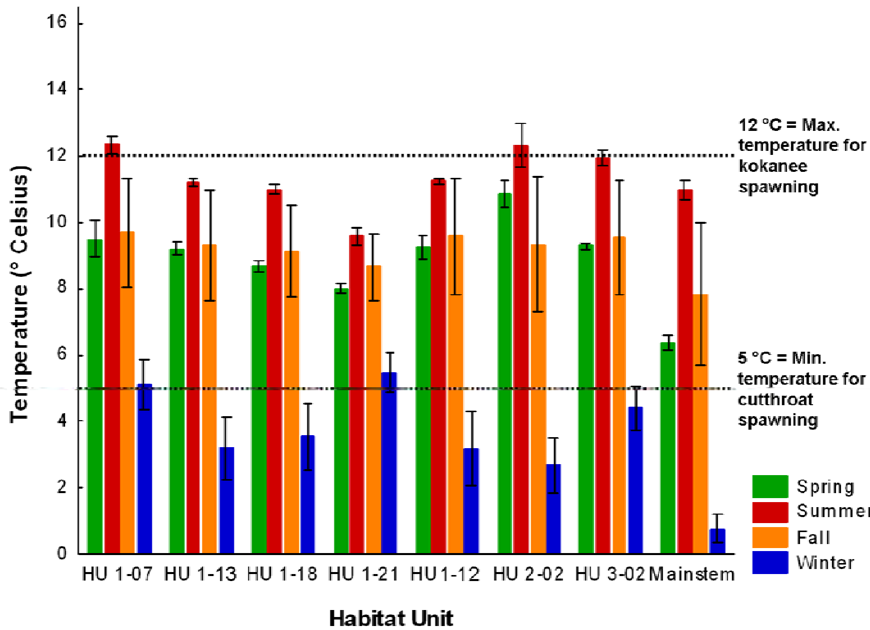

Figure 4 Mean water temperature (^{o} Celsius) at habitats (glide, pool, and Bull River mainstem) sampled for water quality assessments of the Aberfeldie side channel. Dashed lines mark the maximum temperature for cutthroat trout rearing (16^{o} C) and maximum temperature for Bull Trout spawning (9^{o} C) (BC MoE, 2001).

3.1.2 pH

Factorial ANOVA results indicated that there were significant differences in pH for factors project year, season, and project year-season interaction (Table 3; 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 ($p<0.05$). Generally, mean pH was minimal during summer and maximal during fall for all habitat units, except in habitat unit 2-01 (Glide) (Figure 5).

There were significant differences in pH during the fall for both pools and glides, during the spring for pools, and during the winter for glides. Fall 2010 pH was higher than both 2009 and 2011 pH. In pools, spring 2009 pH was lower than 2010 pH. Winter glide pH was lowest in 2010 and highest in 2011 (Table 4).

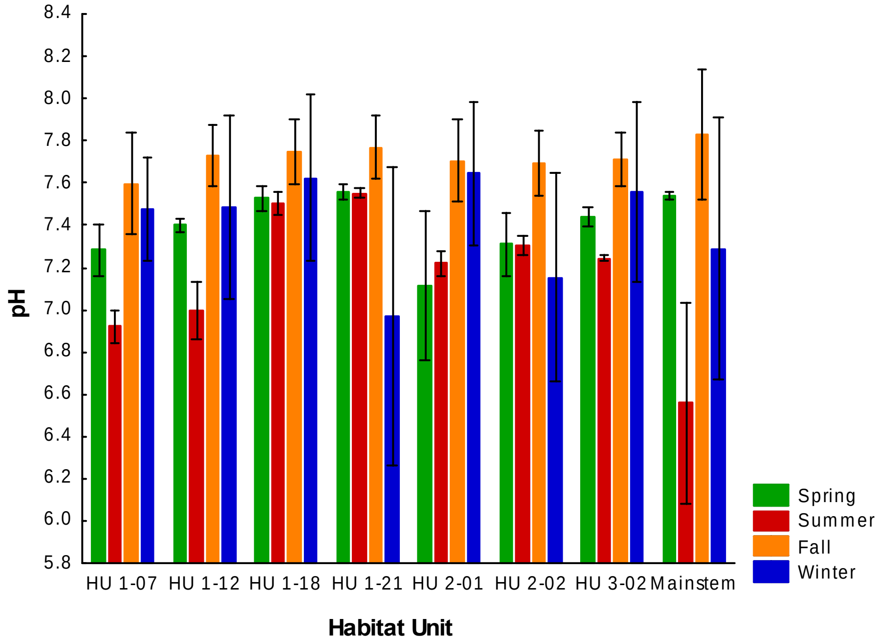

Figure 5 Mean pH at habitat units sampled for water quality assessments of the Aberfeldie side channel.

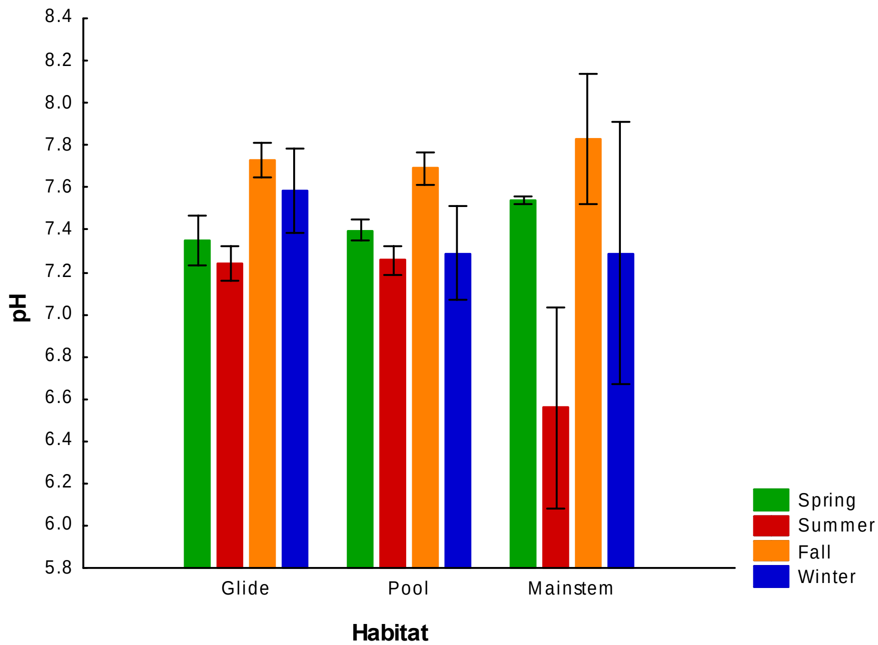

Figure 6 Mean pH at habitats (glide, pool, and Bull River mainstem) sampled for water quality assessments of the Aberfeldie side channel.

3.1.3 Dissolved oxygen (DO)

Factorial ANOVA results indicated that there were significant differences in dissolved oxygen concentration (DO) and per cent DO for factors; season, habitat, and project year-season interaction (Table 3; 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 7, Figure 8, Figure 9, and Figure 10). Tukey's HSD tests revealed that mean DO was highest during spring (p<0.05) and in the Mainstem (p<0.01), whereas DO was lowest in Pools (p<0.005).

Dissolved oxygen levels were significantly different among winter project years for glide habitats. Winter glide DO was lowest in 2010 as compared to 2011 and 2012 DO levels. There was no significant difference between DO levels in 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. During the 2011 water monitoring program, DO concentrations at the Aberfeldie side channel never reached the minimum level required for successful development of buried embryos/alevins (9 mg/L) (Figure 7). 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 and 1-13 (two adjacent glides) consistently met this minimum requirement in 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 mg/L. Comparatively, DO concentration in the Bull River mainstem exceeded 9 mg/L in all seasons.

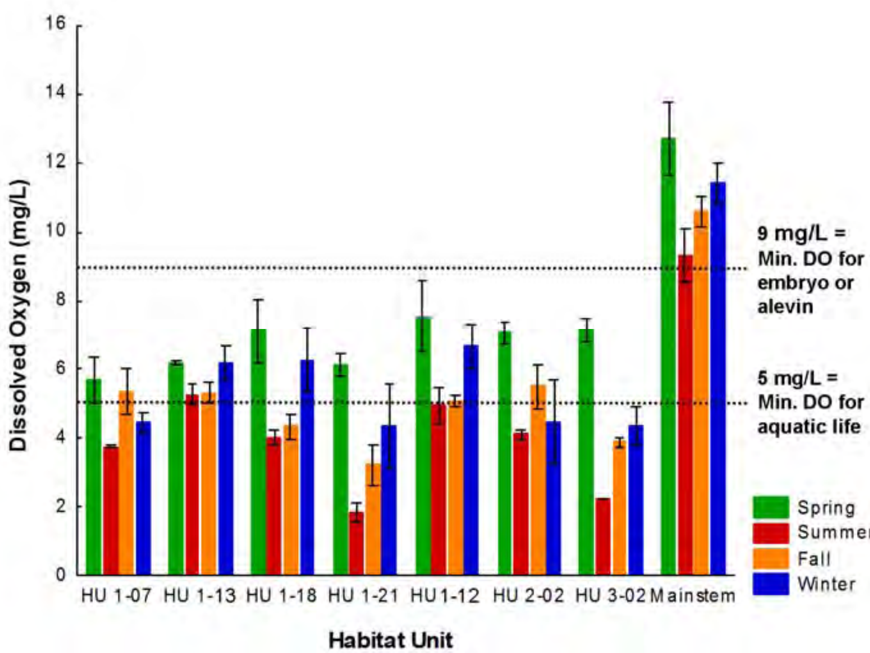

Figure 7 Mean dissolved oxygen concentration (mg/L) at habitat units sampled for water quality assessments of the Aberfeldie side channel. Dashed lines indicate the minimum dissolved oxygen concentration required for embryo and alevin rearing (9^{o} C) and minimum dissolved oxygen concentration required for aquatic life (5^{o} C) (BC MoE, 2001).

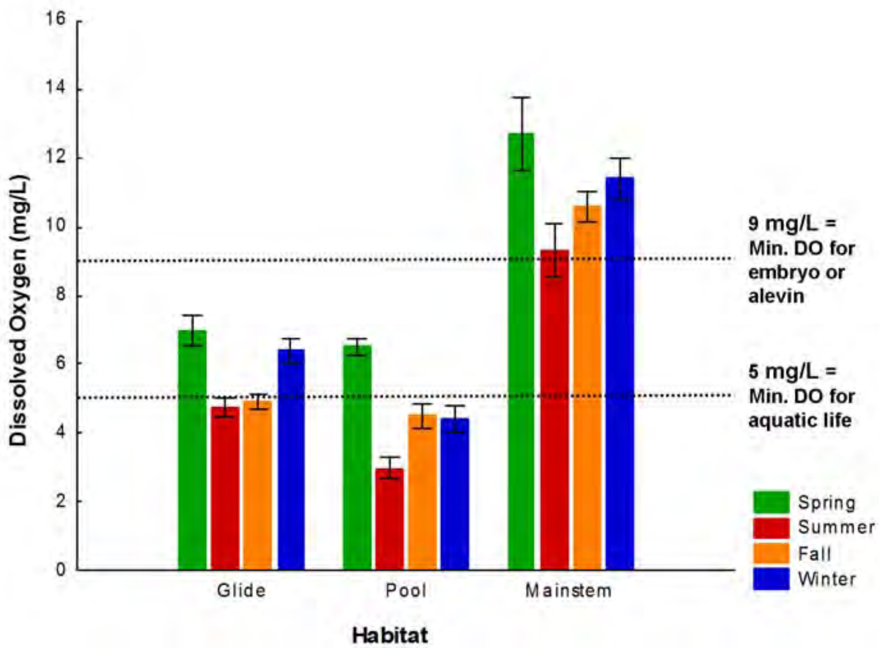

Figure 8 Mean dissolved oxygen concentration (mg/L) at habitat types sampled for water quality assessments of the Aberfeldie side channel. Dashed lines indicate the minimum dissolved oxygen concentration required for embryo and alevin rearing (9^{o} C) and minimum dissolved oxygen concentration required for aquatic life (5^{o} C) (BC MoE, 2001).

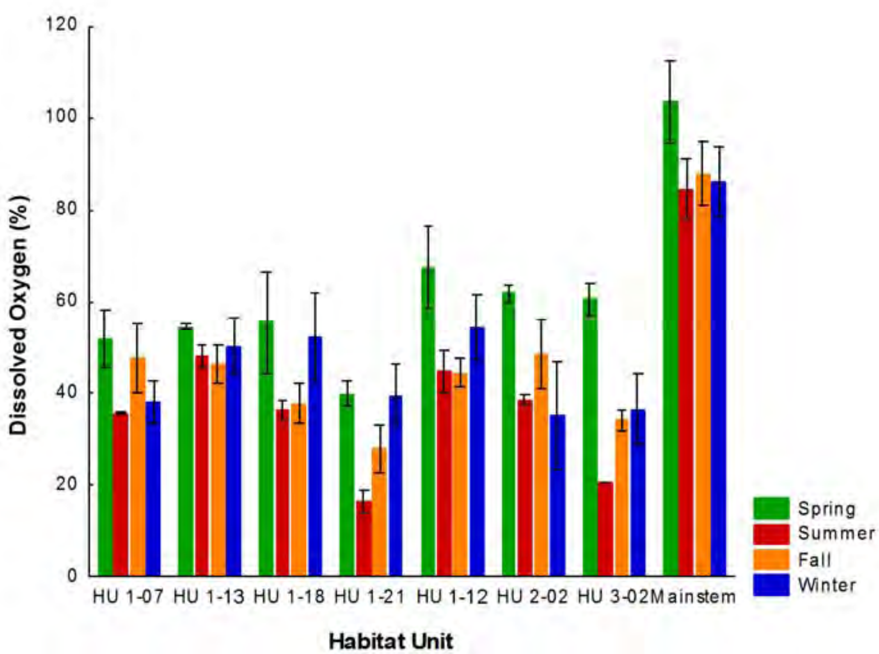

Figure 9 Mean dissolved oxygen saturation (per cent) at habitat units sampled for water quality assessments of the Aberfeldie side channel.

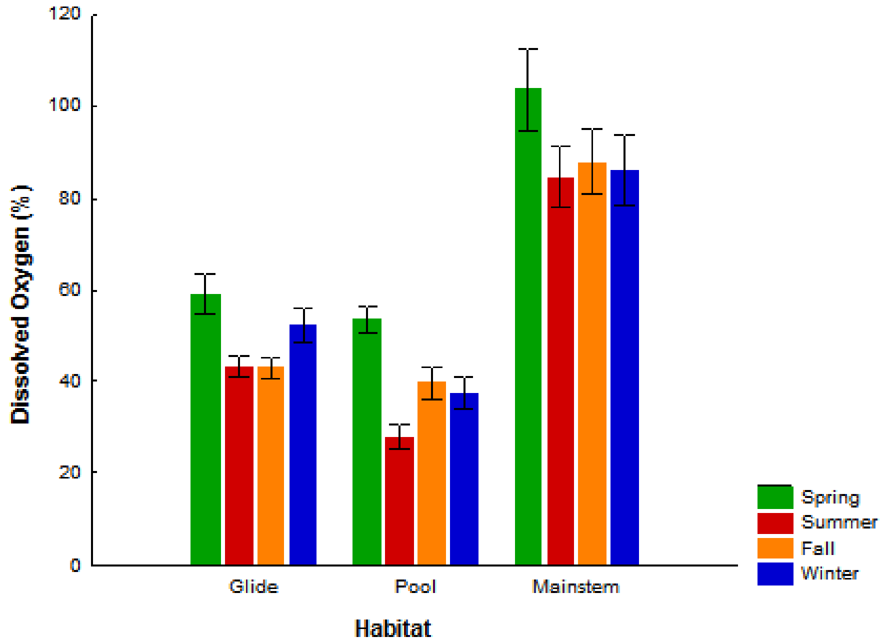

Figure 10 Mean dissolved oxygen saturation (per cent) at habitat types (glide, pool, and Bull River mainstem) sampled for water quality assessments of the Aberfeldie side channel.

3.1.4 Specific Conductance

Factorial ANOVA results indicated that there were significant differences in specific conductance for factors habitat and project year-season interaction (Table 3; 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 winter (**Figure 9**). Habitat unit 1-7 (Pool) had significantly higher specific conductance than all other habitat units (p<0.007;**Figure 9**). Pool habitats also had significantly higher specific conductance than other habitat (p<0.05;**Figure 10**).

There were no significant differences in specific conductance among project years for any habitat-season combination.

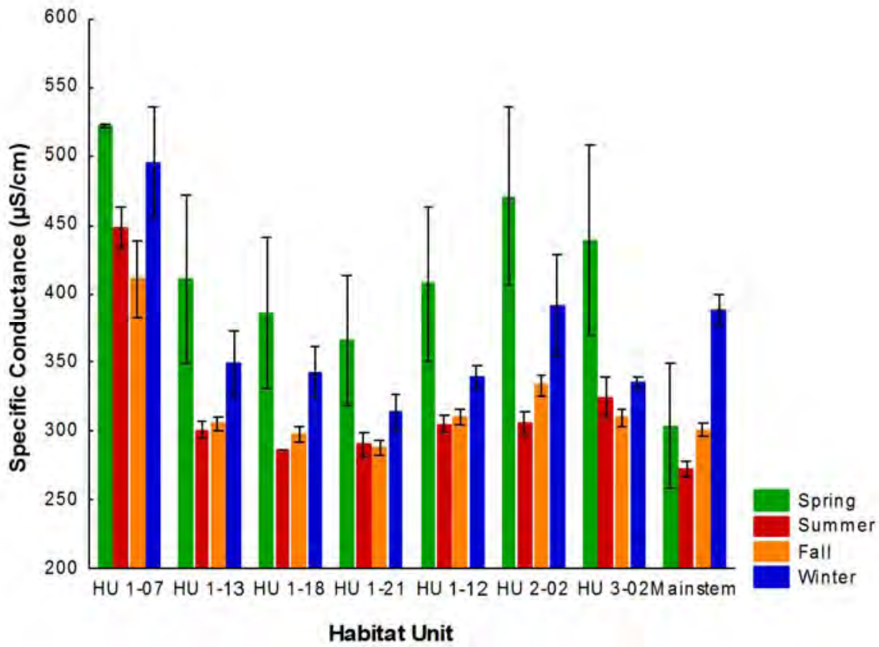

Figure 11 Mean specific conductance (µS/cm) at habitat units sampled for water quality assessments of the Aberfeldie side channel.

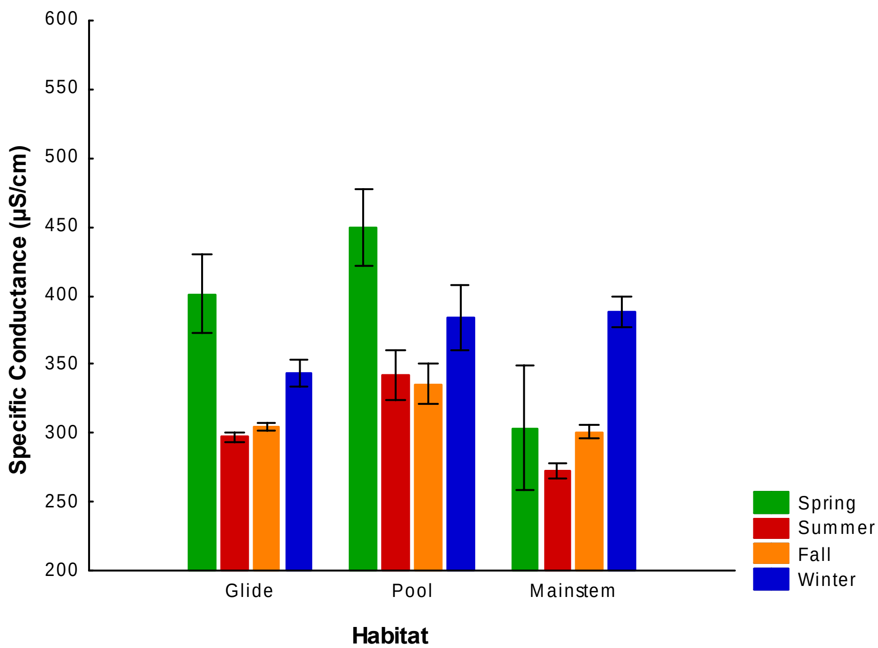

Figure 12 Mean specific conductance (µS/cm) at habitat type (glide, pool, and Bull River mainstem) sampled for water quality assessments of the Aberfeldie side channel.

3.1.5 Salinity

Factorial ANOVA results indicated that there were significant differences in salinity for factors 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 13**). Similarly to the trends for specific conductance, habitat unit 1-7 (Pool) had significantly higher salinity than all other habitat units ($p<0.007$; **Figure 13**) and pool habitats also had significantly higher salinity than other habitats ($p<0.05$; **Figure 14**).

Salinity levels were significantly different among project years during spring in glide habitats. Glide 2011 spring salinity was higher than both 2009 and 2010 spring salinity levels.

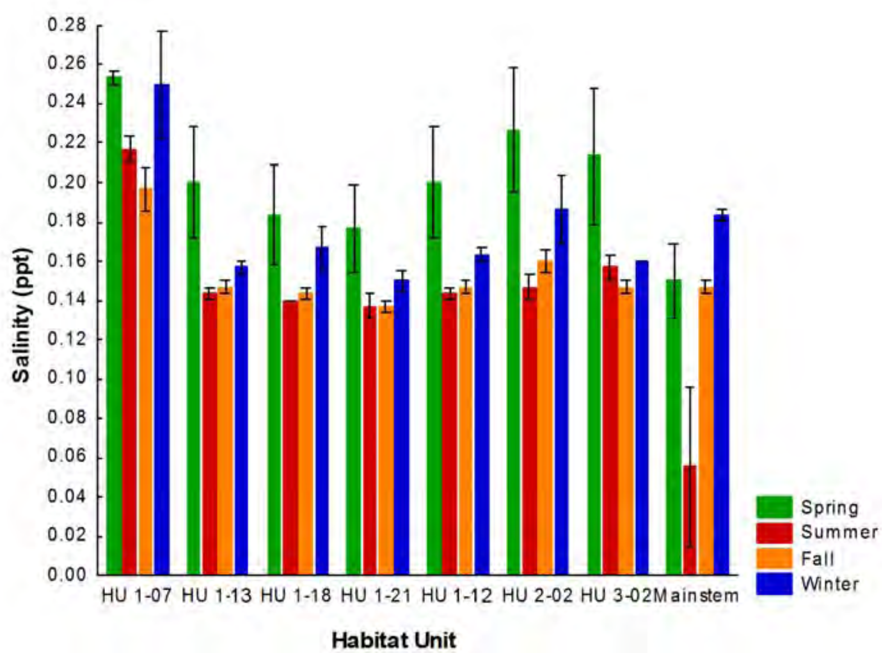

Figure 13 Mean salinity (ppt) at habitat units sampled for water quality assessments of the Aberfeldie side channel.

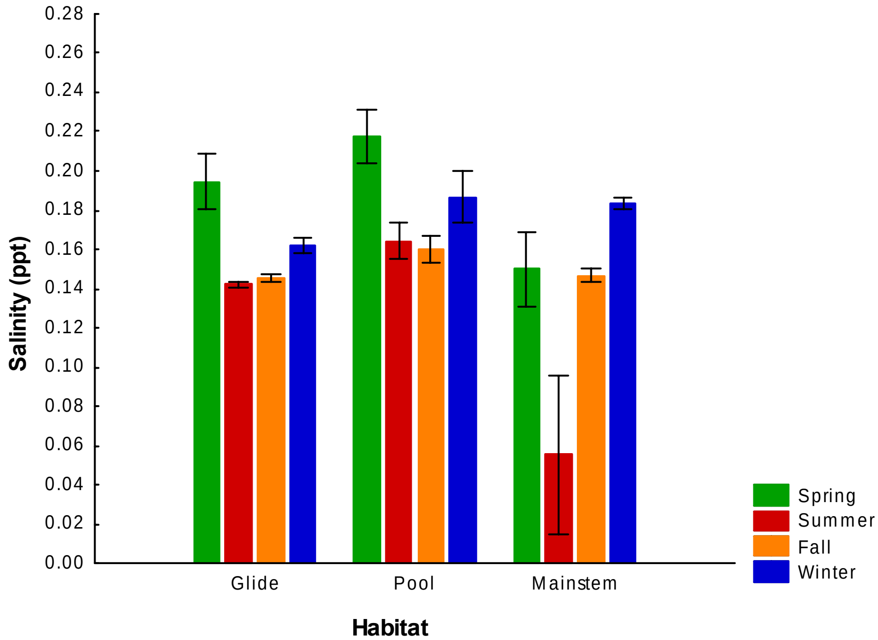

Figure 14 Mean salinity (ppt) at habitats types (glide, pool, and Bull River mainstem) sampled for water quality assessments of the Aberfeldie side channel.

3.1.6 Redox Potential

Factorial ANOVA results indicated that there were significant differences in redox potential for factors season and project year-season interaction (Table 1; all $p < 0.007$). Redox potential during winter was significantly higher than other seasons ($p < 0.007$; Figures 13 and 14).

For both pools and glides, there were significant differences in winter, spring, and summer redox levels among study years. Winter and summer redox values followed the same trend for both pools and glides; 2011 winter redox was higher than 2010 and 2012 redox in pools and glides; 2010 summer redox was higher than 2009 and 2011 redox levels in pools and glides. Spring redox values were lower in 2011 than 2009 and 2010 for both pools and glides. Additionally, spring 2009 redox was significantly lower than 2010 redox in pools.

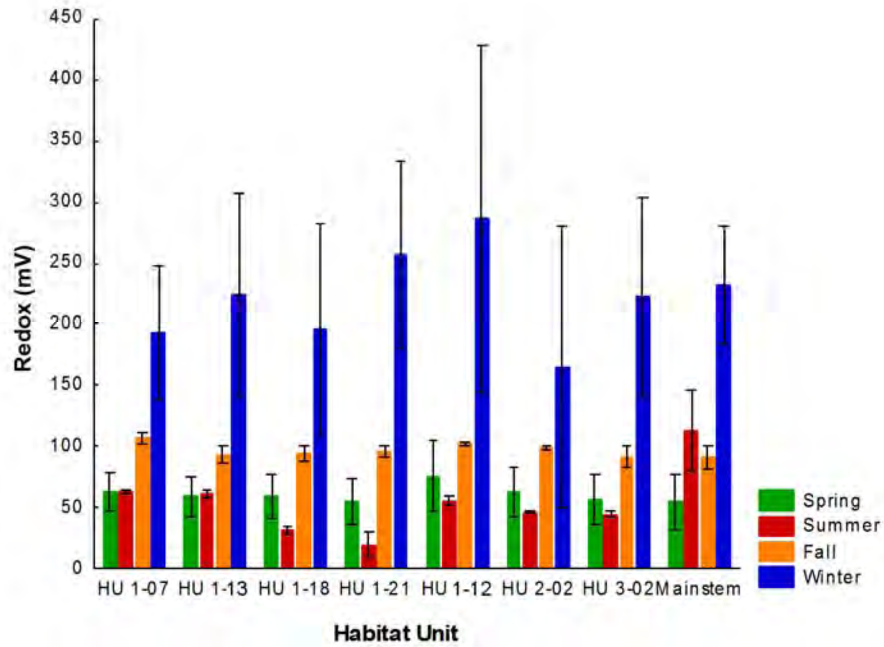

Figure 15 Mean redox potential (mV) at habitat units sampled for water quality assessments of the Aberfeldie side channel.

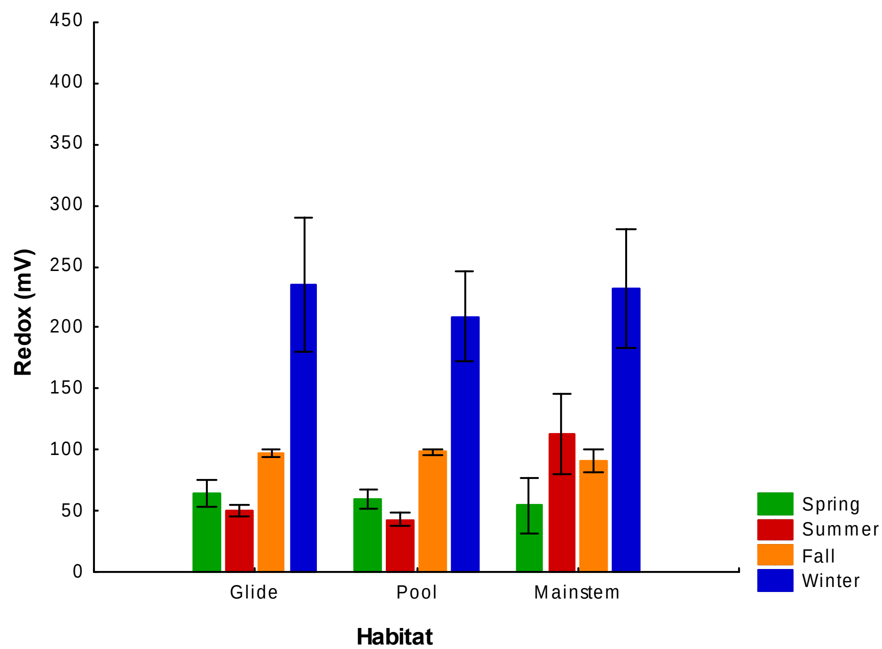

Figure 16 Mean redox potential (mV) at habitats (glide, pool, and Bull River mainstem) sampled for water quality assessments of the Aberfeldie side channel.

3.1.7 Algae

Similarly to Year 1 and 2 of the monitoring program, algae growth was observed in the Aberfeldie side channel (Figure 17). Algae growth is presumed to be the result of nutrient excess following the decomposition of Kokanee carcasses, as well as nutrient availability in the newly constructed channel.

Figure 17 Algal growth in pool habitat unit 1-02 (July 5, 2011)

3.1.8 Discharge

Water levels recorded at the hydrometric weir and calculated discharges are provided in Appendix 4. Figure 18 shows discharge trends measured in year 1, 2, and 3 of the monitoring program. The highest Year 3 discharge values were measured at 0.033 m^3/s on July 5, 2011. Discharge gradually decreased through the summer, reaching a low of 0.006 m^3/s on September 12, 2011. A spike of 0.012 m^3/s was observed at the end of September likely due to rainy conditions. Through the fall and winter, levels dropped to a low of 0.001 m^3/s, measured during the overwintering assessment on January 19, 2012. These observations are consistent with the fluctuations of the Bull River mainstem discharge measured during the same period (Environment Canada 2011; Figure 19). ANOVA results indicated that there was no significant difference in discharge of the Aberfeldie side channel among project years. The channel morphology 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). Average water velocity measured in the fall in glide habitat was only 0.065 m/s ± 0.122.

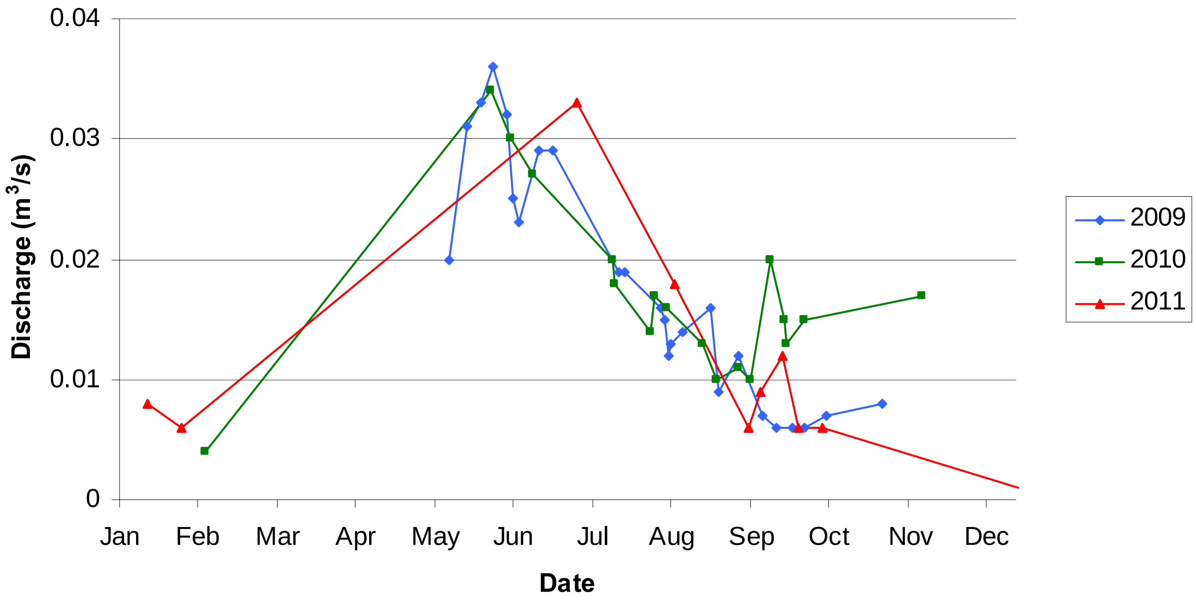

Figure 18: Aberfeldie side channel discharge (m^3/s) measured at the weir from 2009 to 2011.

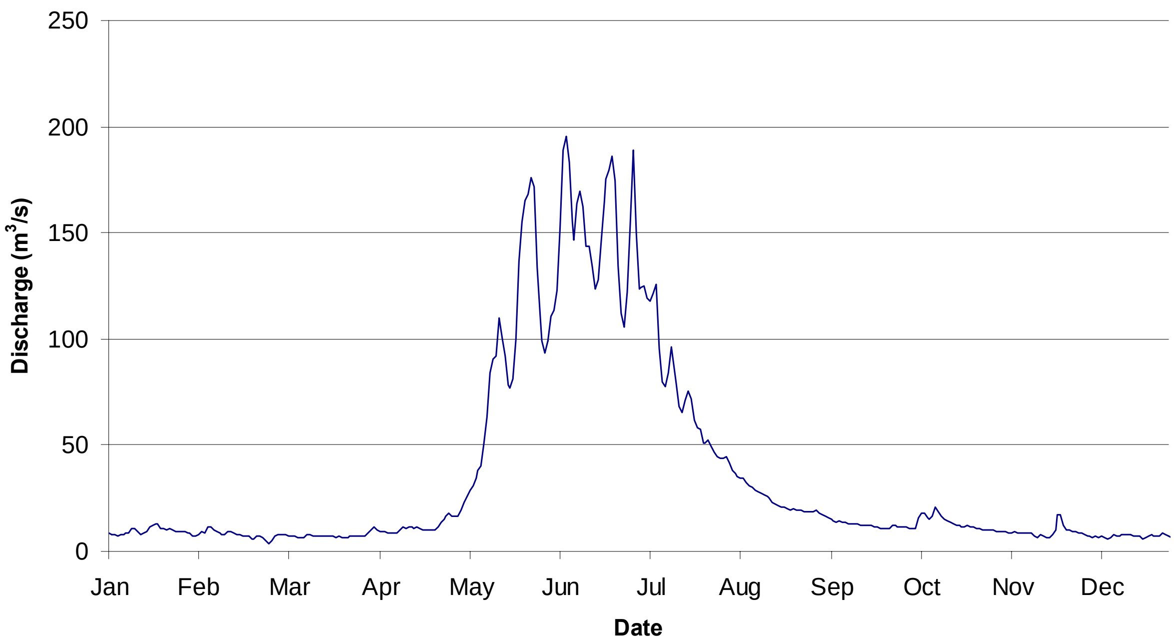

Figure 19. Bull River discharge (m^3/s) from January 1, 2011 to December 31, 2011 (Environment Canada 2012, Hydrometric Station 08NG002, located at the Bull River near Wardner).

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 October 3, 2011. This assessment followed the high spring discharge period on the river (peak estimated at 195 m3/s on June 7), which would have contributed to any erosional or stability impacts.

3.2.1 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 20 and Figure 21, respectively. During the spring flows, the rock groyne appeared to be functioning as designed. The water flowed through the rip rap substrate and the outlet of the channel helping to maintain the outlet of the channel through scour. 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 21). 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 22).

Figure 20. Side channel outlet and groyne under spring flow conditions (July 5, 2011).

Figure 21. Side channel outlet and groyne under fall flow conditions (October 3, 2011).

Figure 22. Side channel outlet under winter base flow conditions (January 19, 2012).

3.2.2 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 2011 assessment found that the berm is adequately protecting the side channel from the inputs of any materials from these sources (Figure 23). 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 26).

Figure 23. Berm on right downstream bank of the Aberfeldie side channel, protecting the channel from sediment input from adjacent eroding slopes (October 3, 2011).

3.2.3 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.

Figure 24. Berm on left downstream boundary of the Aberfeldie side channel (October 3, 2011).

3.2.4 Bull River Bank Stability at Upstream End of Channel

As noted in the 2009 and 2010 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 25. Bull River Bank at upstream end of the Aberfeldie side channel (October 3, 2011).

3.2.5 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. The issue was brought to the attention of BC Hydro staff and no subsequent evidence of cattle was observed during the winter assessment. 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.

3.2.6 Beaver activity

No beaver activity was noted at the side channel during Year 3 of the monitoring program. In year 4, 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.

3.2.7 Slope Stability and Revegetation

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 revegetation were noted throughout the project. Of key importance, 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 26). Bank revegetation and bioengineering work have not been effective in stabilizing the slopes. Sedimentation caused by erosion of bank slopes have been recorded in different habitat units of the side channel (Figure 27). In particular, sedimentation has been noted around the periphery of pools (Figure 26), which are utilized by Kokanee for spawning.

Figure 26. Erosion along slope of pool habitat unit 1-7 (right downstream boundary) of the Aberfeldie side channel (February 18, 2012). Red arrows indicate run-off of fine sediments into the channel.

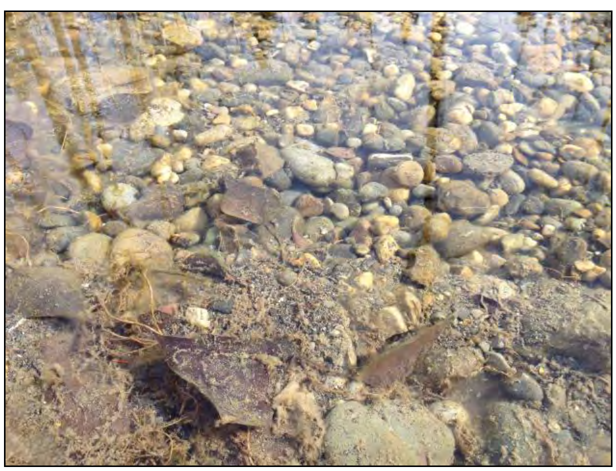

Figure 27. Sedimentation at glide habitat unit 1-12 of the Aberfeldie side channel (February 18, 2012).

3.3 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. Overall, only Kokanee spawners were observed; no brook trout or Bull Trout were seen. Depths at the outlet were very shallow throughout the spawning period, with measurements as low as 0.05 m in glide habitat at the downstream end of the channel. This did not appear to prevent Kokanee migration from the Bull River mainstem into the side channel.

3.3.1 Weekly Fish Counts and Habitat Use

Although Kokanee in spawning colours could be seen at the mouth of the Bull River and in the nearby Wild Horse River, no fish were observed in the Aberfeldie side channel during the first survey on September 12, 2011. The first Kokanee were seen in the side channel during the second survey on September 17. Additional surveys were conducted on September 26, October 3 and October 12, for a total of five visits. The October 12th visit was an additional visit to the four planned and was conducted to ensure that the peak of the spawning period had been recorded. The highest number of spawners observed in the side channel was 1906 Kokanee on October 3, 2011 (Table 5).

Table 5: 2011 Kokanee spawners counts by habitat unit (HU) in the Aberfeldie side channel.

Habitat Unit	Habitat Type	HU Length (m)	Kokanee Spawner Counts					Mortality Count (12 Oct)
			17-Sep	26-Sep	03-Oct	12-Oct	Total	
1-1	Glide	21.1	0	12	2	2	16	0
1-2	Riffle	5.7	0	0	0	0	0	0
1-3	Glide	11.8	0	3	1	0	4	0
1-4	Riffle	4.1	0	1	0	0	1	0
1-5	Glide	19.7	0	9	24	1	34	7
1-6	Riffle	8.3	0	2	0	0	2	0
1-7	Pool	47.6	8	76	186	37	307	34
1-8	Glide	7.2	0	37	26	8	71	3
1-9	Cascade	2	0	0	1	0	1	0
1-10	Glide	48.6	0	45	106	32	183	6
1-11	Riffle	5.9	0	0	1	0	1	0
1-12	Glide	41.3	2	336	283	95	135	19
1-13	Cascade	2.9	0	22	72	6	136	0
1-14	Glide	29.2	6	75	98	53	716	44
1-15	Riffle	4.8	0	10	14	15	100	10
1-16	Glide	43.2	5	118	150	81	232	51
1-17	Cascade	3.8	0	19	29	12	39	7
1-18	Glide	38.9	2	104	115	57	152	34
1-19	Cascade	5.3	0	3	6	5	568	9
1-20	Glide	72.3	12	163	140	110	354	25
1-21	Pool	54.6	41	197	243	141	60	36
2-1	Glide	12.5	10	66	56	3	278	24
2-2	Pool	41.9	0	46	70	20	14	63
3-1	Glide	8	0	53	59	40	425	6
3-2	Pool	44.8	3	198	226	141	622	37
		Total	89	1595	1906	858	4653	415

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. 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 of results. In fact, Kokanee abundance was particularly high at cascade habitat unit 1-13 compared to other habitat units. This result 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 (Figure 28).

ANOVA results indicated that there were significant differences in Kokanee density (fish/m^2) for factors habitat type and habitat unit. There was no significant difference in Kokanee density for study year. Kokanee had the highest density in glide habitats compared to other habitat types ($p<0.03$). Fish density was higher in HU 1-12 and 3-1. Similar results were found in the Year 1 fall spawning assessment.

Figure 28. Kokanee congregating in cascade habitat unit 1-13 and leaping over the hydrometric weir

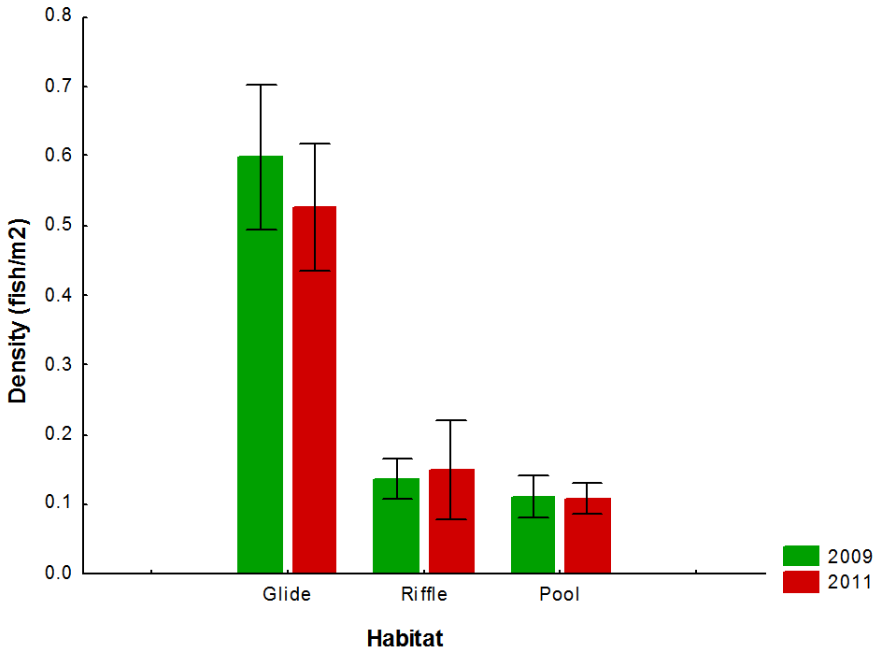

Figure 29: Density of Kokanee (fish/m^2) at each habitat type for 2009 and 2011 fall spawning assessments of the Aberfeldie side channel. Bars represent 95 per cent Standard Deviation.

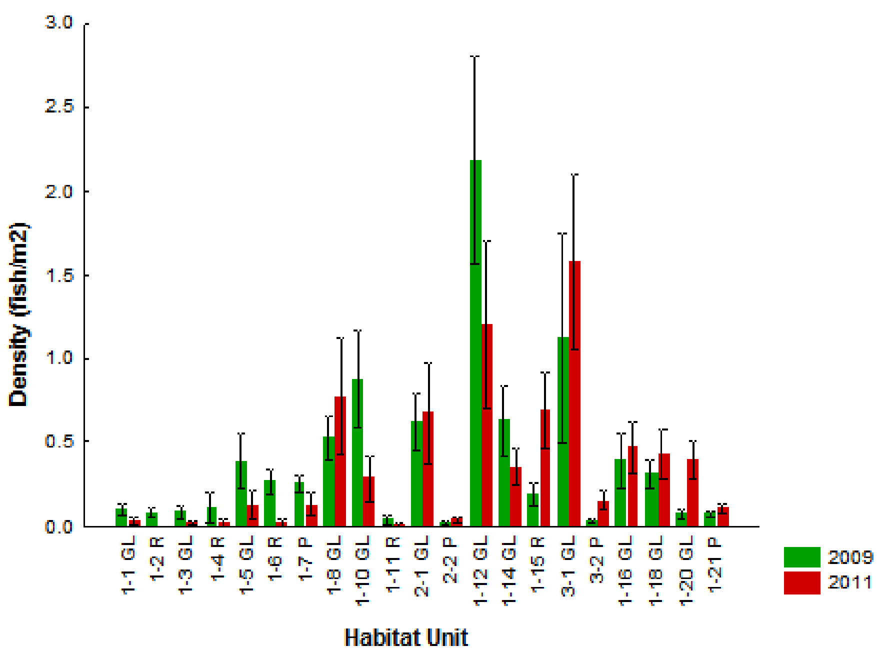

Figure 30: Density of Kokanee (fish/m^2) at habitat units for 2009 and 2011 fall spawning assessments of the Aberfeldie side channel. Bars represent 95% SD

Anecdotal observations revealed that Kokanee were congregating in the upper and lower portion of glides, in the tail-outs of pools, and along pool margins. This was also reported in previous monitoring years. 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 there is 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 2 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 coming from the eroding banks. Kokanee were generally not observed in areas with extensive woody debris at the Aberfeldie side channel.

3.3.2 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 17 and end on October 12. The curve estimated by 2nd-order polynomial regression (Figure 29) had the following equation:

$$y(x) = -8.87x^2 + 554.84x - 6793.2 \quad \text{(with } R^2 = 0.9979\text{)} \quad \text{(Equation 1)}$$

For the x-intercepts, when

$$y(x) = 0\,;\ x_1 = 45.88 \text{ and } x_2 = 16.70$$

Hence, the AUC was estimated to be

$$\sum_{16.70}^{45.88} y(x) = 36566.5 \text{ fish.days}$$

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

$$\text{Escapement} = \frac{AUC}{RT} = \frac{36566.5}{8.5} = 4302 \text{ individuals}$$

The escapement range for the 7-10 days RT estimates is 3657 - 5224 Kokanee.

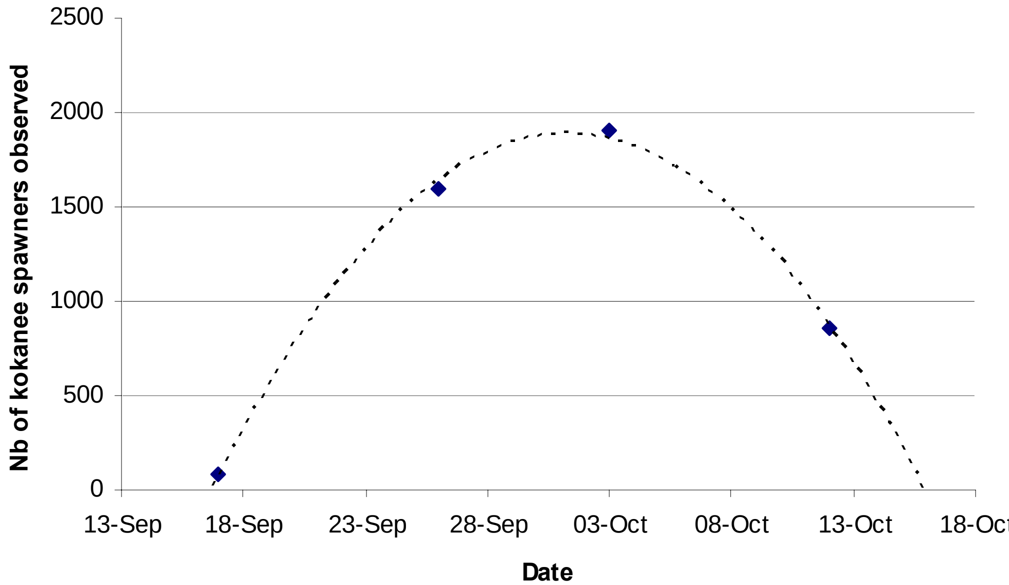

Figure 31: Number of 2011 spawning Kokanee over time, plotted to estimate the total number of spawners that utilized the side channel (i.e., escapement). Equation 1 provides the 2nd-order polynomial regression of the curve.

3.4 Overwintering Assessment

3.4.1 Winter water quality

Seasonal water quality data collected during the overwintering assessment are reported in section 3.1. and provided in Appendix 3. The average water temperature measured in the side channel during winter assessment (5.0^{o} C ± 1.2) was significantly higher than the temperature measured in the Bull River mainstem (1.6^{o} C). The average DO concentrations measured in the side channel was 5.60 mg/L ± 1.64 versus 11.3 mg/l measured in the Bull River mainstem. Dissolved oxygen concentrations measured in pool habitats were particularly low and did not meet the minimum requirements to support aquatic life. Dissolved oxygen concentration in glide habitats (6.93 mg/L ± 0.40) was higher than in pool habitats (4.60 mg/L ± 1.47) but was below the minimum requirement for the development of embryo and alevins.

3.4.2 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. At the time of the survey (January 19, 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 32) 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 on March 03, 2012 (Figure 33).

Figure 32. Logs in pool habitat unit 1-21 provides habitat and cover for overwintering fish (January 19, 2012).

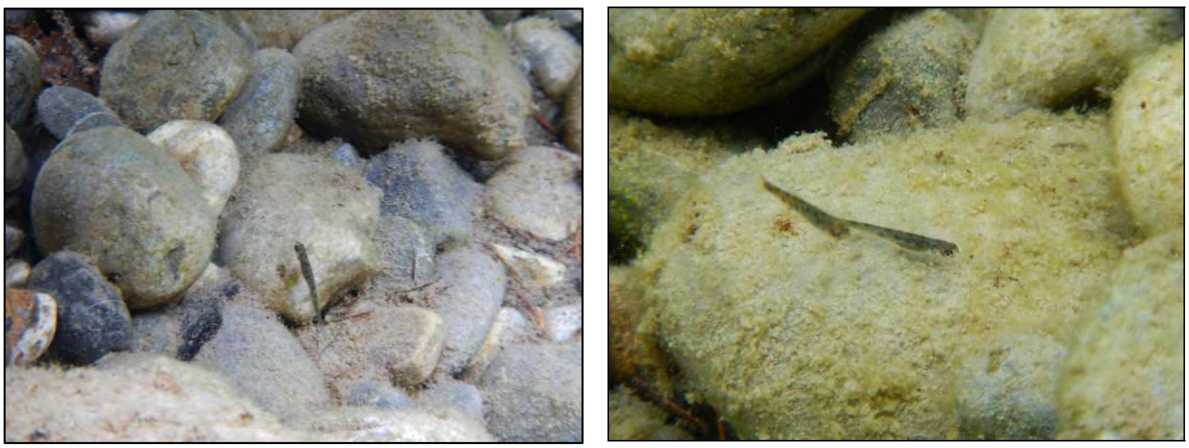

Figure 33. Kokanee fry observed in pool habitat unit 1-13 on March 03, 2012.

4 Discussion

Water Quality

As reported in previous years, findings from Year 3 of the monitoring program revealed that water quality conditions in the Aberfeldie side channel rarely met the requirements for rearing and reproduction of fish species set by BC MOE guidelines (BC MOE, 2006).

A summary of key physical habitat conditions required for each of these potential species to utilize the side channel is shown in Appendix .Water temperatures measured in the side channel were consistently higher than in the Bull River mainstem. Although, temperatures were adequate for cutthroat trout rearing, fall measurements showed that average water temperatures exceeded 9^{o} C, which is considered the maximum temperature for Bull Trout spawning (McPhail and Murray, 1980). While Bull Trout can spawn in 10^{o} C water (Bustard 1996), embryo survival declines dramatically above 8^{o} C (McPhail and Murray, 1980).

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 (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.

Dissolved oxygen measurements collected in the side channel were consistently lower than in the Bull River mainstem. DO concentrations were higher in glide habitat than in pool habitat but marginally met the minimum requirement for the support of aquatic life (5mg/L). Contrary to the Bull River mainstem where the average DO concentration was 11.4 mg/L (± 2.7), 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. Comparison of the year-to-year data revealed that the best DO conditions in the side channel were found in habitat units 1-12 and 1-13 (two adjacent glides) while the most limiting DO conditions are found in habitat units 1-21 and 3-02 (two most upstream pools). ANOVAs showed that there was no significant improvement in DO conditions between Year 1, Year 2, and Year 3. Intragravel DO was not measured in Year 3 but is typically 2 to 6 mg/L less than in overlying water (BC MoE 1997). The acute lethal range for salmonids embryo occurs at 1.5 and 3 mg/L interstitial DO (or at least 4.5 and 7 mg/L water column DO) (BC MoE 1997). Cope (1996) found that sockeye salmon embryo survival rates were affected when intragravel DO dropped below 4.0 mg/L, and that embryos placed in locations with less than 3.0 mg/L intragravel DO did not survive.

Specific conductance and salinity measurements collected in the side channel were generally higher than in the Bull River mainstem. Water upwelling likely contributes to the ion load increase in the side channel. Comparing year-to-year data, it was noted that habitat unit 1-7 (most downstream pool) had significantly higher conductivity and salinity than all other habitat units. Further investigation will be conducted to determine what causes a change in water chemistry in this particular unit.

Redox potential measurements exhibited significant variation on a yearly, seasonal, and habitat type basis. However, these variations 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 during Year 3.

Discharge

Flow data showed that 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 years of the monitoring program. Low water velocities measured in glide habitats and on spawning platforms (0.065 m/s ± 0.12) are of particular concern. 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.

Fall spawning assessment

As in previous year, the fall spawning assessment revealed that Kokanee is the only fish species utilizing the Aberfeldie side channel for spawning at this time of the year. No other species were observed in the side channel during the five scheduled visits of the fall spawning assessment (between September 12 and October 12, 2011). Although this period also corresponds to the Bull Trout spawning season, low water levels associated with low flow velocity, low DO concentration, and water temperature greater than 9º C likely prevented gravid Bull Trout from selecting the side channel as a suitable spawning site.

An estimated 4300 Kokanee entered the side channel for spawning in Year 3 compared to 4050 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 showed 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 Year 1 of the monitoring program. Spawning pairs were seen in the side channel exhibiting territorial behaviour over clearly defined redds. However, no egg deposition was witnessed at the time of the survey. Spawning activities were more evident in pool habitats where most redds appeared to be located in the peripheral area of the pools (as opposed to the centre of the pool). Fish were more densely aggregated in glides where redds were not clearly defined. Kokanee appeared to avoid large gravel on spawning platforms (D50 = 45 ± 4.75 mm) and preferred sediments entering the channel from erosion of the banks as spawning substrate. Approximately 415 dead Kokanee were found in the side channel. Dissection of a sub-sample of dead individuals (n=44) showed that the majority had successfully spawned (n=16; 80 per cent). The large majority of observed Kokanee (90 per cent) returned to the Bull River. It is unknown whether the individuals who returned to the mainstem had successfully spawned. Anecdotal dig tests confirmed that eggs had been deposited in the channel substrate. Despite limiting water quality conditions, Kokanee fry were observed in pool habitat unit 1-21 on March 03, 2012. The incubation success rate of deposited eggs in Year 3 is unknown. A study conducted in Year 2 showed that incubation success of eggs deposited in the side-channel was nearly half of those deposited in the Bull River mainstem. Water depth, which is directly correlated to water velocity and DO delivery to the eggs, was found to be the main parameter explaining the variations in incubation success rates.

Overwintering assessment

Year 3 of the monitoring program showed that the side channel remained accessible to fish in winter but that overwintering habitat availability within the side channel was limited by low DO concentration in pools and low water levels in glide habitats. Deeper glide sections with LWD and the upper water layer of pool habitats constitute the most suitable overwintering habitat in the side channel.

Structural stability and physical parameters

The seasonal monitoring showed that the outer structure of the site functions as intended. The groyne at the downstream end of the channel offers suitable protection to the outlet during high spring flows. The right downstream berm adequately prevents sediments from adjacent unstable slopes from entering the channel.

As reported in previous years, monitoring of the channel structure revealed important stability concerns. Evidence of bank erosion was present throughout the side channel, likely caused by an inadequate slope of the banks (*Pers. Comm.* S. Vokey, P.Eng., Interior Reforestation Co. Ltd.). Bank erosion is aggravated by precipitation and animal activity in the side channel area (wildlife and cattle). Bioengineering efforts conducted to reinforce the banks and prevent erosion is not functioning as intended. Revegetation attempts on the banks and unstable slopes on the right downstream side of the channel have also been inadequate. 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), in combination with ABFMON #1 and #3, is to provide qualitative and quantitative assessments to verify whether the side-channel meets the objectives of its design and whether the compensation requirements have been achieved. In the case that the side-channel doesn't function as intended, results from the monitoring program will provide information upon which to base future operating decisions. After five years, the results from the monitoring program will be used to determine acceptability of the recommended flow regime (BC Hydro 2008a). A re-opening of the Water Use Plan could be triggered if biologically significant issues occur with the recommended flow option or if it is shown that the goal of no-net-loss of productive capacity can't be achieved with a lower summer flow release in combination with the productive capacity realized from the compensatory habitat. (BC Hydro, 2008a).

In order to maximize the biological productivity of the Aberfeldie compensatory side-channel and determine whether the objective of no-net-loss of productive capacity has been achieved, Interior Reforestation recommends that the following issues be addressed:

Water Quality

In year 3 of the monitoring program, low DO concentration in combination with low water velocity remained the factors most limiting to fish productivity in the Aberfeldie side channel. Low DO levels affect fish at all life stages and should be addressed. Various solutions were discussed in previous monitoring years including:

- Remodelling the channel morphology to increase water velocity and atmospheric mixing. This could be achieved by diminishing water depth in selected areas and by adding new cascades.

- Reducing summer water temperature through revegetation of the banks to create shade/cover. This would also help stabilize eroding banks.

- Increasing the inflow from the Bull River. Possible options include extending the channel upstream to intercept more flow and/or incorporating a surface water intake.

Physical Habitat Quality

Spawning habitat on man-made spawning platforms could be improved with the placement of suitably sized gravels (25 mm). The gravels could be placed on the existing substrate, thereby decreasing the depth of the platforms. This would result in higher velocities, with improved oxygen delivery to incubating eggs.

In the interim, the proportion of fine sediment at spawning locations should be investigated using McNeil core sampling in order to assess and monitor changes in spawning habitat quality.

Fish Utilization and Fish Productivity

To accurately quantify the biological productive capacity achieved through the habitat compensation work the residence time (RT) of spawning Kokanee in the side channel and the incubation success of deposited eggs should be investigated further. The incubation success study conducted in Year 2 provided important quantitative data on fish production in the side-channel. Interior Reforestation recommends that this study be repeated in Year 4 and Year 5 using hydraulic sampling, incubation capsules, and measurement of intragravel DO levels. Knowledge of the residence time will significantly improve our estimation of the number of spawning individuals accessing the side channel throughout the duration of the run. This parameter could be easily and cost-effectively investigated using video equipment. Interior Reforestation recently purchased a set of monitoring video cameras able to continuously record images of the side channel for up to a week without the need of an operator. This equipment would be suitable to enumerate spawners moving in and out of the side channel.

Video equipment could also be used to assess spring fry escapement and overwinter utilization of the side channel.

Control Site

In order to improve the robustness of the monitoring data, Interior recommends that a future study be conducted to compare fish and fish habitat attributes of the Aberfeldie side channel with a comparable side channel off of the Bull River (control site). Interior can perform a reconnaissance of the area upstream and downstream of the Aberfeldie side channel to identify a suitable location.

6 Closure

Interior Reforestation Co. Ltd. trusts that this report satisfies the requirements of the Terms of Reference. Should BC Hydro have any comments, please contact us at your convenience.

Interior Reforestation Co. Ltd.

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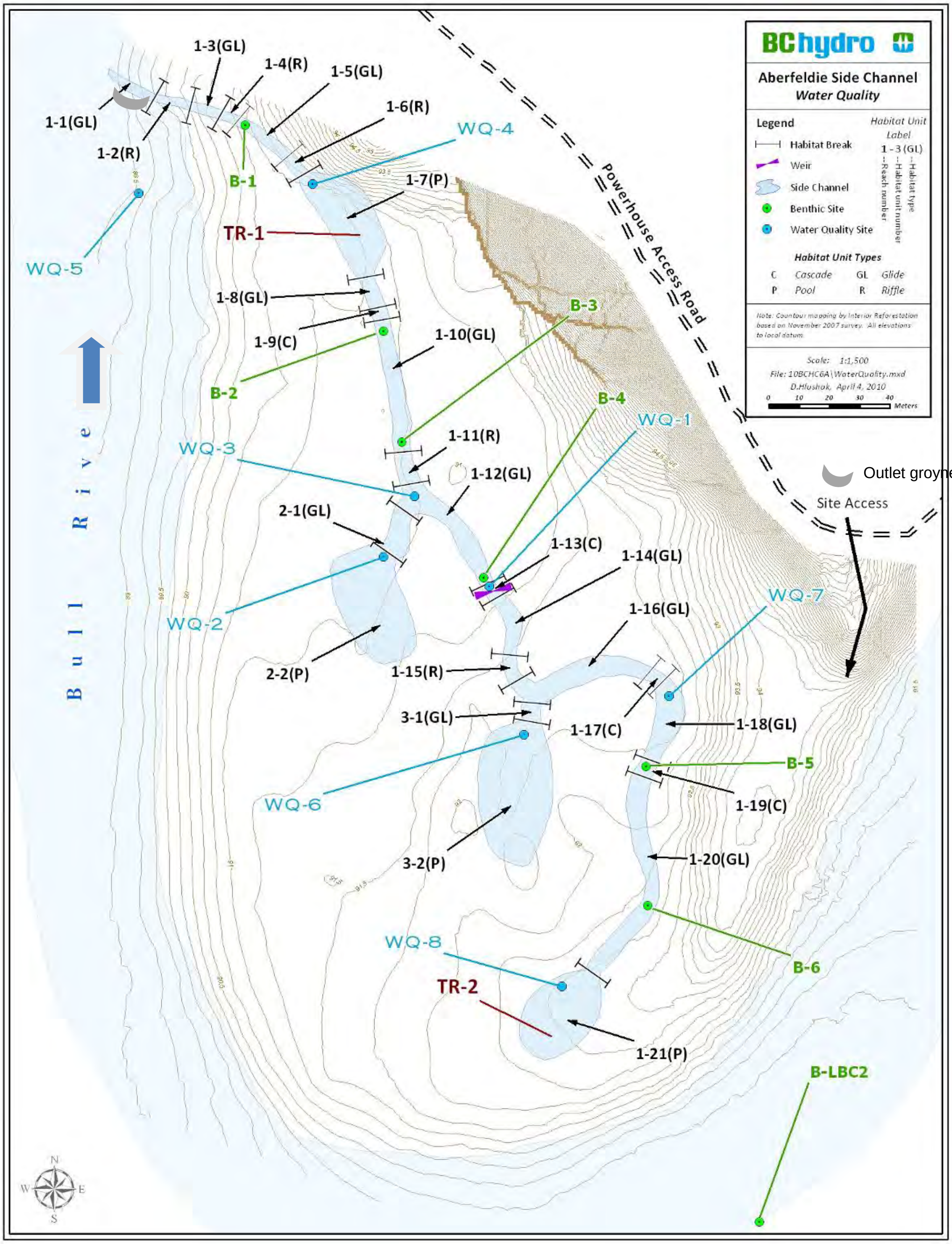
Appendices

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



Appendix 2. Documentation and Photo Index

Task	Date	Image #	Image Time	Caption
Spring Water Quality Monitoring	05-Jul	110705_01	9:26	Downstream view of Bull River mainsteam upstream of side channel
Spring Water Quality Monitoring	05-Jul	110705_02	9:52	Groyne partly submerged during freshet
Spring Water Quality Monitoring	05-Jul	110705_03	10:19	Algae blum in pool habitat
Spring Water Quality Monitoring	05-Jul	110705_04	10:44	Water level at the weir
Spring Water Quality Monitoring	05-Jul	110705_05	11:06	*Trichoptera sp.* larvae
Spring Water Quality Monitoring	05-Jul	110705_06	11:07	Upstream view of HU 2-1 and 2-2
Fall Spawning Assesment	12-Sep	110912_01	9:59	Channel outlet and mouth of Bull River (d/s)
Fall Spawning Assesment	12-Sep	110912_02	9:59	Across Bull River (from groyne)
Fall Spawning Assesment	12-Sep	110912_03	9:59	Channel outlet confluence with Bull River mainstem at groyne (u/s)
Fall Spawning Assesment	12-Sep	110912_04	10:02	Fine sediment in HU 1-2 R (seen from HU 1-1 GL to 1-6 R)
Fall Spawning Assesment	12-Sep	110912_05	10:04	Colouration in water and rocks in HU 1-6 R (also in HU 1-4 R and 1-8 GL)
Fall Spawning Assesment	12-Sep	110912_06	10:05	Sediment in HU 1-3 GL near a pool
Fall Spawning Assesment	12-Sep	110912_07	10:06	Sediment in HU 1-3 GL near a pool
Fall Spawning Assesment	12-Sep	110912_08	10:10	Possible redd in HU 1-5 GL above HU 1-4 R
Fall Spawning Assesment	12-Sep	110912_09	10:12	Macrophytes in 1-5 GL
Fall Spawning Assesment	12-Sep	110912_10	10:27	Blackfly larvae on rocks in HU 1-11 R (d/s)
Fall Spawning Assesment	12-Sep	110912_11	10:28	Algae in HU 2-2 P
Fall Spawning Assesment	12-Sep	110912_12	10:37	Water level at weir (d/s)
Fall Spawning Assesment	12-Sep	110912_13	10:52	Algal bloom in HU 1-21 P
Fall Spawning Assesment	17-Sep	110917_01	10:50	Evidence of cattle trampling in HU 1-2 R
Fall Spawning Assesment	17-Sep	110917_02	11:03	Male and female pair in HU 1-7 P
Fall Spawning Assesment	17-Sep	110917_03	11:25	Water level at weir (d/s)
Fall Spawning Assesment	17-Sep	110917_04	11:31	Male and female pair under log in HU 1-16 GL (across bank)
Fall Spawning Assesment	17-Sep	110917_05	11:58	Kokanee in HU 1-21 P; algal blooms
Fall Spawning Assesment	17-Sep	110917_06	11:58	Kokanee in HU 1-21 P; algal blooms
Fall Spawning Assesment	17-Sep	110917_07	11:59	Kokanee in HU 1-21 P
Fall Spawning Assesment	03-Oct	111003_01	12:48	Grizzly bear tracks in HU 1-3 GL; likely predating on Kokanee
Fall Spawning Assesment	03-Oct	111003_02	12:58	Fish spawning on east-side of HU 2-2 P
Fall Spawning Assesment	03-Oct	111003_03	12:58	Fish spawning on east-side of HU 2-2 P
Fall Spawning Assesment	03-Oct	111003_04	14:41	Dead female (HU 1-5 GL); successful spawner.
Fall Spawning Assesment	03-Oct	111003_05	15:08	Dead female (HU 1-8 GL); successful spawner.

Task	Date	Image #	Image Time	Caption
Fall Spawning Assesment	03-Oct	111003_06	15:21	Dead female (HU 2-1 GL); the individual died before releasing all its eggs
Fall Spawning Assesment	03-Oct	111003_07	15:25	Dead female (HU 2-1 GL); the individual died before releasing all its eggs
Fall Spawning Assesment	03-Oct	111003_08	16:02	Dead female (HU 1-12 GL); unsuccessful spawner; ovaries are still full of eggs.
Structural Stability Assessment	03-Oct	111003_09	16:02	Berm on west side of channel (d/s)
Structural Stability Assessment	03-Oct	111003_10	16:03	Berm on west side of channel (d/s); close to groyne
Structural Stability Assessment	03-Oct	111003_11	16:04	Side channel and groyne (d/s)
Structural Stability Assessment	03-Oct	111003_12	16:04	Side channel and groyne (across bank)
Structural Stability Assessment	03-Oct	111003_13	16:04	Side channel and groyne (d/s in channel)
Structural Stability Assessment	03-Oct	111003_14	16:05	Side channel and groyne (d/s on top of groyne)
Fall Spawning Assesment	12-Oct	111012_01	9:41	Evidence of cattle along HU 1-1 GL
Fall Spawning Assesment	12-Oct	111012_02	9:55	Dark sediment from decomposition HU 1-10 GL
Fall Spawning Assesment	12-Oct	111012_03	10:03	Apparent increase in algae growth and decreased clarity in HU 2-2 P
Fall Spawning Assesment	12-Oct	111012_04	10:03	Apparent increase in algae growth and decreased clarity in HU 2-2 P
Fall Spawning Assesment	12-Oct	111012_05	10:04	Apparent increase in algae growth and decreased clarity in HU 2-2 P
Fall Spawning Assesment	12-Oct	111012_06	10:15	Weir
Fall Spawning Assesment	12-Oct	111012_07	10:27	Algae and redds in HU 3-2 P
Fall Spawning Assesment	12-Oct	111012_08	11:39	Algae mats on water surface HU 1-21 P
Fall Spawning Assesment	12-Oct	111012_09	11:39	Algae mats on water surface HU 1-21 P
Fall Spawning Assesment	12-Oct	111012_10	11:58	Water clarity in HU 1-21 P
Fall Spawning Assesment	12-Oct	111012_11	12:10	Berm on west side of channel, protecting channel from eroding slopes
Fall Spawning Assesment	12-Oct	111012_12	12:24	Berm along east side of channel
Fall Spawning Assesment	12-Oct	111012_13	12:24	Berm along east side of channel
Fall Spawning Assesment	12-Oct	111012_14	12:28	Upstream view of the right bank of the Bull River near the upper end of the side channel
Fall Spawning Assesment	12-Oct	111012_15	12:28	Upstream view of the right bank of the Bull River near the upper end of the side channel
Fall Spawning Assesment	12-Oct	111012_16	13:00	Kokanees avoided large gravel and preferred sediment entered from erosion of bank; no spawning activity in middle of channel but on edges
Fall Spawning Assesment	12-Oct	111012_17	13:01	Kokanees avoided large gravel

Task	Date	Image #	Image Time	Caption
				and preferred sediment entered from erosion of bank; no spawning activity in middle of channel but on edges
Overwintering Habitat Assessment	19-Jan	120119_01	13:41:00 PM	Open water patch at 1-21 HU P (ice cover 70%)
Overwintering Habitat Assessment	19-Jan	120119_02	13:42:00 PM	Water quality measurement at frozen end of 1-21 HU P
Overwintering Habitat Assessment	19-Jan	120119_03	14:34:00 PM	Water quality measurement at 3-2 HU P (ice cover 100%)
Overwintering Habitat Assessment	19-Jan	120119_04	14:34:00 PM	North end of completely frozen 3-2 HU P (opening to 3-1 HU GL)
Overwintering Habitat Assessment	19-Jan	120119_06	14:56:00 PM	Partially ice-free 2-2 HU P
Overwintering Habitat Assessment	19-Jan	120119_08	16:06:00 PM	Weir at 1-13 HU C
Overwintering Habitat Assessment	19-Jan	120119_09	16:12:00 PM	Side channel outlet and groyne from 1-1 HU GL
Overwintering Habitat Assessment	28-Feb	120228_01	8:12	Water quality measurement at WQ-8 (1-21 HU P)
Overwintering Habitat Assessment	28-Feb	120228_02	8:53	Algal blooms at 1-21 HU P
Overwintering Habitat Assessment	28-Feb	120228_03	11:59	Water quality measurement at WQ-2 (2-2 HU P); 100% ice cover
Overwintering Habitat Assessment	28-Feb	120228_04	12:00	Water quality measurement at WQ-3 (1-12 HU GL); 75% ice cover
Overwintering Habitat Assessment	28-Feb	120228_05	12:02	Algal blooms at WQ-3 (1-12 HU GL)
Overwintering Habitat Assessment	28-Feb	120228_06	12:03	Erosion at banks of 1-12 HU GL; contributes to sedimentation at spawning gravels
Overwintering Habitat Assessment	28-Feb	120228_07	12:03	Erosion at banks on eastern side of 1-12 HU GL; contributes to sedimentation at spawning gravels
Overwintering Habitat Assessment	28-Feb	120228_08	13:03	Erosion at banks of WQ-4 (1-7 HU P); contributes to sedimentation at spawning gravels
Overwintering Habitat Assessment	28-Feb	120228_09	15:03	Erosion at banks of WQ-4 (1-7 HU P); contributes to sedimentation at spawning gravels
Overwintering Habitat Assessment	28-Feb	120228_10	16:03	Erosion at banks of WQ-4 (1-7 HU P); contributes to sedimentation at spawning gravels
Overwintering Habitat Assessment	28-Feb	120228_11	17:03	Panoramic view of southern side of WQ-4 (1-7 HU P); 90% ice cover

Aberfeldie Side Channel Effectiveness Monitoring of Fish Habitat Works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Aberfeldie Side Channel Effectiveness Monitoring of Fish Habitat Works


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Aberfeldie Side Channel Effectiveness Monitoring of Fish Habitat Works


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Aberfeldie Side Channel Effectiveness Monitoring of Fish Habitat Works


110912 _13


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111003 _01

Aberfeldie Side Channel Effectiveness Monitoring of Fish Habitat Works


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Aberfeldie Side Channel Effectiveness Monitoring of Fish Habitat Works


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Aberfeldie Side Channel Effectiveness Monitoring of Fish Habitat Works


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Aberfeldie Side Channel Effectiveness Monitoring of Fish Habitat Works


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Aberfeldie Side Channel Effectiveness Monitoring of Fish Habitat Works


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Appendix 3. 2011 Seasonal Water Quality Data

Season	Date (m/d/y)	Site	Habitat Type	Temp (oC)	Sp. Cond. (µS/cmc)	Salinity (ppt)	pH	DO (mg/L)	%DO	Redox Potential (mV)
Winter	1/12/11	1	Glide	1.18	399	0.16	8.14	6.94	49.2	397.4
Winter	1/12/11	7	Glide	1.44	341	0.16	8.19	7.2	51.4	376.7
Winter	1/12/11	8	Pool	4.4	338	0.16	8.3	6.87	52.9	353.4
Winter	1/12/11	4	Pool	4.42	556	0.3	7.92	3.87	29.6	306.2
Winter	1/12/11	3	Glide	0.82	356	0.17	8.17	7.66	53.7	585.7
Winter	1/12/11	2	Pool	0.91	416	0.2	8.14	5.51	34.6	361.4
Winter	1/12/11	6	Pool	3.05	338	0.16	8.21	4.45	34.1	394.4
Winter	1/12/11	5	Mainstem	0.01	410	0.19	8.37	12.55	86	307.1
Spring	7/05/11	1	Glide	9.03	475	0.23	7.43	6.14	53.9	41.8
Spring	7/05/11	7	Glide	8.52	444	0.21	7.59	6.17	43.9	40.6
Spring	7/05/11	8	Pool	7.88	416	0.2	7.6	6.51	37	35.3
Spring	7/05/11	4	Pool	8.94	521	0.25	7.41	6.38	58.5	46.6
Spring	7/05/11	3	Glide	8.9	467	0.23	7.49	6.45	58.1	45.1
Spring	7/05/11	2	Pool	10.47	539	0.26	7.47	6.72	59.9	41.2
Spring	7/05/11	6	Pool	9.4	511	0.25	7.49	6.8	56.8	34.9
Spring	7/05/11	5	Mainstem	6.13	351	0.17	7.56	11.6	94.06	30.9
Summer	8/13/11	1	Glide	11.12	294	0.14	6.85	5.57	50.8	64.5
Summer	8/13/11	7	Glide	10.87	286	0.14	7.45	4.27	38.6	28.5
Summer	8/13/11	8	Pool	9.3	281	0.13	7.58	1.53	13.5	8.4
Summer	8/13/11	4	Pool	12.08	432	0.21	6.84	3.78	35.9	60.7
Summer	8/13/11	3	Glide	11.17	298	0.14	7.16	4.4	40.1	51.2
Summer	8/13/11	2	Pool	11.61	297	0.14	7.26	4.26	39.6	45.1
Summer	8/13/11	6	Pool	11.7	310	0.15	7.23	2.22	20.5	47.3
Summer	8/13/11	5	Mainstem	10.67	266	0.013	7.06	10.12	91.3	78.6
Fall	9/12/11	1	Glide	11.27	308	0.15	7.56	5.93	54.2	not avail.
Fall	9/12/11	7	Glide	10.66	297	0.14	7.46	5.01	45.1	not avail.
Fall	9/12/11	8	Pool	10.2	285	0.14	7.5	2.59	23.5	not avail.
Fall	9/12/11	4	Pool	12.06	400	0.19	7.52	6.31	58.6	not avail.
Fall	9/12/11	3	Glide	11.63	321	0.15	7.6	5.01	46.2	not avail.
Fall	9/12/11	2	Pool	12.11	322	0.15	7.58	6.36	59.1	not avail.
Fall	9/12/11	6	Pool	11.56	308	0.15	7.49	3.76	34.8	not avail.
Fall	9/12/11	5	Mainstem	10.57	305	0.15	7.88	11.48	97.8	not avail.
Winter	2/28/12	1	Glide	4.3	318	0.15	7.71	6.5	62	129.3
Winter	2/28/12	7	Glide	4.3	309	0.15	7.86	7.3	70	102.2
Winter	2/28/12	8	Pool	6.6	289	0.14	5.72	2.6	37	321
Winter	2/28/12	4	Pool	6.7	518	0.25	7.49	4.5	46	152.3
Winter	2/28/12	3	Glide	4.6	325	0.16	7.81	7	68	131
Winter	2/28/12	2	Pool	3.5	316	0.15	6.93	6	57	189.7
Winter	2/28/12	6	Pool	5	327	0.16	7.76	5.3	52	136.9
Winter	2/28/12	5	Mainstem	1.6	382	0.18	6.11	11.3	100	256.2

Appendix 4. 2011/2012 staff gauge water levels and calculated discharge

Date	Stage (m)	Discharge* (m^3/s)
5-Jul-11	0.0975	0.033
13-Aug-11	0.064	0.018
12-Sep-11	0.01	0.001
17-Sep-11	0.04	0.009
26-Sep-11	0.15	0.063
3-Oct-11	0.03	0.006
12-Oct-11	0.03	0.006
19-Jan-12	0.01	0.001

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

Appendix 5. 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 6: Phy sical habitat requireme nts for potential spaw ners 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)
10) Raleigh *et al.* (1994)
11) Muhlfeld *et al.* (2001)

Appendix 6. Digital Copy of Report (including photos as jpegs for 2009 – 2011)