Whatshan Project Water Use Plan

Lower Whatshan River Fish Habitat Enhancement

Implementation Year 10

Reference: WGSMON-1

Whatshan Water Use Plan Monitoring Program: Lower Whatshan River Fish Habitat Enhancement Physical and Biological Effectiveness Monitoring

Study Period: 2015

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LOWER WHATSHAN RIVER FISH HABITAT ENHANCEMENT PHYSICAL and BIOLOGICAL EFFECTIVENESS MONITORING 2015 (Year 10)

Program No. WGSMON-1

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EXECUTIVE SUMMARY

The Whatshan Hydroelectric Project diverts water from Whatshan Lake via a tunnel to the Whatshan Generating Station (WGS) located on Lower Arrow Lake. Since there is currently no minimum flow release from Whatshan Dam, almost all flow to the Lower Whatshan River is provided by its main tributary, Barnes Creek.

Flow reduction is believed to have negatively affected production of Rainbow Trout (*Oncorhynchus mykiss*) in the Lower Whatshan River. However, providing a fish flow release from Whatshan Dam raised several concerns including increased water temperature, introduction of competing fish species, and loss of power generation revenue. Therefore, the Consultative Committee (CC) for the Whatshan Water Use Plan (WUP) agreed that in lieu of an operational change to provide a minimum flow, BC Hydro would instead undertake fish habitat enhancement in Reach W3.2, a 1.3 km section of low gradient stream with low habitat complexity located in the vicinity of the Highway 6 Bridge. A control reach was also selected at Barnes Creek Reach B3 for comparison with the study reach.

The enhancement project was intended to be conducted over a 10-year time frame in three phases: 1) pre-enhancement work; 2) construction; and 3) post-enhancement monitoring. The primary management questions from the WUP Terms of Reference (TOR) were as follows:

1) Do habitat structures in Reach W3 of the lower Whatshan River increase the availability of suitable habitat for Rainbow Trout?
2) How long do habitat structures continue to function?
3) Do habitat structures increase available habitat for Rainbow Trout in a more cost-effective manner than would a minimum flow release from the Whatshan Dam?
4) Does the increase in available habitat benefit Rainbow Trout in Reach W3?

Pre-enhancement work consisting of channel assessment, habitat designs, and monitoring of physical habitat and fish populations was conducted in 2006, 2007, and 2008, and construction of habitat enhancement measures in Reach W3.2 was completed in the summer of 2009. The enhancement measures were intended to increase habitat complexity, especially pools and large woody debris cover, and to narrow the channel to promote natural channel processes (e.g., scour and deposition) that had been diminished under reduced flows resulting from hydroelectric diversion.

Year 10 of the Lower Whatshan Fish Habitat Enhancement Project provided the third year of post-enhancement fish and fish habitat data for comparison with three years of pre-enhancement data. The present report includes results from post-enhancement monitoring conducted during September 2015, following on two years of post-enhancement monitoring in 2010 and 2012. This final report includes multi-year comparisons and hypothesis testing of whether habitat enhancements in Reach W3.2 of the lower Whatshan River have benefited Rainbow Trout.

Field procedures in 2015 were similar to those reported previously for the earlier pre- and post-enhancement surveys. Physical habitat assessment methodology was based on the Fish Habitat Assessment Procedures (FHAP), while fish sampling was conducted using multiple pass electrofishing within stopnet enclosures.

A total of 15% of total habitat area was sampled in Reach W3.2, while 11% of total area was sampled in Reach B3. The same four fish species that were captured during previous years were found again in 2015- Slimy Sculpin (*Cottus cognatus*), Eastern Brook Trout (*Salvelinus fontinalis*), Longnose Dace (*Rhinichthys cataractae*), and Rainbow Trout (*Oncorhynchus mykiss*) in Whatshan Reach W3.2, and sculpin, brook trout, and Rainbow Trout in Barnes Reach B3. The total number of fishes captured in Reach W3.2 in 2015 was 2,315 compared with 1,332 fish in Reach B3. As in previous years, Slimy Sculpin was by far the most abundant species, making up 69% of the total capture in W3.2 and 79% in B3. The other species contributed 8-14% of the catch. Estimated abundance of juvenile/adult Rainbow Trout was 864 in Reach W3.2 and 833 in Reach B3. There were few significant differences in fish size between reaches.

In the enhancement reach W3.2, there were significant increases in large woody debris cover, spawn gravel area, average depth, number of pools, and number of riffles. All of these variables except large woody debris had significantly increased in relation to the control Reach B3. Results of an Akaike Information Criteria (AIC) analysis indicated that maximum depth and total cover density had the highest relative importance as explanatory variables for density of juvenile/adult Rainbow Trout.

Answers to four questions posed in the Water Use Plan Terms of Reference are provided in the Management Question table below:

WGSMON-1 - STATUS of OBJECTIVES, MANAGEMENT QUESTIONS and HYPOTHESES

Objectives	Management Questions	Management Hypotheses	Final Year (2015) Status
Increase available habitat for rainbow trout.	Do habitat structures in Reach W3 of the lower Whatshan River increase the availability of suitable habitat for Rainbow Trout?	Habitat enhancement in Reach W3 of the lower Whatshan River increases available habitat for rainbow trout.	**Hypothesis Accepted.** Habitat enhancement in W3 has significantly increased the average depth, number of pools, amount of cover, and spawning gravel area.
Install durable habitat structures.	How long do habitat structures continue to function?	Habitat structures have a long functioning life span.	**Hypothesis Accepted**. Habitat structures may be expected to function for at least 25 years before the wood decays to the point that the structures lose integrity.
Increase habitat for rainbow trout in a cost-effective manner.	Do habitat structures increase available habitat for Rainbow Trout in a more cost-effective manner than would a minimum flow release from the Whatshan Dam?	Habitat structures increase available habitat for Rainbow Trout in a more cost-effective manner than a minimum flow release from the Whatshan Dam.	**Hypothesis Accepted**. Available habitat for Rainbow Trout has increased significantly at a total cost of approximately $200K versus an estimated $900K per year for a minimum flow release.
Increase abundance and/or biomass of rainbow trout in the Lower Whatshan River.	Does the increase in available habitat benefit Rainbow Trout in Reach W3?	Habitat enhancement in Reach W3 of the lower Whatshan River will increase rainbow trout standing crop. Habitat enhancement will increase rainbow trout density. Habitat enhancement will increase rainbow trout size.	**Hypothesis Rejected**. Three years of pre-enhancement and 3 years of post-enhancement data do not show any significant effect on Rainbow Trout abundance or biomass. **Hypothesis Rejected**. No significant increase in Rainbow Trout density. **Hypothesis Rejected**. No significant increase in Rainbow Trout size.
No detrimental impact on other fish species.	Does habitat enhancement in Reach W3 of the lower Whatshan River negatively affect the density or size of fish species other than rainbow trout?	Habitat enhancement in Reach W3 of the lower Whatshan River does not negatively affect the density or size of fish species other than rainbow trout.	**Hypothesis Accepted**. The only significant negative effect was a relative 5 mm decrease in fry length for Eastern Brook Trout in W3. This is a non-native invasive species for which a negative effect is likely not a management concern

In answer to Question #1, there was considerable evidence that habitat enhancement in Reach W3.2 has increased the availability of suitable habitat for Rainbow Trout. As for Question #2, the habitat structures may be expected to function for at least 25 years before the wood decays to the point that the structures lose integrity. However, the structures have only experienced short-lived high flows in 2012 and 2013, and higher and/or more prolonged high flows would provide a better test of structure durability and longevity. Regarding Question #3, it appears that habitat structures do increase available habitat for Rainbow Trout in a more cost-effective manner than a minimum flow release, as the enhancement cost was in the range of $200,000 compared with the estimated minimum flow release cost of $900,000 annually. However, it is unknown whether a minimum flow release would be more effective than habitat structures at increasing the abundance of Rainbow Trout in the Lower Whatshan River. For Question #4, there was no evidence that the apparent increase in available habitat for Rainbow Trout has benefitted the species, as BACI comparisons showed no evidence of any effect on Rainbow Trout abundance, density, or biomass.

An additional hypothesis to be tested for this project was that habitat enhancement in Reach W3.2 of the lower Whatshan River does not negatively affect the density or size of fish species other than rainbow trout. The only significant negative BACI effect was a relative 5 mm decrease in fry length ($p = 0.027$) for Eastern Brook Trout, a non-native invasive species.

While habitat enhancement in Whatshan Reach W3.2 has increased the average depth, number of pools, amount of cover, and spawning gravel area, all changes that favour Rainbow Trout, the potential indicators of length, weight, condition, abundance, density, and biomass of juvenile/adult Rainbow Trout do not indicate a benefit to the target species.

The lack of a detectable response by the Rainbow Trout population to habitat enhancement in Whatshan Reach W3.2 is perplexing. Possible factors contributing to this lack of detectable response include the following:

1) Very large year-to-year variation in estimates that is much larger than expected given the uncertainty in the estimates (process error). This year-to-year variability may be related to year-specific effects such as weather.
2) Not all of the proposed enhancement structures were installed, due to private property issues.
3) Angling may be differentially removing more adult rainbow trout from W3.2 than from B3.
4) Increased suitability of habitat for Rainbow Trout may be offset by a reduction in total wetted area as the W3.2 channel adjusts to reduced flows.
5) Insufficient time may have passed for the habitat structures to fully function, or for the Rainbow Trout population to respond.

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

The Lower Whatshan River flows for approximately 7 km from BC Hydro's Whatshan Dam to Lower Arrow Lake. Reaches 1 and 2 of this river section are steep, bedrock-confined sections with falls and cascades that prevent upstream fish passage from Arrow Lake. In contrast, Reach 3 is wide with a gentle gradient and substrate of cobble and boulder, reverting again to bedrock canyon in Reach 4 up to the dam.

The Whatshan Hydroelectric Project diverts water from Whatshan Lake via a tunnel to the Whatshan Generating Station (WGS) located on Lower Arrow Lake approximately 4.5 km north of the Needles-Fauquier ferry crossing. Since there is currently no minimum flow release from Whatshan Dam, almost all flow to the Lower Whatshan River is provided by its main tributary, Barnes Creek, which enters at the upstream end of Reach 3.

Flow reduction is believed to have negatively affected production of Rainbow Trout (*Oncorhynchus mykiss*) in the Lower Whatshan River. However, providing a fish flow release from Whatshan Dam raised several concerns including increased water temperature, introduction of competing fish species, and loss of power generation revenue. Therefore, the Consultative Committee (CC) for the Whatshan Water Use Plan (WUP) agreed that in lieu of an operational change to provide a minimum flow, BC Hydro would instead undertake fish habitat enhancement in Reach W3.2, a 1.3 km section of low gradient stream with low habitat complexity located in the vicinity of the Highway 6 Bridge (Figure 1). A control site was also selected at Barnes Creek Reach B3 for comparison with the study reach.

The enhancement project was intended to be conducted over a 10-year time frame in three phases: 1) pre-enhancement work; 2) construction; and 3) post-enhancement monitoring.

The primary management questions from the WUP Terms of Reference (TOR) are as follows (BC Hydro 2005, p. 7):

1) Do habitat structures in Reach W3 of the lower Whatshan River increase the availability of suitable habitat for Rainbow Trout?
2) How long do habitat structures continue to function?
3) Do habitat structures increase available habitat for Rainbow Trout in a more cost-effective manner than would a minimum flow release from the Whatshan Dam?
4) Does the increase in available habitat benefit Rainbow Trout in Reach W3?

From the original Request for Proposal for WGSMON-1, the primary hypotheses to be tested were:

H_1: Habitat enhancement in Reach W3 of the lower Whatshan River increases available habitat for rainbow trout.

H_2: Habitat enhancement in Reach W3 of the lower Whatshan River will increase rainbow trout standing crop.
H_{2a}: Habitat enhancement will increase rainbow trout density.

H_{2b}: Habitat enhancement will increase rainbow trout size.

H_3: Habitat enhancement in Reach W3 of the lower Whatshan River does not negatively affect the density or size of fish species other than rainbow trout.

"The objective of this program is to evaluate the general ecological and specific fish and fish habitat benefits expected from habitat enhancement structures installed in Reach W3 of the lower Whatshan River." (BC Hydro 2005, p. 8)

Pre-enhancement work consisting of channel assessment, habitat designs, and monitoring of physical habitat and fish populations was conducted in 2006 and 2007 (Naito and Bates 2007, 2008), with an additional year of physical and biological monitoring conducted in 2008 (Naito and Bates 2009). The 2008 studies were conducted because an unplanned outage of the Whatshan Generating Station (WGS) resulted in the release of virtually all freshet flows from Whatshan Dam for the first time since its completion in 1952. These unusual large spill flows had the potential to change the channel morphology in Reach W3.2, with consequent effects on proposed enhancement activities. Furthermore, the abnormally high flows might have affected the fish populations, potentially resulting in a negative impact.

The original enhancement plan called for habitat enhancement measures at thirty sites that were intended to increase habitat complexity, especially pools and large woody debris cover, and to narrow the channel to promote natural channel processes (e.g., scour and deposition) that had been diminished under reduced flows resulting from hydroelectric diversion. The proposed enhancement measures consisted of 20 log/debris jams, 7 additions of large woody debris cover, and 3 additions of large boulders. Some sites combined more than one enhancement measure (e.g., boulders plus wood debris).

Construction of habitat enhancement measures in Reach W3.2 was completed in the summer of 2009. Since eight structures could not be completed due to lack of consent from private landowners, additional habitat enhancement was completed at other sites by incorporating more material than originally planned. In addition to these larger structures, extra boulder habitat was created at four sites, and additional LWD was installed near three sites. The end result was that enhancement work was successfully completed at a total of 31 sites in Reach W3.2. These sites consisted of 12 triangular log jams, 6 lateral log jams, 8 boulder groups, 3 single or double boulder placements, and 2 single or multiple log placements. Twenty-two of the sites were in the original enhancement plan, while the others were added to utilize excess materials. A comparison of the enhancement measures that were originally proposed versus actually constructed is provided in Table 1. In relation to the enhancement objectives, one notable difference is that only 12 of 18 triangular log jams, the primary pool-forming measure, were constructed.

Table 1. Comparison of habitat enhancement measures proposed versus actually constructed in Lower Whatshan River Reach W3.2 in August 2009.

Enhancement Measure	No. Proposed	No. Constructed
triangular log jam	18	12
lateral log jam	2	6
boulder group	2	8
single/double boulder	0	3
single/multiple log	7	2
boulders + logs	1	0
TOTAL	30	31

This report provides results of the third year of post-enhancement monitoring (Year 10) conducted in 2015. The first year of post-enhancement monitoring was conducted in 2010 (Naito 2011), and the second year of monitoring was in 2012 (Year 7) (Naito 2013). This is intended to be the final year of study for the Lower Whatshan Fish Habitat Enhancement Project, and aims to provide answers to the management questions posed in the WUP TOR around the benefits of habitat enhancement structures to Rainbow Trout.

2 METHODS

2.1 STUDY TEAM

The fisheries study team in 2015 consisted of Mr. Gerry Naito, R.P. Bio (Naito Environmental, Vernon, BC), with field assistance provided by Ms. Ashley Boksteyn, Kelowna, BC for the physical habitat survey, and by Ms. Robyn Laubman, R.P.Bio., (Ecora Natural Resource Group, Kelowna, BC) and Mr. Chad Unser, R.P.Bio. (Kingfisher Environmental, Kelowna, BC) for the fish sampling. Physical assessment of habitat structures and channel changes was conducted by Mr. Alan Bates, P.Eng., Streamworks Inc., Salmon Arm, BC. Statistical analyses comparing pre- and post-enhancement fish populations and physical conditions were conducted by Dr. Carl Schwarz of the Statistical Consulting Service at Simon Fraser University, Burnaby, BC.

2.2 SITE ACCESS

Access to the study sites in 2015 had not changed from previous years. There was easy automobile access to Whatshan Reach W3.2 from the Whatshan Forest Service Road (FSR), while access to Barnes Creek Reach B3 was by automobile via Whatshan FSR and the power line road to the creek crossing, from which there was reasonably easy foot access downstream. Accommodation was at a field camp at the south end of Whatshan Lake.

2.3 HABITAT STRUCTURE ASSESSMENT

A field survey of Whatshan River Reach 3.2 was conducted by Alan Bates, P.Eng. of Streamworks Consulting Inc. on September 11, 2015. Mr. Bates has been involved in the project since 2006, conducted the original cross section surveys, and carried out the channel modeling and design of the structures. He is therefore familiar with the channel condition prior to the installation of the structures, and immediately post-construction. During the 2015 site visit, numerous photographs were taken of each structure/installation for comparison with photo-documentation from 2009. No cross sections were re-surveyed to assess channel dimensional change. A handheld GPS was used to confirm structure locations. The Streamworks structure and channel condition review report is included as Appendix 1.

2.4 FISH HABITAT SURVEY

Physical habitat was assessed to detect changes resulting from enhancement and to relate those changes to changes in the fish population. As recommended in the TOR, a Before-After-Control-Impact (BACI) design was used to detect whether habitat enhancement resulted in an increase in abundance and/or biomass of Rainbow Trout. The same assessment methods used in the pre-enhancement studies (Naito and Bates 2007, 2008, 2009) and in the first two post-enhancement studies in 2010 (Naito 2011) and 2012 (Naito 2013) were repeated in 2015.

2.4.1 FIELD ASSESSMENT PROCEDURES

The physical habitat survey took place during September 1-4, 2015, prior to the fish sampling that occurred during September 8-16, so that habitat units could be identified and selected for fish sampling. The physical habitat monitoring methodology used in previous years, based on the Fish Habitat Assessment Procedures (FHAP) (Johnston and Slaney 1996), was repeated in 2015. Starting from the downstream end of both Reach W3.2 and Reach B3, the distance, length, and wetted width of each habitat unit (pool, riffle, glide, side channel/back channel) were measured under late summer, low flow conditions. Habitat unit length was measured with a 50 m fiberglass tape. Habitat unit width was the average of one to six wetted widths (depending on variability of width) measured with the same tape.

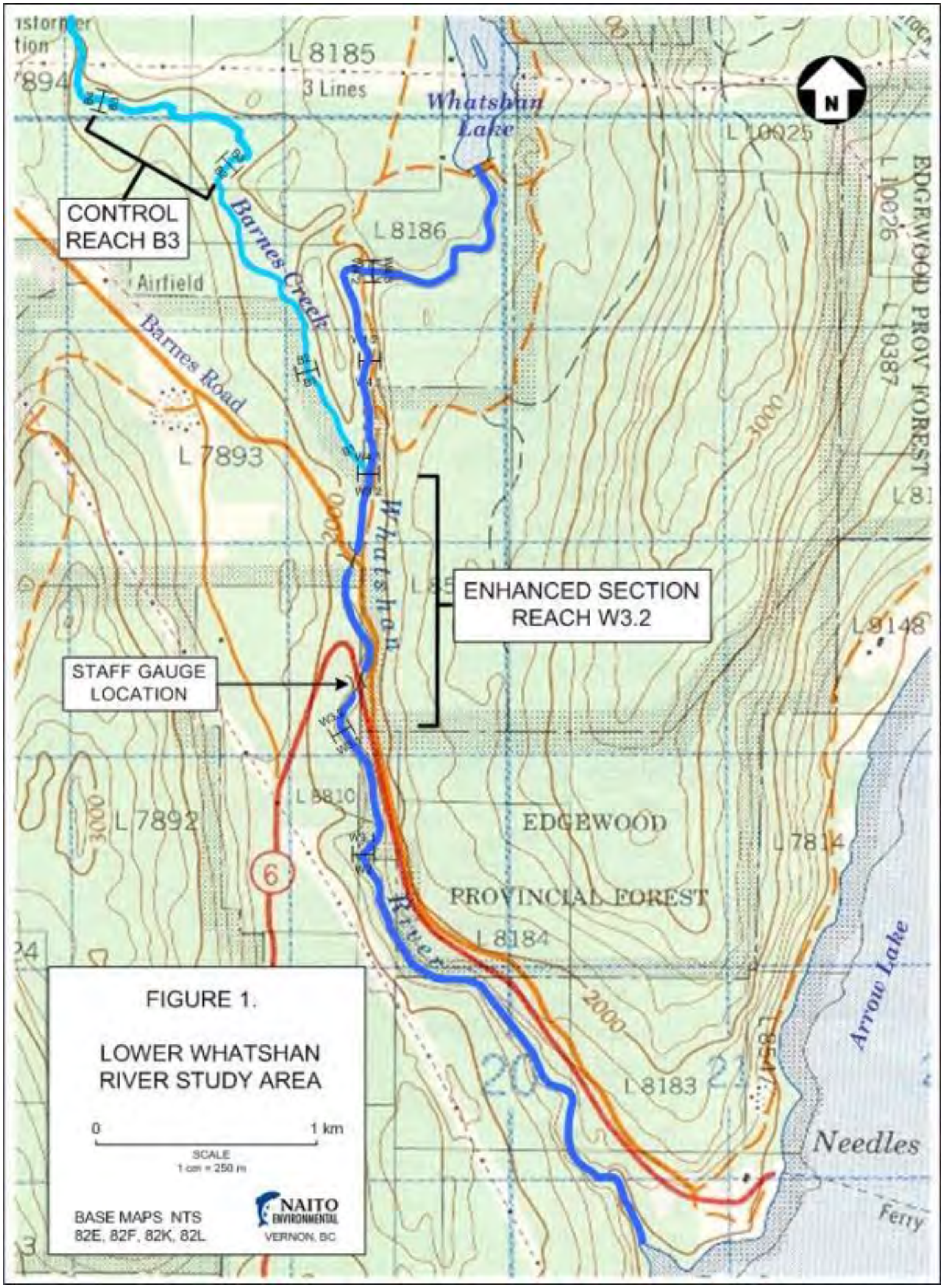


Figure 1. Map showing location of Lower Whatshan River study area.

Habitat units were distinguished using FHAP definitions and minimum size criteria. For each habitat unit, the following physical habitat variables were documented:

- estimated cover area (m^2) of large woody debris, small woody debris, boulders, undercut banks, overhanging vegetation, deep pool;
- substrate composition;
- area of spawning gravel (10-40 mm) suitable for (small) resident trout;
- water depth measured at ¼, ½, and ¾ of unit width; and
- maximum and pool outlet (crest) water depth in pools.

Areas of cover and spawning gravel were estimated by tallying individual pieces or patches whose areas were visually estimated or measured with meter stick or tape. Spawning area included gravel dewatered in September but likely to have been wetted during the Rainbow Trout spawning and incubation season. Water depths were measured with a meter stick.

Physical data were recorded on custom-designed field forms printed on waterproof paper.

The permanent markers posted at 100 m intervals starting from the downstream end of each reach in September 2006 were still in place and used to identify distance locations of individual habitat units. Distance locations were measured from the nearest permanent marker using a 50 m fiberglass tape.

2.4.2 DATA SUMMARIZATION AND ANALYSES

Physical data were entered and summarized using MS Excel. The area of each habitat unit was calculated by multiplying length × mean wetted width, and the overall areas of each habitat type were summed to yield total reach area. Mean values by habitat type were calculated by reach to summarize and/or calculate physical characteristics including habitat unit length and area, wetted width, water depth, cover area, and spawning gravel area.

There were two sets of pre- and post-enhancement habitat comparisons. The first set consisted of before/after comparisons (i.e., is the mean of the response variable the same before and after habitat enhancement?) for each response variable in each stream. The second set of comparisons was a BACI (before/after control/impact) analysis that tried to separate temporal effects from the enhancement effects. Since Barnes Creek B3 was a control reach (i.e., no enhancement), changes in B3 therefore represent simple temporal effects (e.g., wet vs. dry or cold vs. warm years, etc.). In the BACI analysis, the differential change between the control and impact streams is of interest (i.e., is the change in Whatshan between before and after different from the change in Barnes Creek (the control)?).

The first step was to reduce each measured variable to one measurement per stream per year by calculating a mean. Weighted means were also calculated to see if that would affect results. For example, the average width variable, measured in each habitat unit, was weighted by habitat unit length, while average depth and the substrate and cover variables were weighted by habitat unit area.

The before/after comparison for each stream-response variable was a simple t-test comparing the mean response in the before period versus the after period. In other words, is the mean of the variable the same in the before period versus the after period ($H : \mu_B = \mu_A$)?

The BACI analysis compared the differential response between the two stream reaches. That is, it compares the difference in means before versus after for B3 to the difference in means before versus after for W3 ($H :\left(\mu_{B,W3} - \mu_{A,W3}\right)=\left(\mu_{B,B3} - \mu_{A,B3}\right)$).

2.5 FISH SAMPLING

2.5.1 SAMPLE SITE SELECTION

As in 2010 and 2012, the sampling protocol for the 2015 survey was a stratified random sampling design, where each reach was first stratified into four habitat types (glide, pool, riffle, side/back channel). A systematic sample of habitat units was then randomly selected from each habitat stratum by first dividing the number of habitat units *n* in the stratum by *i*, the desired number of units to be sampled, and sampling every *n/i*th unit, starting with a unit between 1 and *n/i* randomly selected by rolling a die. A multiple-pass removal method was then used to sample fish from all or a portion of each selected unit.

2.5.2 FISH CAPTURE

Fish sampling was conducted by multiple-pass removal electrofishing with a Smith-Root Model 12B backpack electrofisher operated as a shore-based unit with a 30 m anode cable using a two-person crew plus an equipment attendant. Electrofisher settings were 300 or 400V, 60 Hz, and 6 ms.

Smaller habitat units were sampled in their entirety while representative portions of larger units were sampled. All fish sample sites were fully enclosed within stopnets with 9.5 mm stretched mesh. The number of passes conducted varied from two to five and was primarily determined by whether an adequate decline in catch had occurred for all species and life stages of fish, although time constraints (e.g., onset of darkness) sometimes required compromises to be made. An “adequate decline in catch” was defined subjectively to result in acceptably narrow confidence limits for the population estimate, based on the lead biologist’s experience in calculating multiple pass population estimates. The acceptable decline in catch differed by species and the number of fish involved, with the most stringent standard for Rainbow Trout and the least stringent for Slimy Sculpin.

Captured fishes were anaesthetized in a CO_2 solution created by dissolving one or two tablets of Alka Seltzer™ in 3-4 L of water, measured for fork length (trout, dace) or total length (sculpins) to the nearest millimeter on a fish board, and weighed to the nearest 0.1 gram using an AccuLab VIC-1501 electronic balance. Scale samples were collected from selected trout and submitted to Hamaguchi Fish Aging Services in Kamloops for age determination. After being measured and weighed, captured fishes were allowed to recover in a single screened live bucket outside of the enclosed sample area until completion of all removals and fish measurements, then were released back to the sample area.

2.5.3 FISH HABITAT DOCUMENTATION

To correlate fish use with habitat characteristics, the following physical habitat variables were measured or documented at fish sample sites in both the treatment and control reaches:

- depth and velocity measured with a Swoffer Model 2100 flow meter with topset wading rod at 1 m intervals along a fiberglass tape extended across a representative portion of the sample site;
- cover area (m^2) for same cover types as in the physical survey;
- maximum depth; and
- substrate composition.

In cases where an entire habitat unit was fish sampled, the cover, depth, and substrate data collected in the physical habitat survey were used rather than being measured again during the fish sampling.

2.5.4 DATA ANALYSES

2.5.4.1 Age Distribution

A mixture-of-normal distributions was fit to the observed length frequency data using the methods outlined in Benaglia et al. (2009). Following the fit, a posterior assignment to either fry (first component) or juvenile/adult (remaining components) was done. For example, a 35 mm fish might have a posterior probability of 0.65 of belonging to the first component and 0.35 of belonging to the second component. It would be assigned to the component with the largest posterior probability.

This method worked well for all species except Longnose Dace, which are known to have a bimodal fry length distribution from an early and a late emergence (McPhail 2007, p. 130). Therefore, in some years, early-emerging fry overlapped with juvenile fish from the previous year and, in at least one year, no fry were captured, making the "first component" for that year the juvenile adult stage. To avoid problems, a constraint was placed on the mean of the first component indicating that it must be close to 25 mm as indicated by the length frequency distributions of more "normal" years and by the size range of 20-35 mm fork length given by McPhail (2007, p. 130) for young-of-the-year Longnose Dace.

Due to indistinct peaks in fish length frequency distributions, plus potential different ages of maturity for male and female fish, it was not considered practical to differentiate between juvenile and adult fish. The number of fish captured at most sample sites was also not sufficient to generate separate population estimates by age class. Fish aging by scale analysis (for Rainbow Trout) and lengths at age from McPhail (2007) and Scott and Crossman (1998) were used to corroborate the fry versus older fish length breaks determined by the mixture software.

2.5.4.2 Condition Factor

Condition factor is a measure of the general health or well-being of a fish based on its weight in relation to its length. A fish that is heavier than another one for a given length will have a higher condition factor. A Fulton-type condition factor was calculated for all fishes to compare fish condition between the treatment and control reaches. The formula used to calculate condition was

$$K = (W/L^3) \times 100{,}000$$

where W = weight in grams and L = length in millimeters.

Due to differences in body form among different species, condition factors are only comparable among members of the same species. No account was made for differences in reproductive status or stomach fullness, but sample sizes were likely large enough for these factors to average out for the groups being compared.

2.5.4.3 Population and Biomass Estimates

The sampling protocol for this survey began as a stratified sampling design, where each reach was stratified into four habitat types (glide, pool, riffle, side/back channel). A sample of habitat units or segments was selected from each habitat stratum, and a multiple-pass removal method was used to sample fish from a portion of each selected segment. The selection of habitat segments and sample sites within segments was not random in 2006, 2007, and 2008 but was instead based on factors such as "representativeness" and accessibility. However, it is believed that this non-random selection can be treated as a random sample because a range of conditions within each habitat type was selected (e.g., not just high quality habitats based on depth, velocity, and cover were sampled), sample sites were distributed along the length of each reach, and because it was assumed that accessibility was not related to density. Sample site selection was switched to a stratified random sampling design for the post-construction period (refer to Section 2.5.1).

2.5.4.3.1 Total Abundance and Density for Each Species.

Let $\hat{N}_{yhs}$ be the estimated number of fish in the sampled area a_{yhs} for year y, habitat type h and segment s. This was computed using the maximum likelihood estimator of Zippen (1958) based on the results of a multi-pass removal sampling for each sampled area in the segments.

The estimate of the total number of fish for each creek was computed using the separate-ratio method for surveys as outlined in Cochran (1977). This starts with estimating the density of fish ($\hat{d}_{yh}$) in year y and habitat h as the ratio of the total fish in the sampled segments to the total sampled area within each habitat type:

$$\hat{d}_{yh} = \frac{\sum_s \hat{N}_{yhs}}{\sum_s a_{yhs}} \qquad SE(\hat{d}_{yh}) = \frac{1}{\bar{a}_{yh}}\sqrt{\frac{1}{n_{yh}}\frac{\sum_s \left(\hat{N}_{yhs} - \hat{d}_{yh}a_{yhs}\right)^2}{n_{yh} - 1}}$$

where n_{yh} is the number of sampled segments and $\bar{a}_{yh}$ is the average segment area sampled year y and habitat type h. The SE incorporates both the uncertainty in the estimated fish numbers from the removal estimate and the uncertainty because only a fraction of each habitat was sampled. In some habitats, only a single segment was sampled and no SE could be computed and a value of zero was imputed (it would be possible to impute an SE based on the results of a similar habitat type, but the contribution from the habitat type was so small that this imputation was not needed).

The estimated total number of fish ($\hat{T}_{yh}$) for the entire habitat type *h* in year *i* was found by expanding the density by the total area (A_{yh}) of habitat type *h:*

$$\hat{T}_{yh} = \hat{d}_{yh} A_{yh} \quad SE(\hat{T}_{yh}) = SE(\hat{d}_{yh}) A_{yh}$$

Estimated densities were computed by dividing the estimated total abundance by the corresponding total area. The se is found in the same way.

The estimated total number of fish for entire creek ($\hat{F}_y$) in year *y* was then found by summing over the totals for each habitat:

$$\hat{F}_y = \sum_h T_{yh} \quad SE(\hat{F}_y) = \sqrt{\sum_s SE(\hat{T}_{yh})^2}$$

These computations were done for each species in turn and separately for each stream.

2.5.4.3.2 Total Biomass and Biomass-Density

The estimated biomass was found by taking the estimated fish number in a habitat type in a year ($\hat{T}_{yh}$) and multiplying by the mean weight of fish for that habitat ($\overline{w}_{yh}$) where the latter was estimated from the mixed-model ANOVA. The SE was found using Goodman's (1960) formula for the variance of a product of independent random variables using the form suitable when the variances of the two parts are estimated:

$$\hat{B}_{(2)yh} = \hat{T}_{yh} \overline{w}_{yh} \quad SE(\hat{B}_{(2)yh}) = \sqrt{\hat{T}_{yh}^2 SE(\overline{w}_{yh})^2 + SE\left(\hat{T}_{yh}\right)^2 \overline{w}_{yh}^2 - SE(\overline{w}_{yh})^2 SE\left(\hat{T}_{yh}\right)^2}$$

These estimates were then summed over habitat types within year in a similar fashion as seen earlier. There were two stream-years where no fish of a particular species were captured and measured in a year; in these cases, the mean weight was imputed as the average of the average weights across the other years in the study.

This method assumes that the estimates (of numbers and weight) are independent. If estimates of fish numbers and fish weights were correlated (e.g., more smaller fish versus fewer larger fish in a given habitat segment) the estimated precision may be understated. However, given the small sample sizes present in this study, the influence of any such correlation is expected to be slight and the assumption of independence is expected to be reasonably satisfied.

Estimates of changes in biomass among years and tests of hypotheses of biomass numbers over time are computed in a similar fashion as estimates of changes in fish numbers with the same caveats.

Notice that we assume that the mean weight is the same across all habitat types within the stream-year being considered. A mixed-linear model was used to test if there was evidence that the mean weight differed among the habitats, but there were only a small number of cases where the overall p-value was small and there was no consistent pattern.

The biomass and biomass-density estimates were rolled up over all species by simply summing the biomass estimates from each species.

2.5.4.3.3 Changes in Fish Numbers/Density/Biomass/Biomass-density.

The estimated change in fish numbers between year *y* and year *y'* was found as:

$$\Delta\hat{F}_{y,y'} = \hat{F}_y - \hat{F}_{y'} \quad SE(\Delta\hat{F}_{y,y'}) = \sqrt{SE(\hat{F}_y)^2 + SE(\hat{F}_{y'})^2}$$

A test of the hypothesis of no change in fish numbers between the two years was conducted by computing a z-score:

$$z = \frac{\Delta\hat{F}_{y,y'} - 0}{SE(\Delta\hat{F}_{y,y'})}$$

and the p-value for a test of the hypothesis of no change in fish numbers between the two years was computed as the two-sided tail area using this z-score and a standard normal distribution.

Estimates of change in density, biomass, and biomass-density were computed in a similar fashion.

It should be noted that failure to detect a change in fish numbers (i.e., not statistically significant) does not imply no change in fish numbers. Given the relatively wide standard errors for the individual estimates, the estimated change in fish numbers between years has very poor precision.

The above estimate of the difference in fish numbers assumes that estimates are independent across years. However, the same segment was often sampled in multiple years. This could induce a positive correlation in the estimates across years which would imply that the estimated standard error of the change in fish numbers could be an overestimate; that is, the computed se for the difference would tend to be too large. An alternative estimator of $\Delta\hat{F}_{y,y'}$ and its SE was computed using a model-assisted estimator accounting for the same segments sampled across years using Proc SurveyReg and Proc Mixed of SAS/STAT software, Version 9.1.3 of the SAS System for Unix (SAS 2009). Generally, the estimated correlation across years was very small and the estimates and estimated se of the two approaches were not materially different.

2.5.4.3.4 Estimated Mean Weight, Length, and Condition Factor.

A comparison of the mean weights, lengths, or condition factors for each species among habitat types and years was done using a mixed-model Analysis-of-Variance with habitat type and year as fixed effects, and segment as random effects. This mixed-model ANOVA allowed for correlation in weights of fish sampled from the same segment in the same year. The analysis was performed using Proc Mixed of SAS/STAT software, Version 9.1.3 of the SAS System for Unix (SAS 2009).

2.5.4.3.5 Effects of Habitat Characteristics on Density

The effects of velocity, depth, and coverage on the density of dish were examined using regression methods.

A preliminary scatterplot showed a very strong relationship between average stream velocity and maximum segment velocity; between average depth and maximum segment depth; and somewhat weaker relationships between segment LWD, Bldr, and total cover (as the latter includes the two former variables). Cover variables were normalized to a per area basis by dividing total cover of each type by the area of each segment.

Many covariates were measured at each site in each year:

AvgWidt, MaxDep , B , C, G, F, LWD, SWD, Bldr, UCB, OH, CovTot, Davg, Vavg, Vmax, LWDdens, SWDdens, Bldrdens, UCBdens, OHdens, CovTotdens

A priori, it was also felt that certain covariates have a joint effect:

DavgVavg, DavgVmax, MaxDepVmax, MaxDepVavg, CovTotMaxDep, CovTotVavg, LWDdensMaxDep.

Because many covariates tend to operate multiplicatively (e.g., a covariate may tend to increase the density by a certain percentage rather an absolute change), the analyses were done on the logarithmic scale. Preliminary plots showed the relationship between the log(density) and log(biomass-density) and the covariates above to be approximately linear.

There were a large number of covariates, many of which were interrelated. Model selection, (i.e., deciding which covariates are important in predicting the response) can be done in many ways. Stepwise regression is an older method that is no longer recommended.[1] A more modern method is LASSO (Tibshirani 1996). In LASSO, variables are selected that best explain the relationship between the response and the set of covariates but under restrictions that, as more variables are added to the model, the newer variables should not be smallish effects. It avoids many of the problems found using stepwise regression.

A LASSO model selection was done for both log(density) and log(biomass density) using the individual covariates, the important two-variable interactions above, and a variable representing the stream.

One potential problem with the LASSO methods is that when covariates are highly related among each other, the method tends to pick one covariate and once that covariate is entered into the model, it effectively excludes the other highly related covariates. The choice of which of several highly-related covariates enters the model is highly data dependent; slight changes to the data may change which of the highly-related covariates is chosen first.

[1] http://www.stata.com/support/faqs/statistics/stepwise-regression-problems/

An alternate method is based on the Akaike Information Criteria (AIC) (Burnham and Anderson 2002). In this method, many candidate models are compared among themselves and ranked in terms of relative fit based on a fit-complexity trade-off. For example, if there are two models that fit the data equally well, but one model has fewer parameters (i.e., fewer habitat covariates), then the simpler model is preferred. Each of the candidate models is given a model weight which sum to 1 over the models considered. A variable's relative importance is found by summing the model weights of the models that contain this variable. Therefore, if there are two highly related variables, the two models that differ only in which of the two variables is present will have comparable fits and comparable weights. As a rule of thumb, a strong explanatory variable will have a relative importance of around 0.8 or higher, moderate effects of around 0.6-0.8, and very weak effects with a model importance less than 0.6. Notice that using AIC does not guarantee that the model is actually useful (tight predictions), as the comparison is only among models that contain the specified set of variables. Model assessment of the best fitting models (e.g., residual and other plots) did not show any evidence of lack-of-fit.

3 RESULTS

3.1 PHYSICAL HABITAT

3.1.1 HABITAT ENHANCEMENT MEASURES

As described in Section 1, habitat enhancement work in 2009 could not be completed at eight out of 30 sites due to lack of consent from private landowners. Therefore, more material than originally planned was incorporated into some enhancement structures such as log jams to utilize excess materials, while other extra material was used to create new boulder groups and single boulder or log placements.

All of the constructed rock and debris structures have since remained in place and are still structurally sound with little change to original configurations. Two bent eyebolts were noted, but that damage could have occurred during construction. Most debris jam structures had successfully recruited small woody debris, and in some cases, larger logs had been captured. Smaller boughs and branches (with needles) placed as 'preload' debris on the structures in 2009 were mostly stripped clean.

In most cases, some degree of bed scour was noted near the tip of the encroachment structures. Scour was likely due to increased velocity of flow around the tip, or by high flows pouring over the submerged log ends. Stream armour had often been excavated near the structure tips during construction to initiate/promote scour. Fish were often observed in and around structures, utilizing the cover provided by the debris and deeper water.

The complex velocities in and around the debris structures caused localized scour and deposition resulting in substrate sorting. Eddies, formed downstream of the structures, collected sediments precipitated by lower local velocities. This process resulted in the accumulation of sand and gravel bars downstream of many of the bank structures. In some cases, vegetation was beginning to colonize the deposits. The debris structures, lateral bars and boulder placements worked well together to narrow the effective channel width, force meanders within the oversized channel, and increase channel complexity.

In addition to the debris structures, instream boulder placements were used to increase velocity complexity and augment fish habitat. Positions of boulders were not surveyed; however it was apparent that some have likely moved or at least sunk lower into existing substrates. Individually, boulders created small eddies and pour-overs that were intended to cause scour and sort substrates. The amount of scour and sorting accomplished by the boulders was minimal. Most boulders did exhibit a 'shadow' of finer material deposited on their downstream side. However this did not represent a significant change in fish habitat quality.

Typically, channel adjustments occur in creeks and rivers during events at or greater than bank full flow, approximated by a 2 year return period (often termed channel-forming flows). Based on flow records for Barnes Creek, which now provides almost all of the flow to Whatshan Reach W3.2, the design flow for the habitat enhancement structures was set at 45 m^3/s. Channel constrictions were designed to increase local velocities to a point that initiated mobilization/scour of surveyed substrate sizes. The design flow was selected with the goal of generating bed mobilization and channel reforming, on average, once every five years.

In the six years since enhancement work was completed in 2009, the Barnes Creek daily mean flow has only exceeded the 45 m^3/s design flow on one day in 2013. Therefore, the habitat enhancement structures have had very limited opportunity to contribute to adjustment of the channel to smaller flows.

The complete enhancement structure and channel condition review by Streamworks Consulting Inc., including before and after photographs, is provided as Appendix 1.

3.1.2 HABITAT TYPES AND CHARACTERISTICS

Table 2 and Table 3 provide a summary of physical characteristics for Whatshan W3.2 and Barnes B3 in 2015. Photographs of habitat at fish sample sites are provided in Appendix 2, physical data from fish sample sites are provided in Appendix 3, and physical data for all habitat units are provided in Appendix 4.

Table 2. Physical characteristics by habitat type for Whatshan Reach W3.2, September 2015.

Characteristic	Habitat Type				
	Glide	Pool	Riffle	Channel[a]	ALL
No. of Units	18	15	19	2	54
Total Length[b] (m)	449	324	708	105	1585
Total Habitat Area (m^2)	6,420	4,193	9,341	293	20,247
% of Total Area	32%	21%	46%	1%	100%
Mean Area (m^2)	357 (SD=361)	280 (SD=236)	492 (SD=330)	146 (SD=121)	375 (SD=321)
Total Spawn Gravel Area (m^2)	275	145	283	22	724
Mean Wetted Width (m)	13.3 (SD=4.1)	12.4 (SD=2.4)	12.6 (SD=4.3)	2.9 (SD=0.3)	12.4 (SD=4.1)
Mean Depth (m) [c]	0.33 (SD=.07)	0.70 (SD=.14)	0.23 (SD=.05)	0.12 (SD=.07)	0.39 (SD=.22
Mean Max. Depth[c] (m)	0.42 (SD=.10)	0.88 (SD=.17)	0.30 (SD=.07)	0.13 (SD=.07)	0.49 (SD=.28)
Mean Max. Pool Depth[d] (m)		1.00 (SD=.16)			
Mean Resid. Pool Depth[e] (m)		0.70 (SD=.19)			
Cover Area (m^2): Total	461	1,175	677	44	2,358
large woody debris	108	342	114	12	576
small woody debris	25	43	34	8	109
boulder	239	181	269	3	692
undercut bank	3	9	4	0	16
overhanging vegetation	86	45	258	21	410
deep pool	0	556	0	0	556

[a] Side or Back Channel.
[b] Overall total exceeds reach length due to sections of multiple channel and side channels.
[c] From habitat unit measurements at ¼, ½, and ¾ of wetted width at most units.
[d] From individual maximum depth measurements in each pool.
[e] From habitat unit assessment. Equal to maximum pool depth minus pool crest (outlet) depth.

Table 3. Physical characteristics by habitat type for Barnes Reach B3, September 2015.

Characteristic	Habitat Type				
	Glide	Pool	Riffle	Channel[a]	TOTAL
No. of Units	21	15	21	10	67
Total Length[b] (m)	491	314	694	667	2,166
Total Habitat Area (m^2)	4,382	2,813	6,506	2,110	15,811
% of Total Area	28%	18%	41%	13%	100%
Mean Area (m^2)	209 (SD=129)	188 (SD=87)	310 (SD=217)	211 (SD=288)	236 (SD=187)
Total Spawn Gravel Area (m^2)	54	44	47	121	265
Mean Wetted Width (m)	9.1 (SD=1.7)	8.8 (SD=1.3)	10.5 (SD=4.0)	2.5 (SD=1.2)	8.5 (SD=3.6)
Mean Depth[c] (m)	0.36 (SD=.07)	0.73 (SD=.19)	0.21 (SD=.06)	0.13 (SD=.05)	0.36 (SD=.24)
Mean Max. Depth[c] (m)	0.44 (SD=.10)	0.94 (SD=.19)	0.27 (SD=.08)	0.15 (SD=.06)	0.45 (SD=.30)
Mean Max. Pool Depth[d] (m)		1.06 (SD=.22)			
Mean Resid. Pool Depth[e] (m)		0.80 (SD=.23)			
Cover Area (m^2): Total	308	1,115	448	287	2,159
large woody debris	52	335	61	104	552
small woody debris	48	70	48	30	196
boulder	70	74	230	25	399
undercut bank	19	39	25	21	103
overhanging vegetation	112	59	84	68	323
deep pool	7	539	0	40	586

[a] Side or Back Channel.
[b] Overall total exceeds reach length due to meandering flow within channel, sections of multiple channel, and backchannels.
[c] From habitat unit measurements at ¼, ½, and ¾ of wetted width.
[d] From individual maximum depth measurements in each pool.
[e] From habitat unit assessment. Equal to maximum pool depth minus pool crest (outlet) depth.

3.1.3 WATER TEMPERATURE AND CONDUCTIVITY

Water temperature at the Whatshan W3.2 and Barnes B3 fish sample sites in mid-September 2015 ranged from 9.0 to 15.2°C, while conductivity varied between 105 and 146 µS/cm (Table 4). Conductivity tended to be slightly higher and maximum water temperature was 2 degrees higher in W3.2 than in B3.

Table 4. Minimum and maximum water temperature and conductivity at mainstem Whatshan W3.2 and Barnes B3 fish samples sites during 2006, 2007, 2008, 2010, 2012, and 2015.

Reach	Year	Dates	Water Temperature (°C)		Conductivity (µS/cm)	
			Minimum	Maximum	Minimum	Maximum[a]
W3.2	2006	Sep 11-18	10.4	16.2	144	151
	2007	Sep 10-13	10.2	16.0	140	150
	2008	Sep 29-Oct 8	7.8	12.9	97	119
	2010	Sep 22-27	7.3	12.2	80	84
	2012	Sep 10-17	8.1	12.9	127	138
	2015	Sep 8-13	11.2	15.2	114	140
B3	2006	Sep 15-17	7.4	13.0	121	138
	2007	Sep 14-17	10.6	13.7	116	187
	2008	Oct 3-6	6.3	11.5	87	107
	2010	Sep 28-30	7.6	12.4	67	123
	2012	Sep 10-17	8.4	11.2	111	126
	2015	Sep 14-16	9.0	13.2	105	146

[a] Conductivity 279 µS/cm in a side channel site on Barnes Creek in 2012 and 224 µS/cm in a side channel site on Barnes Creek in 2015.

3.1.4 Stage and Discharge

A staff gauge was installed at the Highway 6 Bridge in 2006, and staff gauge readings and discharge measurements from 2006, 2007, and 2008 (Table 5) yielded the following stage-discharge relationship:

$$Q = 0.0754e^{5.7942x} \quad (R^2 = 0.934)$$

where Q is discharge (m^3/s) and x is staff gauge reading (m).

Comparisons of the measured, predicted, and WSC Barnes Creek discharge show that the three values compare reasonably well from 2006 through 2012 but the predicted value is almost three times the WSC value in 2015, indicating that the channel at the staff gauge location has probably changed, and that the previous stage-discharge relationship therefore no longer applies (Table 5).

Table 5. Stage-Discharge Measurements for Staff Gauge at Highway 6 Bridge.

Date	Staff Gauge Reading (m)	Measured Discharge (m^3/s)[a]	Predicted Discharge (m^3/s)[b]	Barnes Creek Discharge (m^3/s)[c]
September 13/06	0.330	0.506	0.510	0.610
August 30/06	0.343	0.631	0.550	0.667
September 16/07	0.310	0.428	0.454	0.620
October 23/07	0.450	1.039	1.023	1.180
October 4/08	0.388	0.657	0.714	0.838
September 8/10	0.426	not measured	0.890	0.700E
September 20/10	0.586	not measured	2.249	2.50
September 21/10	0.622	not measured	2.771	2.61
September 22/10	0.532	not measured	1.645	1.74
September 23/10	0.501	not measured	1.374	1.42
September 24/10	0.491	not measured	1.297	1.41
September 17/12	0.388	0.730	0.714	0.660
September 16/15	0.549	0.688	1.815	0.616

[a] Measured at discharge transect established downstream of Barnes FSR Bridge.
[b] Calculated from stage-discharge relationship on previous page.
[b] Environment Canada, Water Survey of Canada Station No. 08NE077 Barnes Creek Near Needles.
E = estimated.

3.2 FISH RESOURCES

3.2.1 FISH SAMPLING EFFORT

Similar to previous years, four of each mainstem habitat type (glide, pool, riffle) and one side channel were sampled in Reach W3.2 in 2015, while three of each mainstem habitat type and two side/back channels were sampled in B3 (Table 6). A total of 3,098 m^2, or 15% of total habitat area, was sampled in Reach W3.2 with a total effort of 51,289 electrofishing seconds, while 1,748 m^2, 11% of total area, was sampled in Reach B3 with 26,674 seconds of effort. The amount of sampling time per unit area in each reach was approximately equal (16.5 s/m^2 in W3.2 versus 15.3 s/m^2 in B3). Photographs of 2015 fish sample sites are provided in Appendix 1 while electrofishing specifications are provided in Appendix 5.

Table 6. Number of electrofishing sites, area sampled, and electrofishing effort by habitat type in Whatshan Reach W3.2 and Barnes Reach B3 during September 8-16, 2015.

Habitat Type	Area Sampled (m^2) and Electrofishing Effort (seconds)							
	Whatshan W3.2				Barnes B3			
	# of Sites	Area	% Area	EF sec	# of Sites	Area	% Area	EF sec
glide	4	1,038	34	16,371	3	386	25	6,948
pool	4	704	23	12,933	3	463	30	8,781
riffle	4	1,286	41	20,834	3	544	35	7,990
s/b chnl	2	70	2	1,151	2	151	10	2,955
ALL	**14**	**3,098**	**100**	**51,289**	**11**	**1,748**	**100**	**26,674**

3.2.2 SPECIES AND NUMBERS CAPTURED

The same four fish species that were captured during previous years were found again in 2015 - Slimy Sculpin (*Cottus cognatus*), Eastern Brook Trout (*Salvelinus fontinalis*), Longnose Dace (*Rhinichthys cataractae*), and Rainbow Trout (*Oncorhynchus mykiss*) in Whatshan Reach W3.2, and sculpin, brook trout, and Rainbow Trout in Barnes Reach B3.

Table 7. Common and scientific names and species codes of fishes captured in Whatshan Reach W3.2 and Barnes Reach B3 during September -16, 2015.

Common Name	Scientific Name	Species Code	Reaches
Slimy Sculpin	*Cottus cognatus*	CCG	W3.2, B3
Eastern Brook Trout	*Salvelinus fontinalis*	EB	W3.2, B3
Longnose Dace[a]	*Rhinichthys cataractae*	LNC	W3.2
Rainbow Trout	*Oncorhynchus mykiss*	RB	W3.2, B3

[a] Longnose dace not present in Reach B3.

The total number of fishes captured in Reach W3.2 in 2015 was 2,315 compared with 1,332 fish in Reach B3 (Table 8). Slimy Sculpin was by far the most abundant species, making up 69% of the total number captured in W3.2 and 79% in B3. Rainbow Trout contributed 13-14% of the fishes captured in each reach, Eastern Brook Trout 9-10% in each reach, and Longnose Dace making up 8% of fishes captured in W3.2. A breakdown by life stage (fry versus juvenile/adult) is provided in the Fish Collection Form in Appendix 5.

Table 8. Number of fishes captured, by species and life stage, in each habitat type in Whatshan Reach W3.2 and Barnes Reach B3, during September 8-16, 2015.

W3.2	Glide	Pool	Riffle	Channel[a]	ALL	% of Total
CCGf	88	20	68	9	185	8
CCGja	484	158	753	6	1,401	61
EBf	41	49	79	13	182	8
EBja	14	23	6	0	43	2
LNCf	15	1	3	0	19	1
LNCja	48	17	90	0	155	7
RBf	33	26	129	19	207	9
RBja	30	61	32	0	123	5
ALL	**753**	**355**	**1,160**	**47**	**2,315**	**100%**
% of Total	***33%***	***15%***	***50%***	***2%***	***100%***	
B3	Glide	Pool	Riffle	Channel	ALL	% of Total
CCGf	87	64	30	1	182	14
CCGja	181	118	535	31	865	65
EBf	8	12	12	46	78	6
EBja	8	21	3	5	37	3
RBf	29	14	32	2	77	6
RBja	20	52	17	4	93	7
ALL	**333**	**281**	**629**	**89**	**1,332**	**100%**
% of Total	***25%***	***21%***	***47%***	***7%***	***100%***	

[a] Side channel or backchannel.

Note: Refer to Table 7 for species code definitions; f = fry, ja = juvenile/adult.

3.2.3 Length and Age

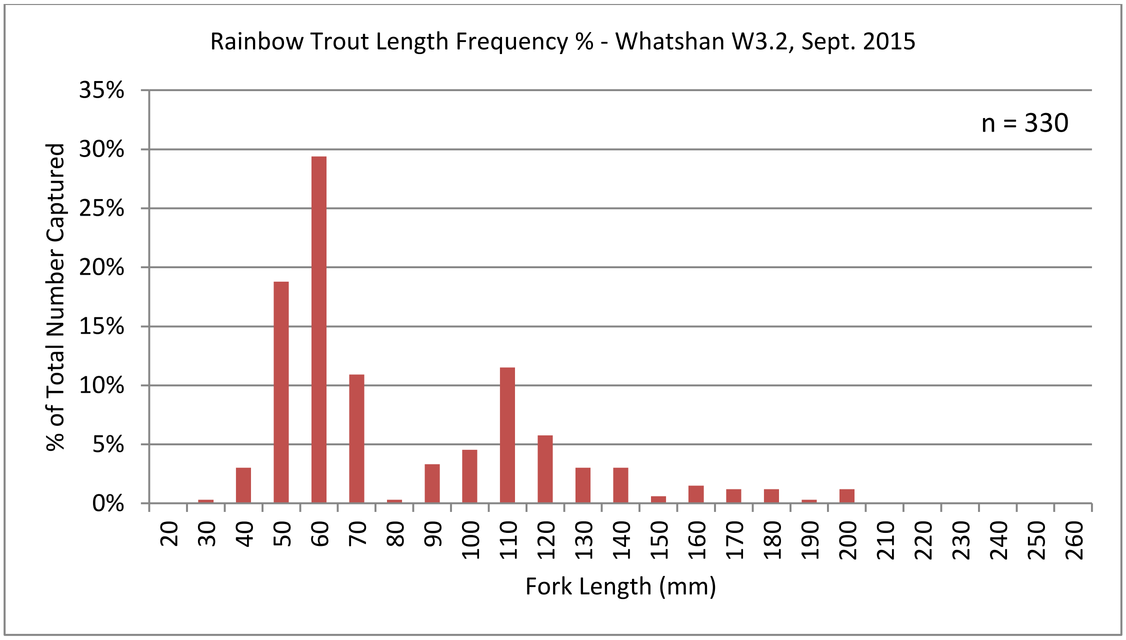
Fishes captured in 2015 ranged in length from a 17 mm Slimy Sculpin up to a 240 mm Eastern Brook Trout, both in Barnes Creek (Table 9). Fish length was fairly consistent across all habitat types except in side/back channels, where rainbow trout were shorter than in other habitats. Fish size distributions were also very similar for all species for both reaches. There were possibly proportionally more older Rainbow Trout in Barnes B3.

Age 1+ Rainbow Trout centered around 110 mm, with Age 2+ around 150-160 mm in both streams (Figure 2). The maximum fry length determined by mixture software was 75 mm. The largest Rainbow Trout that could be aged were two specimens approximately 200 mm from W3.2 that may have been Age 4+.

Table 9. Mean fish length by habitat type in Whatshan Reach W3.2 and Barnes Reach B3 during September 8-16, 2015.

	Mean Length (mm)[a]						
W3.2	Glide	Pool	Riffle	Channel[b]	**ALL**	n	Range
CCGf	29	26	30	30	**29**	185	20-37
CCGja	59	62	62	59	**61**	1,401	40-95
EBf	70	73	76	68	**74**	182	51-93
EBja	145	150	155	---	**149**	43	114-220
LNCf	30	26	27	---	**29**	19	20-33
LNCja	53	77	66	---	**63**	155	34-107
RBf	52	56	54	45	**53**	207	30-71
RBja	123	117	118	---	**119**	123	83-199
B3	Glide	Pool	Riffle	Channel[b]	ALL	n	Range
CCGf	26	27	29	24	**27**	182	17-39
CCGja	58	58	59	60	**59**	865	42-101
EBf	78	80	78	71	**74**	78	52-93
EBja	156	153	144	147	**152**	37	105-240
RBf	55	56	57	38	**55**	77	35-71
RBja	121	120	116	91	**119**	93	80-194

[a] Fork length for EB, LNC, and RB; total length for CCG.
[b] Side or back channel.
Refer to Table 7 for species code definitions; f= fry, ja= juvenile/adult.



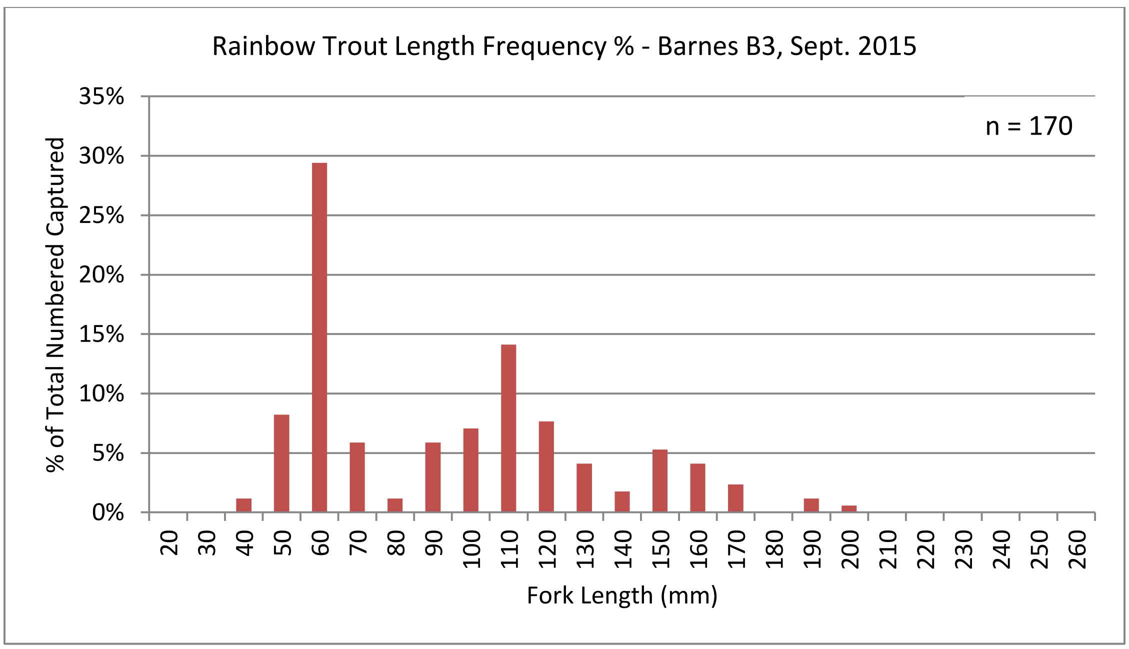
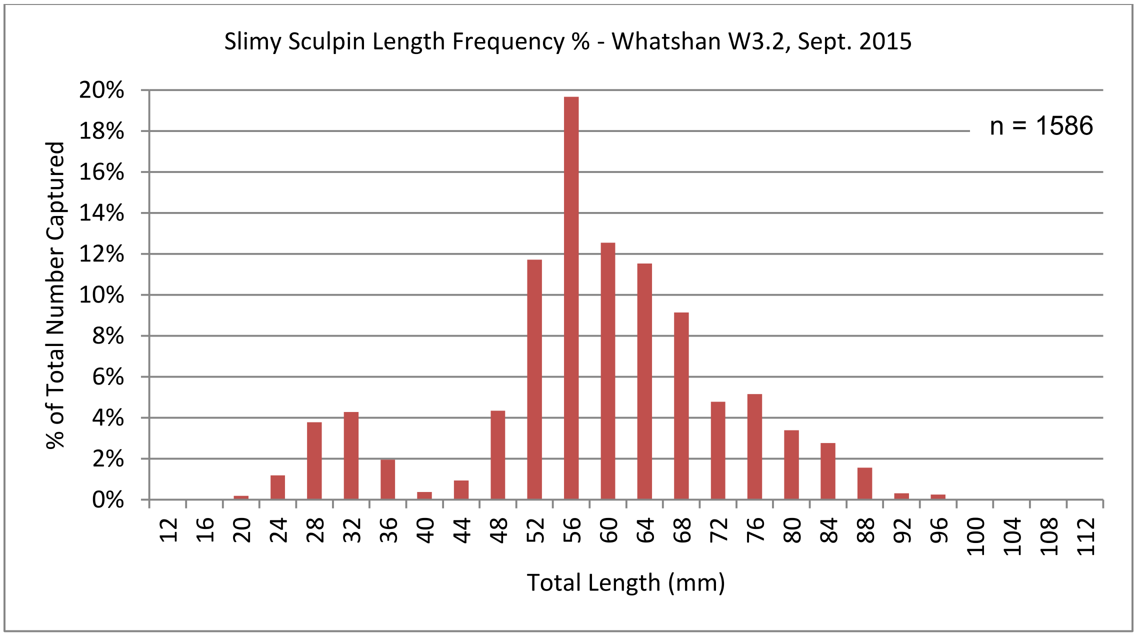


Figure 2. Length frequency distributions of Rainbow Trout captured in Whatshan River Reach W3.2 and Barnes Creek Reach B3 during September 8-16, 2015.



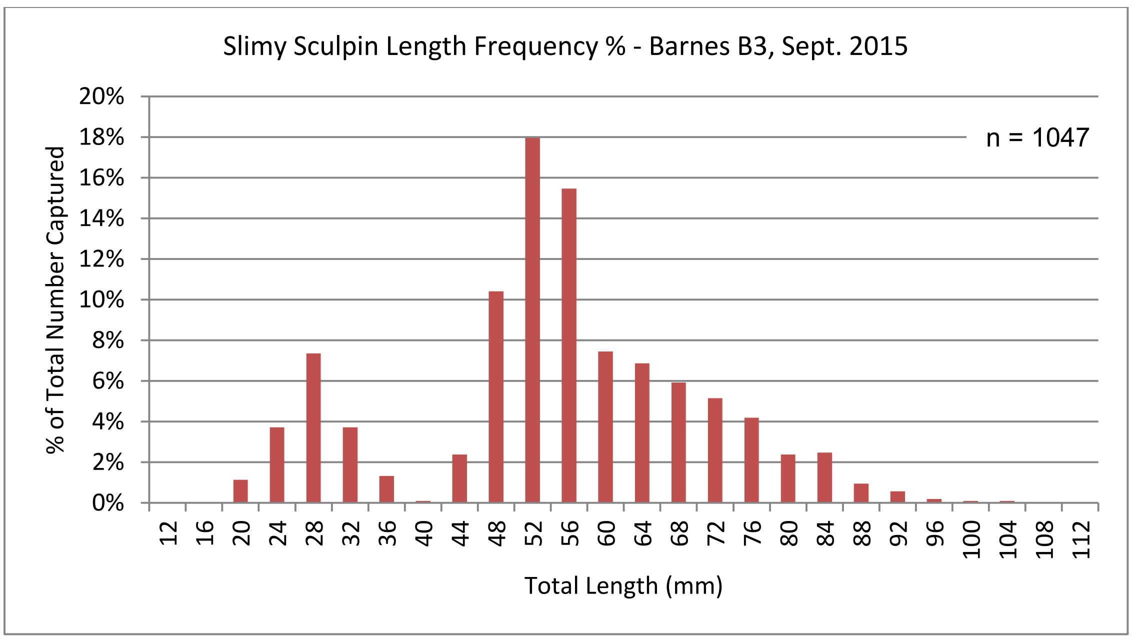
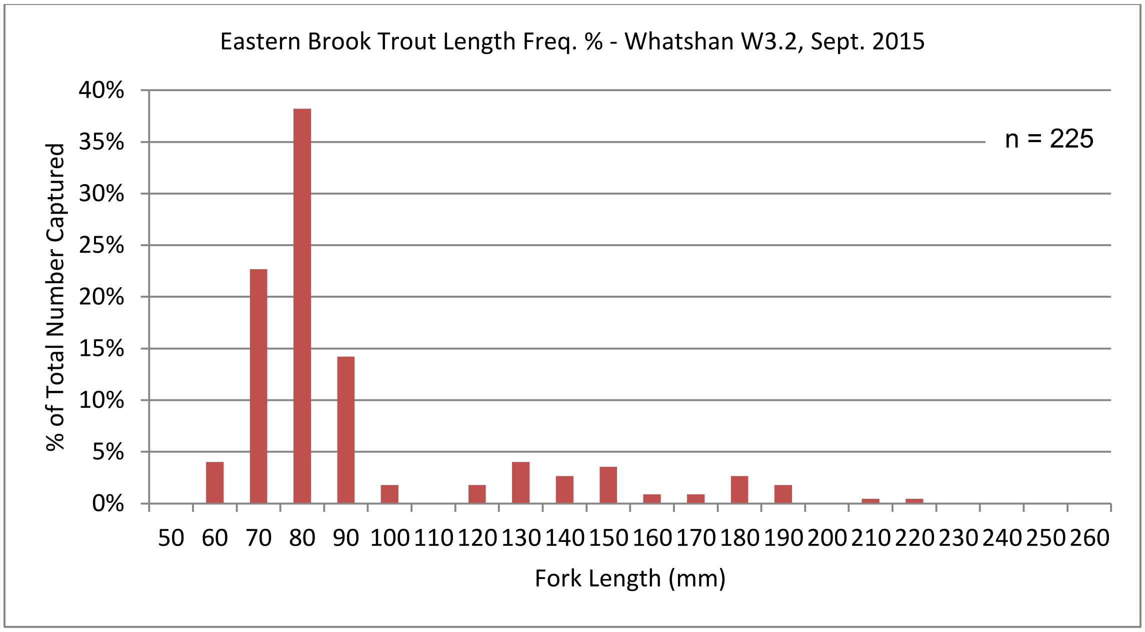


Figure 3. Length frequency distributions of Slimy Sculpins captured in Whatshan River Reach W3.2 and Barnes Creek Reach B3 during September 8-16, 2015.



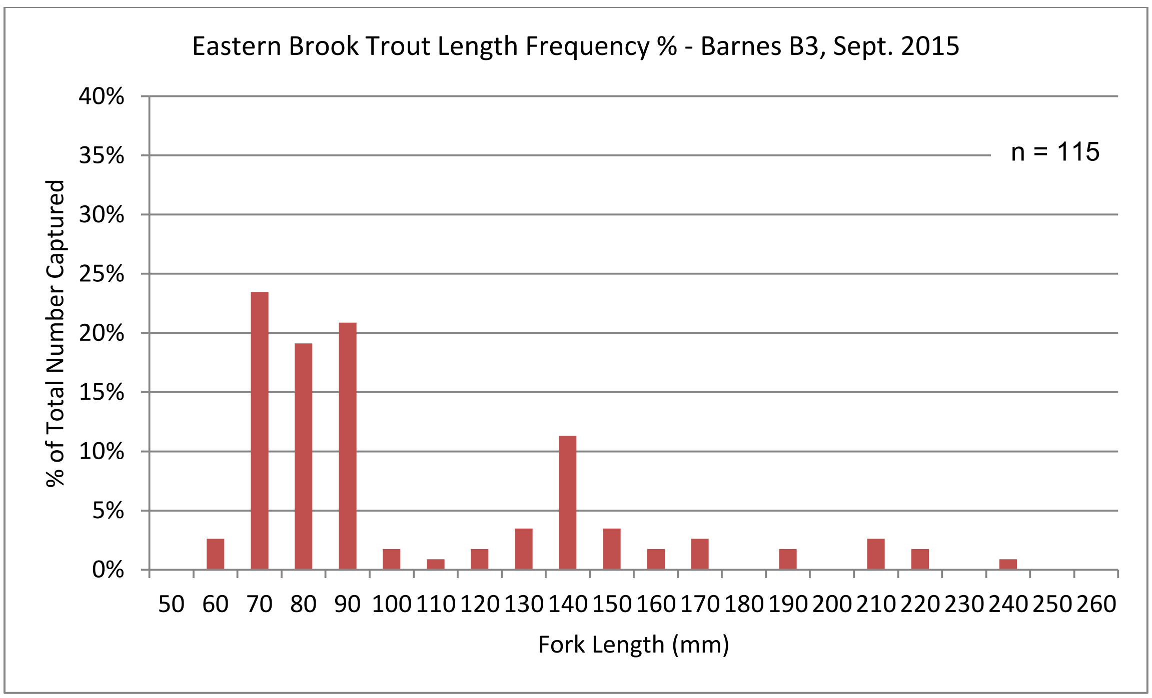


Figure 4. Length frequency distributions of Eastern Brook Trout captured in Whatshan River Reach W3.2 and Barnes Creek Reach B3 during September 8-16, 2015.

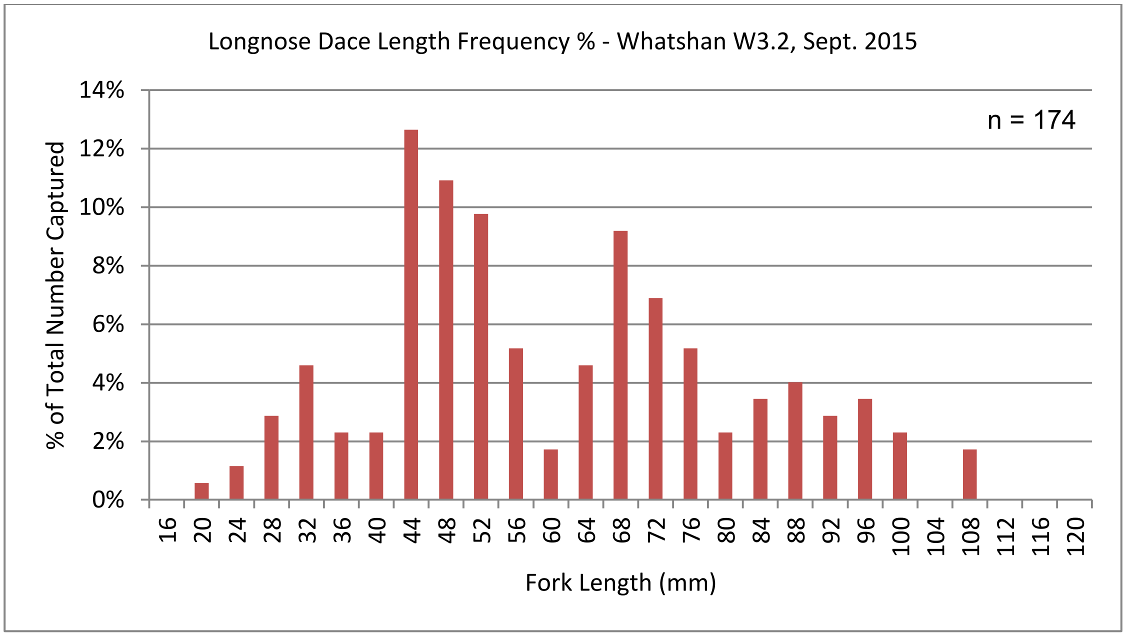


Figure 5. Length frequency distribution of Longnose Dace captured in Whatshan River Reach W3.2 during September 8-16, 2015.

3.2.4 WEIGHT AND CONDITION

Average weight (Table 10) and condition factor (Table 11) of fish of the same species and life stage were similar in Reach W3.2 and B3 in 2015. Average condition factors of Rainbow Trout were between 1.03 and 1.10, within the same range reported by Carlander (1969) from a review of numerous studies, and consistent with the findings of Slaney et al. (1992), who reported that condition factors for this species from Whatshan River and Barnes Creek were generally in the range of 1.0 to 1.1. Eastern Brook Trout had condition factors similar to Rainbow Trout, while those for Longnose Dace were slightly higher and those for Slimy Sculpin were lower. Variability in condition was highest and considered least reliable for fry of Sculpin and Longnose Dace because total fish weight was less than or approximately equal to precision of weight measurements (0.1 g).

Table 10. Mean fish weight by habitat type in Whatshan Reach W3.2 and Barnes Reach B3 during September 8-16, 2015.

	Mean Fish Weight (g)					
W3.2	Glide	Pool	Riffle	Channel[a]	**ALL**	Range
CCGf	0.2	0.2	0.3	0.3	**0.2**	0.0-0.7
CCGja	2.2	2.5	2.4	1.9	**2.4**	0.4-8.4
EBf	3.7	4.5	4.9	3.2	**4.4**	1.4-10.8
EBja	34.0	40.1	46.4	---	**39.0**	14.6-109.7
LNCf	0.3	0.2	0.2	---	**0.3**	0.1-0.7
LNCja	2.3	5.5	3.9	---	**3.6**	0.4-15.0
RBf	1.6	1.9	1.8	0.9	**1.7**	0.3-3.9
RBja	24.1	19.5	18.7	---	**20.4**	6.4-87.9
B3	Glide	Pool	Riffle	Channel	**ALL**	Range
CCGf	0.1	0.2	0.3	0.2	**0.2**	0.0-0.7
CCGja	1.9	2.1	2.3	2.3	**2.2**	0.6-10.6
EBf	5.4	5.9	5.4	4.1	**4.7**	1.4-8.0
EBja	48.7	44.3	29.3	42.0	**43.7**	12.5-136.9
RBf	1.9	1.9	2.1	0.5	**1.9**	0.3-3.6
RBja	21.9	21.2	17.7	7.8	**20.2**	5.3-86.6

[a] Side or back channel.
Refer to Table 7 for species code definitions; f= fry, ja= juvenile/adult.

Table 11. Mean fish condition by habitat type in Whatshan Reach W3.2 and Barnes Reach B3 during September 8-16, 2015.

	Mean Fish Condition by Habitat Type					
W3.2	Glide	Pool	Riffle	Channel[a]	**ALL**	Range
CCGf	0.84	1.22	0.94	0.96	**0.92**	0.00-2.16
CCGja	0.87	0.92	0.90	0.90	**0.89**	0.00-1.72
EBf	1.04	1.10	1.08	1.00	**1.07**	0.72-1.45
EBja	1.03	1.06	1.08	---	**1.05**	0.88-1.38
LNCf	1.25	1.14	0.85	---	**1.18**	0.51-2.17
LNCja	1.22	1.08	1.11	---	**1.14**	0.56-1.89
RBf	1.08	1.08	1.06	0.92	**1.06**	0.64-1.71
RBja	0.99	1.06	1.02	---	**1.03**	0.84-1.36
B3	Glide	Pool	Riffle	Channel	**ALL**	Range
CCGf	0.73	0.93	0.66	1.45	0.79	0.0-1.71
CCGja	0.92	0.93	0.55	0.95	0.69	0.0-1.88
EBf	1.11	1.12	1.11	1.07	1.09	0.77-1.40
EBja	1.05	1.10	0.96	1.15	1.09	0.90-1.38
RBf	1.13	1.04	1.11	0.82	1.10	0.70-1.70
RBja	1.07	1.04	1.02	1.00	1.04	0.90-1.49

[a] Side or back channel.
Refer to Table 7 for species code definitions; f= fry, ja= juvenile/adult.

3.2.5 ABUNDANCE AND BIOMASS

Population estimates were obtained using the following procedure.

(a) For each year-creek-segment-species combination, maximum likelihood estimates (MLE) of the abundance of the species in that segment were obtained using a removal capture-recapture method (refer to Section 2.5.4.3.1). There were 11 cases where the MLE could not be computed because of insufficient depletion over the passes. A plot of the MLE vs. the total number of fish captured showed a very consistent relationship over all segments, and this ratio was then used to expand the total number of fish captured to give an estimate of abundance for the segments where the MLE could not be found.

(b) For each year-creek-habitat-species combination, the total area sampled in the electrofishing passes along with the total abundance over the sampled segments was used to derive an estimate of fish density.

(c) The estimated densities were expanded by the total area in the creek in each habitat to give an estimate of abundance for that habitat type for the year-creek combinations.

(d) The estimates of abundance were summed over the habitat types to give an estimate of total abundance for the year-creek combinations.

The estimated abundances of fish by species and life stage in Whatshan Reach W3.2 and Barnes Reach B3 in September 2015 are presented below in Table 12. The populations of each species were remarkably similar in the two reaches, with the exception of juvenile/adult Eastern Brook Trout, which were twice as abundant in Reach B3.

Table 12. Estimated abundance of fish by species and life stage in Whatshan Reach W3.2 and Barnes Reach B3 in September 2015.

Reach	Species	Stage	Code	Estimated Abundance	SE
W3.2	Slimy Sculpin	fry	CCGf	1,376	273
		juv/adult	CCGja	11,723	2,135
	Eastern Brook Trout	fry	EBf	1,315	172
		juv/adult	EBja	284	62
	Longnose Dace	fry	LNCf	194	59
		juv/adult	LNCja	1,415	574
	Rainbow Trout	fry	RBf	1,510	139
		juv/adult	RBja	864	158
Reach	Species	Stage	Code	Estimated Abundance	SE
B3	Slimy Sculpin	fry	CCGf	1,962	647
		juv/adult	CCGja	14,033	3,701
	Eastern Brook Trout	fry	EBf	964	252
		juv/adult	EBja	535	230
	Rainbow Trout	fry	RBf	826	137
		juv/adult	RBja	833	133

Biomass estimates were obtained using the following procedure:

(a) For each year-creek-species combination, the mean weight was found using a mixed linear model that allowed for segment effects on the individual fish weights.

(b) If no mean weight was available for a year-creek-species, then the mean of the mean weights from other years for this year-species was used. This only occurred for Whatshan-EBja-2006 and Barnes-CCGf-2012.

(c) The estimated abundance was multiplied by the mean weight for that creek-species-year.

The estimated biomasses of fish by species and life stage in Whatshan Reach W3.2 and Barnes Reach B3 in September 2015 are presented below in Table 13. As with abundance, the biomass numbers were remarkably similar between the two reaches, with the exception of juvenile/adult Eastern Brook Trout, which were approximately twice as high in Barnes B3.

Table 13. Estimated biomass of fish by species and life stage in Whatshan Reach W3.2 and Barnes Reach B3 in September 2015.

Reach	Species	Stage	Code	Estimated Biomass (g)	SE
W3.2	Slimy Sculpin	fry	CCGf	356	70
		juv/adult	CCGja	27,902	5,082
	Eastern Brook Trout	fry	EBf	5,760	754
		juv/adult	EBja	11,093	2,400
	Longnose Dace	fry	LNCf	55	17
		juv/adult	LNCja	5,271	2,137
	Rainbow Trout	fry	RBf	2,553	236
		juv/adult	RBja	17,655	3,226
	All	All		70,645	13,922
Reach	Species	Stage	Code	Estimated Biomass (g)	SE
B3	Slimy Sculpin	fry	CCGf	342	113
		juv/adult	CCGja	30,192	7,963
	Eastern Brook Trout	fry	EBf	4,973	1,300
		juv/adult	EBja	23,385	10,035
	Rainbow Trout	fry	RBf	1,582	262
		juv/adult	RBja	16,789	2,688
	All	All		77,263	22,361

Refer to Table 7 for species code definitions; f= fry, ja= juvenile/adult.

3.3 HABITAT USE

Initial pre-enhancement fish and fish habitat studies in 2006 indicated that Reach W3.2 had less cover, shallower depth, and less diversity than Reach B3, and that the narrower, deeper B3 supported more juvenile/adult Rainbow Trout biomass (Naito and Bates 2007). Positive correlations of rainbow trout density with water depth and total cover suggested that increasing these two factors in Reach W3.2 could increase rainbow trout biomass. Therefore, the rehabilitation approach taken was to add cover features that would constrict the channel to simultaneously make it narrower and deeper.

Physical data were collected at fish sample sites in an attempt to confirm relationships between fish abundance and habitat characteristics (refer to Appendix 3). Many covariates were measured at each site in each year, including measures of wetted width, water depth, velocity, substrate, and cover. A priori, it was felt that certain covariates such as depth and velocity, and cover and depth might also have a joint effect.

The LASSO regression analysis indicated that only a few covariates were deemed to be important in explaining fish density at sample sites, and the set of important covariates was not identical across all species (Table 14). No covariate appeared to have a relationship to predicting the density or biomass density for Longnose Dace (LNC). Additional covariates appeared to be useful when prediction was based on log(biomass density) (Table 15) compared with the logarithm of straight density. There seemed to be no impact of stream (Barnes versus Whatshan), as this variable was never selected.

Table 14. Coefficients for variables identified as important from LASSO regression to predict log(density).

Species	Intercept	Davg	MaxDep	LWDdens	UCBdens	AvgWidth	CovTotdens
CCGf	-2.950	-0.879	.	.	.	.	.
CCGja	-0.434	-2.051	.	.	.	.	.
EBf	-3.602	.	.	.	.	.	.
EBja	-4.432	.	0.456	1.245	7.910	.	.
LNCf	-4.107	.	.	.	.	.	.
LNCja	-3.058	.	.	.	.	.	.
RBf	-2.147	-0.822	-0.464	.	.	-0.025	.
RBja	-3.763	.	0.869	.	.	.	1.967

Davg = average depth, MaxDep = maximum depth, LWDdens = large woody debris density, AvgWidth = average sample site width, CovTotdens = total cover density.

The regression results were consistent with known (e.g., Figure 6) and observed relationships between fish density and habitat. Juvenile/adult Rainbow Trout and Eastern Brook Trout density showed a positive relationship with depth and cover, while Rainbow Trout fry and Slimy Sculpin showed a negative relationship with depth. One interesting result was that undercut bank was an important covariate for juvenile/adult Eastern Brook Trout.

Table 15. Coefficients for variables flagged as important from LASSO regression to predict log(biomass density).

Species	Inter-cept	Davg	G	Avg Width	C	MaxDep	UCB dens	SWD dens	B	CovTot dens
CCGf	-3.761	-0.393	.	.	.	.	.	.	.	.
CCGja	0.649	-2.572	-0.002	.	.	.	.	.	.	.
EBf	-1.943	-0.884	.	-0.009	-0.004	.	.	.	.	.
EBja	-3.510	.	.	.	.	1.744	16.937	.	.	.
LNCf	-4.362	.	.	.	.	.	.	.	.	.
LNCja	-2.099	.	.	.	.	.	.	.	.	.
RBf	-1.639	-1.157	.	-0.027	.	-0.603	.	1.574	.	.
RBja	-1.931	.	.	.	.	1.781	.	.	0.007	2.680

Davg = average depth, G = percentage of gravel substrate, AvgWidth = average sample site width, C = percentage of cobble substrate, MaxDep = maximum depth, UCBdens = undercut bank density, SWDdens = small woody debris density, B = percentage of boulder substrate, CovTotdens = total cover density.

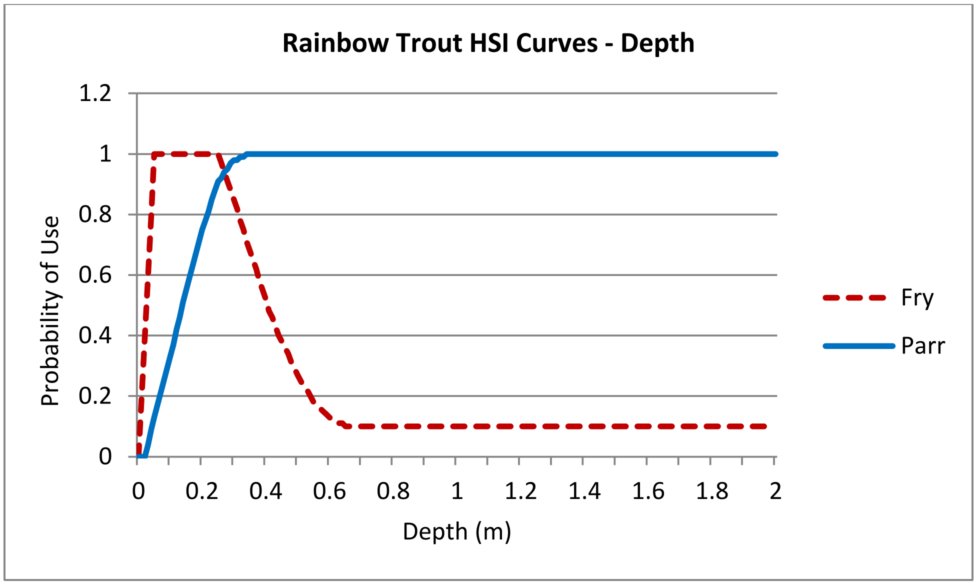


Figure 6. Habitat suitability index curves for Rainbow Trout fry and parr in relation to water depth (Ptolemy 2001).

The AIC analysis to determine the relative importance of habitat variables in relation to fish density indicated that only maximum depth had a relative importance greater than 0.8 (strong explanatory variable) for juvenile/adult Rainbow Trout, while total cover density had a moderate effect (Figure 7).

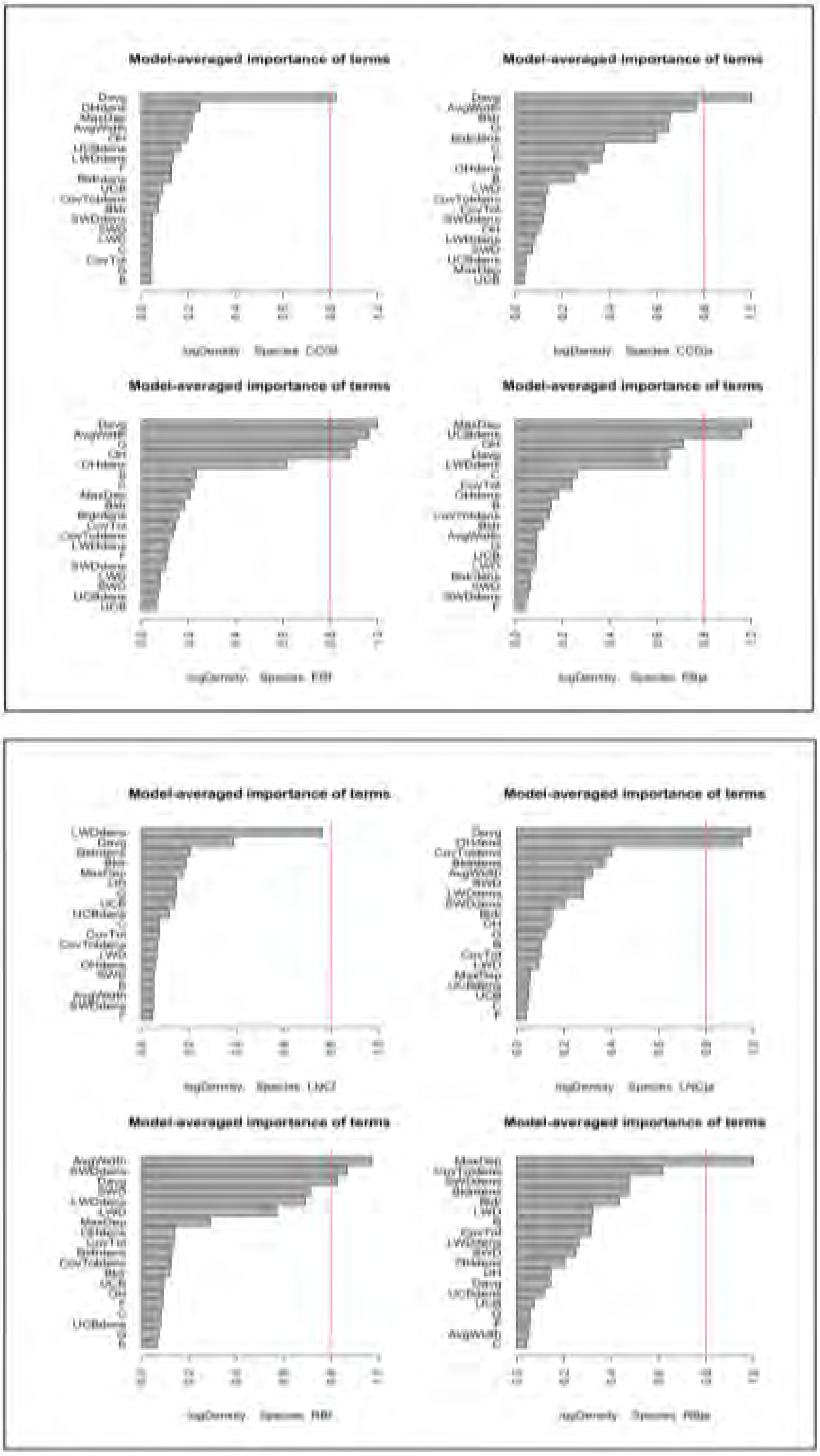


Figure 7. Relative importance of effects in predicting log(Density) as determined using AIC methods.

4 PRE- VERSUS POST-ENHANCEMENT COMPARISONS

Comparisons of pre- and post-enhancement habitat and fish are presented below to identify evidence of habitat changes due to enhancement and any changes to fish resources that may have resulted.

4.1 HABITAT VARIABLES

4.1.1 SUMMARY STATISTICS

Comparisons of a subset of reach level statistics for Whatshan W3.2 and Barnes B3 in 2006, 2007, and 2008 versus 2010, 2012, and 2015 are provided below in Table 16 and Table 17. The reach level values will help to interpret any response variable changes that are found to be significant in statistical comparisons.

Table 16. Comparison of reach-level habitat characteristics of Whatshan River Reach W3.2 in late summer/early fall pre-enhancement (2006, 2007, 2008) and post-enhancement (2010, 2012, 2015).

	Pre-W3.2 Habitat Enhancement			Post-W3.2 Habitat Enhancement		
Characteristic	2006	2007	2008	2010	2012	2015
Reach Length (m)	1,380	1,380	1,380	1,380	1,380	1,380
Number of Habitat Units: Total	37	37	35	40	44	54
glide	13	14	14	10	15	18
pool	7	7	5	10	11	15
riffle	11	12	13	16	17	19
side/backchannel	6	4	3	4	1	2
Habitat Area (m^2): Total	22,714	22,014	23,400	22,294	20,840	20,246
glide	6,549	6,474	9,225	6,910	9,046	6,420
pool	3,553	3,467	2,201	3,249	2,669	4,194
riffle	10,769	11,186	11,318	11,485	8,634	9,340
side/backchannel	1,843	877	656	650	491	292
Total Spawning Gravel Area (m^2)	157	264	157	644	549	724
Total Cover (m^2) (excl. deep pool)	836	1,199	1,036	1,419	1,283	1,802
Large Woody Debris Cover (m^2)	179	119	104	358	383	576
Average Wetted Width (m)	13.0 (SD=5.2)	12.7 (SD=5.0)	13.3 (SD=5.5)	12.8 (SD=5.2)	12.6 (SD=4.0)	12.5 (SD=4.1)
Average Depth[a] (m)	0.32 (SD=.18)	0.33 (SD=.17)	0.36 (SD=.20)	0.37 (SD=.25)	0.41 (SD=.22)	0.39 (SD=.22)
Average Max. Pool Depth[b] (m)	0.93 (SD=.12)	0.96 (SD=.15)	1.07 (SD=.22)	1.03 (SD=.18)	1.06 (SD=.17)	1.00 (SD=.16)

[a] From habitat unit measurements at ¼, ½, and ¾ of wetted width.
[b] From individual maximum depth measurements in each pool.
Means not weighted (e.g., by habitat length or area)
Habitat enhancement in Reach W3.2 was conducted in summer of 2009.

Table 17. Comparison of reach-level habitat characteristics of Barnes Creek Reach B3 in late summer/early fall pre- and post-enhancement of Whatshan Reach W3.2 in 2009.

	Pre-W3.2 Habitat Enhancement			Post-W3.2 Habitat Enhancement		
Characteristic	2006	2007	2008	2010	2012	2015
Reach Length (m)	1,245	1,245	1,245	1,245	1,245	1,245
Number of Habitat Units: Total	72	63	64	61	72	67
glide	23	21	20	23	26	21
pool	19	14	15	9	15	15
riffle	26	23	23	23	24	21
side/backchannel	4	5	6	6	7	10
Habitat Area (m^2): Total	13,228	13,265	15,701	15,822	16,772	15,811
glide	4,228	4,480	5,783	5,975	7,547	4,382
pool	3,573	2,908	3,077	1,349	2,719	2,813
riffle	5,167	5,119	6,070	7,591	5,692	6,506
side/backchannel	261	757	771	908	815	2,110
Total Spawning Gravel Area (m^2)	94	288	200	127	193	265
Total Cover (m^2) (excl. deep pool)	1,547	1,848	1,493	1,443	1,461	1,573
Large Woody Debris Cover (m^2)	880	788	397	459	669	551
Average Wetted Width (m)	7.9 (SD=3.1)	7.4 (SD=2.9)	8.5 (SD=3.6)	8.0 (SD=3.0)	7.4 (SD=2.9)	8.5 (SD=3.6)
Average Depth[a] (m)	0.43 (SD=.22)	0.38 (SD=.23)	0.39 (SD=.24)	0.36 (SD=.23)	0.35 (SD=.22)	0.36 (SD=.24)
Average Max. Pool Depth[b] (m)	1.06 (SD=.22)	1.06 (SD=.21)	1.07 (SD=.22)	1.07 (SD=.19)	1.05 (SD=.21)	1.06 (SD=.22)

[a] From habitat unit measurements at ¼, ½, and ¾ of wetted width.
[b] From individual maximum depth measurements in each pool.
Means not weighted (e.g., by habitat length or area)

4.1.2 SIMPLE BEFORE VERSUS AFTER COMPARISONS

Before versus after statistical comparisons for each stream reach were made for habitat unit measurements of width, length, area, depth, substrate, cover, and number of units. While these changes may represent only temporal changes, they are still useful if a BACI effect is detected as this would indicate a differential change between the impact and control sites. The estimates presented here are useful in trying to interpret such a differential change.

In Whatshan W3.2, there were significant changes in five response variables while, in Barnes B3, there were significant changes in three variables (Table 18). Except for number of riffles, the variables with significant changes in Reach W3.2 reflected the objective of improving habitat for Rainbow Trout, namely increased cover, spawn gravel area, depth, and number of pools. In B3, the increase in total length of all habitat units is attributed to multiple channels forming or being rewetted within the wide floodplain, whereas the narrow W3.2 floodplain inhibits the formation of multiple channels.

Table 18. Response variables in Whatshan Reach W3.2 and Barnes Reach B3 with significant changes between pre-enhancement (2006-2008) and post-enhancement (2010-2015) conditions.

Reach	Variable	Estimated Change in Mean[a]	Standard Error of Change in Mean	P-value
W3.2	large woody debris (m^2)	304	72	0.0138
	spawn gravel area (m^2)	446	62	0.0020
	average depth (m)	0.05	0.015	0.0384
	number of pools	5.7	1.67	0.0273
	number of riffles	5.3	1.05	0.0072
B3	average depth - weighted (m)	-0.05	0.016	0.0321
	% area of fines (sand, silt)	2.9	0.82	0.0228
	total length of all habitat units (m)	293	101	0.0442

[a] Post- minus Pre-Enhancement.

4.1.3 BACI (BEFORE-AFTER CONTROL-IMPACT)

Although the simple before versus after comparisons indicated that significant improvements had occurred in key habitat variables (cover, spawn gravel area, depth, number of pools) for Rainbow Trout in Reach W3.2 following enhancement, a BACI comparison was required to try to separate naturally-occurring changes from those resulting from enhancement activity. The same habitat unit measurements of width, length, area, depth, substrate, cover, and number of units were compared for their differential change between the enhanced and control reaches.

The BACI comparisons increased the number of variables with significant changes between the pre- and post-enhancement periods. The significant differences were consistent with the habitat enhancement objectives and predictions for Reach W3.2, with increased depth, total cover, spawn gravel area, and number of pools, and decreased wetted area and side channel habitat (Table 19).

Table 19. Response variables with significant changes in BACI comparison

Variable	Estimate of Differential Change[a]	Standard Error	P-value
average depth (m)	0.09	0.024	0.0063
average depth – weighted (m)	0.10	0.021	0.0022
% area of fines (sand, silt)	-2.3	0.98	0.0481
total area of all habitat units (m^2)	-3,653	910	0.0164
total cover area (m^2)	615	141	0.0120
riffle area (m^2)	-2,415	418	0.0041
spawn gravel area (m^2)	445	57	0.0015
total length of all habitat units (m)	-458	124	0.0060
total length of riffles (m)	-134	43	0.0358
total length of side/back channel (m)	-355	142	0.0374
number of pools	8.7	2.11	0.0147
number of riffle units	6.7	1.70	0.0044
number of side/back channel units	-4.7	1.83	0.0339

[a] Post-enhancement minus Pre-enhancement.

4.2 FISH SIZE

Fish size was of interest in light of the enhancement project hypotheses that habitat enhancement would increase Rainbow Trout size and would not negatively affect density or size of other fish species. An increase in Rainbow Trout length or condition in W3.2 relative to the control reach B3 would be a possible indication that habitat enhancement was having a beneficial effect.

Size comparisons of fish pre- and post-enhancement were based primarily on juvenile/adult fish, as fry size can vary considerably from year to year depending on emergence timing that is affected by water temperature. Furthermore, fish condition values for fry, especially Sculpin and Longnose Dace, were considered unreliable due to low precision (0.1 g) in relation to total fish weight of 0.0-0.5 g.

Average water temperature tended to be higher in W3.2 than B3 (2 degrees higher in 2015) during the sampling period of later summer, potentially resulting in faster growth in W3.2. The higher W3.2 temperature may have been partly an artifact of the sampling program, which always started with W3.2 and ended with B3 as temperatures were declining. However, water in W3.2 had approximately 1 km of stream in which to warm up (e.g., from solar radiation) after leaving B3. Fish length did tend to be slightly greater in W3.2 than in B3 (Figure 8 through Figure 10), consistent with a higher water temperature in W3.2.

Overall mean fork length of juvenile/adult Rainbow Trout in the enhancement reach W3.2 was relatively constant pre- and post-enhancement except for a jump in 2008 (Table 20,

Figure 8). Conversely, overall mean length in Reach B3 was also relatively constant pre- and post-enhancement except for a drop in 2008. Length of juvenile/adult Eastern Brook Trout and Longnose Dace have stayed relatively constant in Whatshan W3.2 and Barnes B3 over the study period, while length of juvenile/adult Slimy Sculpin has stayed very constant.

Average pre- and post-enhancement lengths of juvenile/adult Rainbow Trout, Eastern Brook Trout, Slimy Sculpin, and Longnose Dace are provided below in Table 20 through Table 23, while plots of the trends in length of the same species, weighted by segment effects, are shown in Figure 8 through Figure 11.

Table 20. Mean fork length by habitat type for juvenile/adult Rainbow Trout in Whatshan Reach W3.2 and Barnes Reach B3 pre- and post-enhancement.

		Rainbow Trout Mean Fork Length (mm) by Habitat					S.D.	n
W3.2	Year	Glide	Pool	Riffle	Channel	**ALL**		
Pre-	2006	117	115	124	128	**117**	30	114
Pre-	2007	110	125	127	121	**122**	28	94
Pre-	2008	137	157	120	125	**143**	42	114
Post-	2010	119	124	116	107	**120**	29	113
Post-	2012	123	131	120	---	**127**	33	209
Post-	2015	121	120	116	91	**119**	27	123
B3	Year	Glide	Pool	Riffle	Channel	**ALL**		n
Pre-	2006	110	129	116	88	**124**	30	87
Pre-	2007	151	117	115	100	**117**	29	71
Pre-	2008	103	110	99	106	**106**	23	65
Post-	2010	127	116	106	119	**118**	27	71
Post-	2012	106	126	117	---	**118**	34	112
Post-	2015	123	117	118	---	**119**	27	93

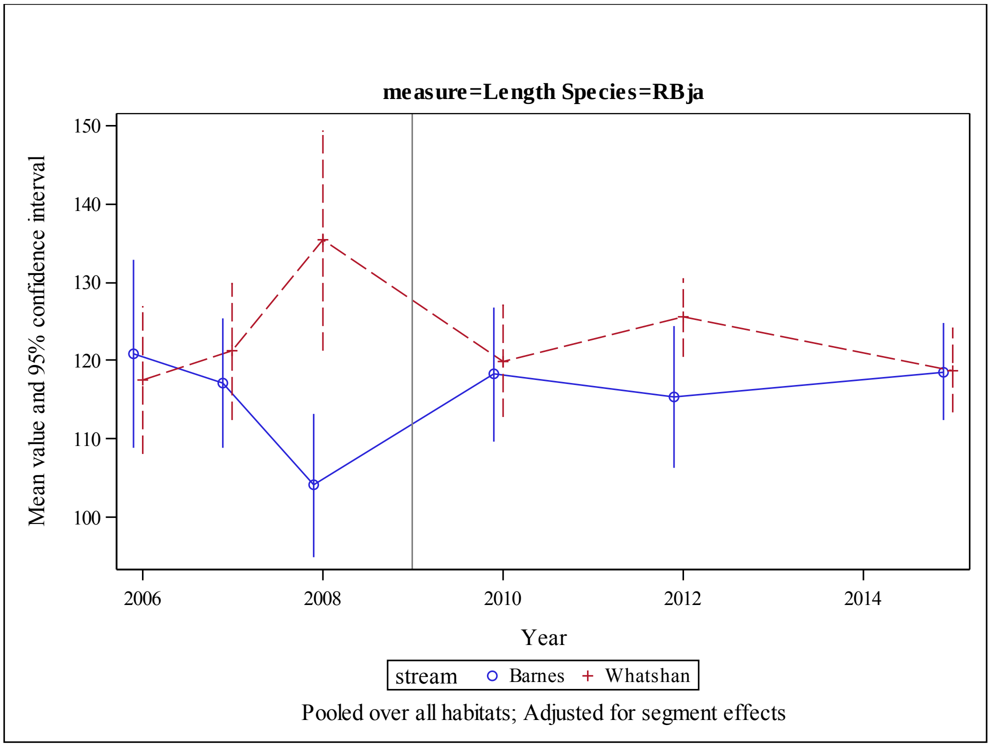


Figure 8. Trends in fork length of juvenile/adult Rainbow Trout in Whatshan Reach W3.2 and Barnes Reach B3 pre- and post-enhancement in W3.2. Vertical line separates pre- from post-enhancement periods

Table 21. Mean fork length by habitat type for juvenile/adult Eastern Brook Trout in Whatshan Reach W3.2 and Barnes Reach B3 pre- and post-enhancement.

		Brook Trout Mean Fork Length (mm) by Habitat Type					S.D.	n
W3.2	Year	Glide	Pool	Riffle	Channel	**ALL**		
Pre-	2006	117	---	---	---	**117**	---	1
Pre-	2007	159	159	---	---	**159**	26	7
Pre-	2008	154	168	121	---	**146**	39	14
Post-	2010	145	174	151	---	**156**	34	25
Post-	2012	136	159	142	---	**152**	33	27
Post-	2015	145	150	155	---	**149**	26	43
B3	Year	Glide	Pool	Riffle	Channel	**ALL**		n
Pre-	2006	---	190	---	---	**190**	52	4
Pre-	2007	---	205	---	125	**178**	74	3
Pre-	2008	140	157	233	120	**159**	51	11
Post-	2010	160	138	166	149	**152**	33	17
Post-	2012	133	130	140	---	**135**	27	36
Post-	2015	156	153	144	147	**152**	33	37

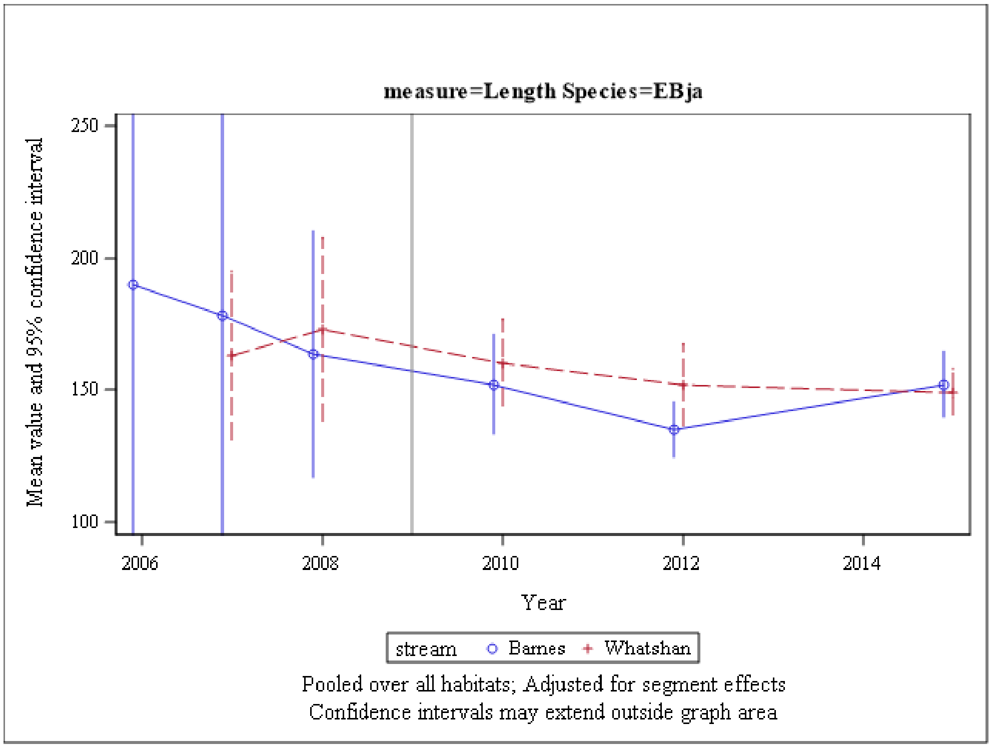


Figure 9. Trends in fork length of juvenile/adult Eastern Brook Trout in Whatshan Reach W3.2 and Barnes Reach B3 pre- and post-enhancement in W3.2.

Table 22. Mean total length by habitat type for juvenile/adult Slimy Sculpin in Whatshan Reach W3.2 and Barnes Reach B3 pre- and post-enhancement.

		Slimy Sculpin Mean Total Length (mm) by Habitat					S.D.	n
W3.2	Year	Glide	Pool	Riffle	Channel	**ALL**		
Pre-	2006	60	61	58	56	**59**	11	1167
Pre-	2007	65	66	67	64	**66**	10	665
Pre-	2008	59	62	60	53	**60**	8	1049
Post-	2010	65	67	67	60	**66**	11	762
Post-	2012	66	64	65	58	**65**	12	786
Post-	2015	59	62	62	59	**61**	10	1401
B3	Year	Glide	Pool	Riffle	Channel	**ALL**	S.D.	n
Pre-	2006	61	64	62	64	**62**	12	544
Pre-	2007	67	64	67	61	**66**	10	714
Pre-	2008	60	63	59	62	**60**	12	616
Post-	2010	63	65	67	52	**64**	11	413
Post-	2012	61	62	62	---	**62**	10	889
Post-	2015	58	58	59	60	**59**	11	865

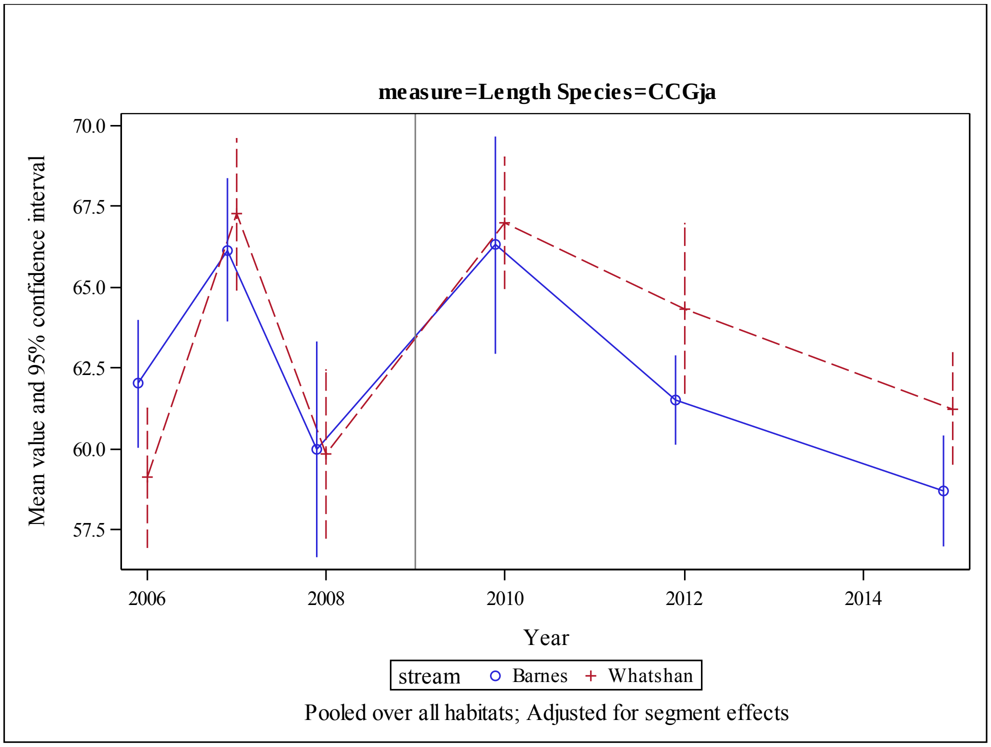


Figure 10. Trends in total length of juvenile/adult Slimy Sculpin in Whatshan Reach W3.2 and Barnes Reach B3 pre- and post-enhancement in W3.2.

Table 23. Mean fork length by habitat type for juvenile/adult Longnose Dace in Whatshan Reach W3.2 pre- and post-enhancement.

		Longnose Dace Mean Fork Length (mm) by Habitat					S.D.	n
W3.2	Year	Glide	Pool	Riffle	Channel	**ALL**		
Pre-	2006	80	80	85	88	**82**	20	99
Pre-	2007	74	87	80	65	**78**	16	35
Pre-	2008	72	78	71	---	**72**	13	43
Post-	2010	69	71	63	---	**67**	12	84
Post-	2012	71	83	83	---	**77**	15	79
Post-	2015	74	78	77	---	**77**	13	86

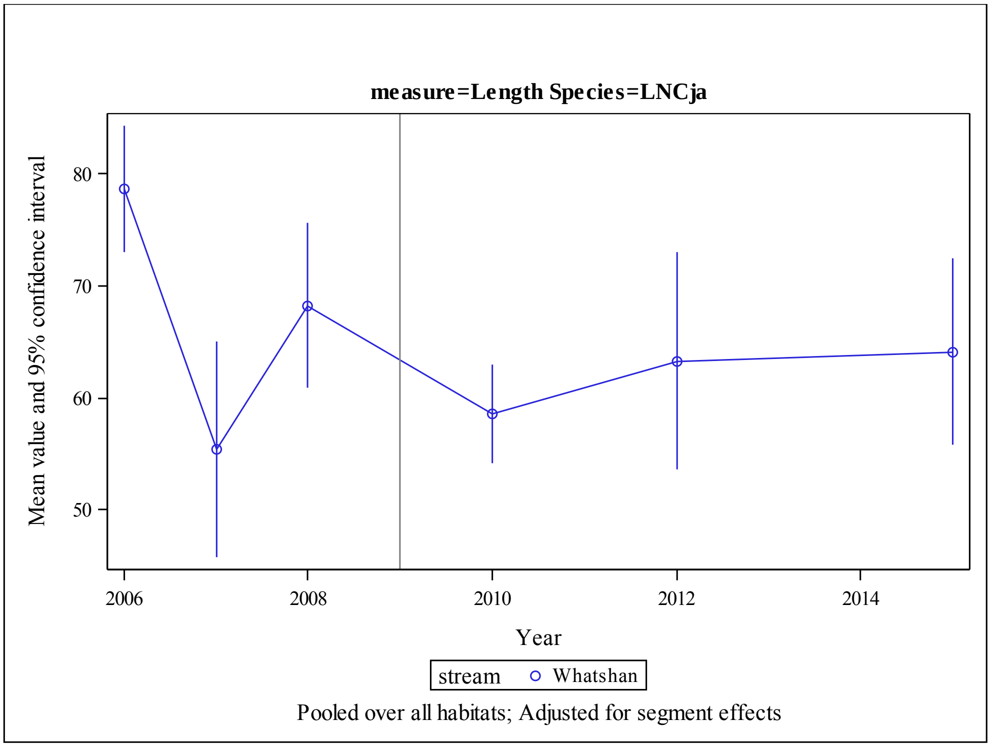


Figure 11. Trends in fork length of juvenile/adult Longnose Dace in Whatshan Reach W3.2 pre- and post-enhancement in W3.2.

4.2.1 BACI (Before-After Control-Impact)

Comparisons of the differential changes in fish length and condition between the enhanced and control reaches are presented below in Table 24 and Table 25. No BACI comparison was possible for Longnose Dace because this species was only present in Reach W3.2.

There were significant differences in mean length of Sculpin fry, Brook Trout fry, and juvenile/adult Rainbow Trout, and in condition factor of juvenile/adult Eastern Brook Trout. The differences in length of Sculpin (+3 mm) and Brook Trout (-5 mm) fry were in the range of 10% and not considered significant because they may be artifacts of earlier emergence timing and subsequent early growth in W3.2 due to higher water temperature. The difference in length of juvenile/adult Rainbow Trout (-10 mm or 10%) may be due to differentially higher harvest of larger Rainbow Trout in W3.2.

Table 24. Estimate of BACI effect comparing differential change in mean length between before and after periods at Whatshan W3.2 and Barnes B3.

Species	Differential Change (W3.2 vs B3)	SE	p-value
CCGf	**3.19**	**0.97**	0.0010
CCGja	1.75	0.91	0.0556
EBf	**-4.82**	**2.18**	0.0271
EBja	14.30	12.08	0.2385
RBf	-0.84	1.48	0.5719
RBja	-10.39	4.86	0.0325

Values bolded where a BACI effect was detected.

Table 25. Estimate of BACI effect comparing differential change in mean condition factor between before and after periods at Whatshan W3.2 and Barnes B3.

Species	Differential Change (W3.2 vs B3)	SE	p-value
CCGf	-0.10	0.10	0.3377
CCGja	0.00	0.02	0.8085
EBf	-0.00	0.03	0.9441
EBja	**0.12**	**0.04**	0.0020
RBf	-0.02	0.03	0.6250
RBja	-0.02	0.01	0.1717

Values bolded where a BACI effect was detected.

4.3 FISH POPULATION AND BIOMASS

The goal of fish habitat enhancement in Whatshan Reach W3.2 was to increase the abundance or biomass of Rainbow Trout. Whether such an increase would occur at the expense of other fish species was also of interest. The estimated abundances of fish by species and life stage in Whatshan Reach W3.2 and Barnes Reach B3 pre- and post-enhancement are presented below in Table 26.

Table 26. Estimated abundance of fish by species and life stage in Whatshan Reach W3.2 and Barnes Reach B3 pre- and post-enhancement.

	Pre-Enhancement			Post-Enhancement		
W3.2	2006	2007	2008	2010	2012	2015
CCGf	176	9596	304	2366	953	1376
CCGja	18625	9848	12782	8084	9623	11723
EBf	154	363	226	290	608	1315
EBja	12	42	39	198	140	284
LNCf	214	57	714	17	434	194
LNCja	1214	3594	1126	1984	1468	1415
RBf	870	2383	244	2721	848	1510
RBja	868	713	617	904	1397	864
B3	2006	2007	2008	2010	2012	2015
CCGf	617	4732	205	970	62	1962
CCGja	10814	8394	8106	5982	12653	14033
EBf	41	397	191	530	533	964
EBja	24	24	76	218	291	535
RBf	709	1372	668	986	1092	826
RBja	715	546	485	663	1009	833

Refer to Table 7 for species code definitions; f= fry, ja= juvenile/adult.

There was considerable variability in estimates of abundance/density/biomass/biomass-density over the six years. An initial analysis examined if these observed changes were larger than expected given the precision (the SE) of each estimate in each year. A variant of a single factor ANOVA was used to examine if there were changes in the parameters over time. Because of the high variability in the individual habitat types, only the results from the analysis of the parameters for the entire creek (i.e., all habitat types) are reported in Table 27 and Table 28. Similar tables were produced for biomass and biomass density. In many cases, there was evidence that abundance or biomass has changed over time, but these tables do not indicate if the changes are regular (e.g. a general decline), or a step change (e.g. pre- vs. post-construction), or just due to irregular year-to-year effects (e.g., weather).

Table 27. Summary of evidence of changes in Abundance over time in Whatshan Reach W3.2 and Barnes Reach B3.

W3.2		2006		2007		2008		2010		2012		2015		Omnibus test
Species	Habitat	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	
CCGf	All	176	35	9596	4858	304	97	2366	714	953	320	1376	273	<.0001
CCGja	All	18625	3810	9848	2011	12782	1597	8084	1537	9623	1170	11723	2135	0.1058
EBf	All	154	24	363	64	226	51	290	84	608	106	1315	172	<.0001
EBja	All	12	7	42	18	39	27	198	48	140	58	284	62	<.0001
LNCf	All	214	87	57	27	714	441	17	12	434	178	194	59	0.0042
LNCja	All	1214	464	3594	1137	1126	335	1984	516	1468	231	1415	574	0.3488
RBf	All	870	49	2383	500	244	70	2721	378	848	140	1510	139	<.0001
RBja	All	868	194	713	258	617	98	904	131	1397	181	864	158	0.0252

The Omnibus Test is the p-value for evidence of a year effect, regardless of where it occurred.

B3		2006		2007		2008		2010		2012		2015		Omnibus test
Species	Habitat	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	
CCGf	All	617	316	4732	1785	205	81	970	417	62	20	1962	647	0.0016
CCGja	All	10814	1968	8394	1460	8106	1090	5982	1629	12653	1536	14033	3701	0.0508
EBf	All	41	15	397	45	191	48	530	103	533	57	964	252	<.0001
EBja	All	24	9	24	13	76	19	218	86	291	64	535	230	0.0003
LNCf	All	0	1	0	1	0	1	0	1	0	1	0	1	1.0000
LNCja	All	0	1	0	1	0	1	0	1	0	1	0	1	1.0000
RBf	All	709	175	1372	256	668	176	986	306	1092	164	826	137	0.1884
RBja	All	715	183	546	177	485	150	663	171	1009	181	833	133	0.2700

The Omnibus Test is the p-value for evidence of a year effect, regardless of where it occurred.

Table 28. Summary of evidence of changes in density over time in Whatshan Reach W3.2 and Barnes Reach B3.

W3.2		2006		2007		2008		2010		2012		2015		Omnibus test
Species	Habitat	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	
CCGf	All	0.8	0.2	43.6	22.1	1.3	0.4	10.6	3.2	4.6	1.5	6.8	1.3	<.0001
CCGja	All	82.0	16.8	44.8	9.1	54.6	6.8	36.3	6.9	46.2	5.6	57.9	10.5	0.1405
EBf	All	0.7	0.1	1.7	0.3	1.0	0.2	1.3	0.4	2.9	0.5	6.5	0.8	<.0001
EBja	All	0.1	0.0	0.2	0.1	0.2	0.1	0.9	0.2	0.7	0.3	1.4	0.3	<.0001
LNCf	All	0.9	0.4	0.3	0.1	3.1	1.9	0.1	0.1	2.1	0.9	1.0	0.3	0.0039
LNCja	All	5.3	2.0	16.3	5.2	4.8	1.4	8.9	2.3	7.0	1.1	7.0	2.8	0.2784
RBf	All	3.8	0.2	10.8	2.3	1.0	0.3	12.2	1.7	4.1	0.7	7.5	0.7	<.0001
RBja	All	3.8	0.9	3.2	1.2	2.6	0.4	4.1	0.6	6.7	0.9	4.3	0.8	0.0078

The Omnibus Test is the p-value for evidence of a year effect, regardless of where it occurred.

B3		2006		2007		2008		2010		2012		2015		Omnibus test
Species	Habitat	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	
CCGf	All	4.7	2.4	35.7	13.5	1.3	0.5	6.1	2.6	0.4	0.1	12.4	4.1	0.0014
CCGja	All	81.7	14.9	63.3	11.0	51.6	6.9	37.8	10.3	75.4	9.2	88.8	23.4	0.0500
EBf	All	0.3	0.1	3.0	0.3	1.2	0.3	3.3	0.6	3.2	0.3	6.1	1.6	<.0001
EBja	All	0.2	0.1	0.2	0.1	0.5	0.1	1.4	0.5	1.7	0.4	3.4	1.5	0.0007
LNCf	All	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0000
LNCja	All	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0000
RBf	All	5.4	1.3	10.3	1.9	4.3	1.1	6.2	1.9	6.5	1.0	5.2	0.9	0.1626
RBja	All	5.4	1.4	4.1	1.3	3.1	1.0	4.2	1.1	6.0	1.1	5.3	0.8	0.3866

The Omnibus Test is the p-value for evidence of a year effect, regardless of where it occurred.

A more focused comparison of the average abundances/densities in the pre-construction period (2006 to 2008) and the post-construction period (2010 to 2015) is reported in Table 29 and Table 30. Because of the strong relationship between the SE and the estimate of total abundance and total biomass, the comparison was done after a logarithmic transform was applied. In this case, the estimate of the difference in means (After-Before) has a simple interpretation; that is, a difference of 0.10 (After-Before) on the log-scale corresponds to an approximate 10% increase in mean abundance or mean biomass in the after period compared to the mean abundance or mean biomass in the before period. The pre- versus post-construction changes in log(abundance) for each species are shown graphically in Figure 12 through Figure 15.

Most of the changes in mean abundance or mean biomass were positive (i.e., the mean abundance or mean biomass in the after period was larger than the mean abundance or biomass in the before period), but there was evidence of an effect only for juvenile/adult Eastern Brook Trout in both creeks. The key reason why differences in means were not detected between the before and after periods is the large year-to-year variation in each period that is much larger than expected given the uncertainty in the estimates. As noted previously, this year-to-year variability may be related to year-specific effects (e.g., weather). A generic term for this source of variability is process error to distinguish it from variability introduced by sampling.

Table 29. Focused comparison of Before/After mean log(abundance) in Whatshan Reach W3.2 and Barnes Reach B3. Before period is 2006 to 2008 and after period is 2010 to 2015.

W3.2	log (Abundance)								
Species	2006	2007	2008	2010	2012	2015	After-Before	SE(A-B)	p-value
CCGf	5.17	9.17	5.72	7.77	6.86	7.23	0.60	1.28	0.6636
CCGja	9.83	9.19	9.46	9.00	9.17	9.37	-0.31	0.21	0.2151
EBf	5.03	5.90	5.42	5.67	6.41	7.18	0.97	0.50	0.1254
EBja	2.45	3.74	3.68	5.29	4.94	5.65	2.01	0.47	**0.0128**
LNCf	5.37	4.04	6.57	2.83	6.07	5.27	-0.60	1.22	0.6469
LNCja	7.10	8.19	7.03	7.59	7.29	7.26	-0.06	0.39	0.8878
RBf	6.77	7.78	5.50	7.91	6.74	7.32	0.64	0.74	0.4337
RBja	6.77	6.57	6.42	6.81	7.24	6.76	0.35	0.18	0.1271
ALL	10.00	10.19	9.68	9.72	9.65	9.84	-0.23	0.16	0.2237

B3	log (Abundance)								
Species	2006	2007	2008	2010	2012	2015	After-Before	SE(A-B)	p-value
CCGf	6.42	8.46	5.32	6.88	4.13	7.58	-0.54	1.40	0.7189
CCGja	9.29	9.04	9.00	8.70	9.45	9.55	0.12	0.28	0.6883
EBf	3.71	5.98	5.25	6.27	6.28	6.87	1.49	0.70	0.0994
EBja	3.20	3.16	4.34	5.38	5.67	6.28	2.22	0.47	**0.0091**
RBf	6.56	7.22	6.50	6.89	7.00	6.72	0.10	0.24	0.6906
RBja	6.57	6.30	6.18	6.50	6.92	6.72	0.36	0.17	0.0977
ALL	9.47	9.65	9.18	9.14	9.66	9.86	0.12	0.25	0.6551

Table 30. Focused comparison of Before/After mean density in Whatshan Reach W3.2 and Barnes Reach B3.

W3.2	Mean Density (fish/100m^2)								
Species	2006	2007	2008	2010	2012	2015	After-Before	SE(A-B)	p-value
CCGf	0.78	43.61	1.30	10.61	4.58	6.79	-7.90	14.30	0.6101
CCGja	82.00	44.76	54.62	36.26	46.18	57.90	-13.68	12.78	0.3445
EBf	0.68	1.65	0.97	1.30	2.92	6.50	2.47	1.56	0.1883
EBja	0.05	0.19	0.17	0.89	0.67	1.40	0.85	0.22	**0.0186**
LNCf	0.94	0.26	3.05	0.08	2.08	0.96	-0.38	1.02	0.7294
LNCja	5.35	16.34	4.81	8.90	7.04	6.99	-1.19	3.81	0.7709
RBf	3.83	10.83	1.04	12.21	4.07	7.46	2.68	3.75	0.5144
RBja	3.82	3.24	2.64	4.06	6.70	4.27	1.78	0.92	0.1244
ALL	97.45	120.87	68.60	74.31	74.24	92.27	-15.37	16.26	0.3982

Before period is 2006 to 2008; after period is 2010 to 2015

B3	Mean Density (fish/100m^2)								
Species	2006	2007	2008	2010	2012	2015	After-Before	SE(A-B)	p-value
CCGf	4.66	35.68	1.31	6.13	0.37	12.41	-7.58	11.48	0.5452
CCGja	81.75	63.29	51.62	37.81	75.44	88.76	1.78	17.60	0.9242
EBf	0.31	2.99	1.21	3.35	3.18	6.10	2.70	1.23	0.0930
EBja	0.18	0.18	0.49	1.38	1.73	3.38	1.88	0.63	**0.0398**
RBf	5.36	10.34	4.26	6.23	6.51	5.23	-0.66	1.91	0.7462
RBja	5.41	4.11	3.09	4.19	6.02	5.27	0.96	0.85	0.3264
ALL	97.67	116.59	61.98	59.09	93.25	121.14	-0.92	24.05	0.9713

It is important to distinguish process and sampling error because this has implications on the performance of a monitoring plan. Increasing effort in a year (e.g., by sampling more segments) will reduce sampling error, but has no effect on process error. Even if a census was done on every year (so the exact abundance was known and there was no sampling error), the abundances would still vary from year to year because of this process error. The process error is often the limiting factor that affects the ability to detect difference in the mean response over time. Estimates of sampling and process error are shown in Table 31 and Table 32. Generally speaking, process error is the major component of year-to-year variability in log(Abundance) and log(Biomass) except for estimates of RBja in both creeks.

The estimates of process and sampling error can then be used to estimate the power to detect a 20% increase in Abundance, Density, Biomass, or Biomass-Density between the two periods (i.e., the mean abundance in the after period is at least 20% higher than the mean abundance in the before period). If the analysis is performed on the log-scale (for abundance), this is equivalent to testing that the difference (on the log scale) in the mean log-abundance between the two periods is at least 0.20. From Table 29, the observed differences already exceed 0.20, except for Slimy Sculpin juvenile/adults and Rainbow Trout fry in Barnes Creek, and juvenile/adult Longnose Dace in Whatshan River. Unfortunately, in many cases the uncertainty (i.e., the SE of the difference) was large enough that the changes were not statistically significant.

Table 31. Estimates of sampling and process error in log(Abundance) and % of total variation due to process error for Whatshan Reach W3.2.

Species	Habitat	Sampling SD	Process SD	%Process Error
CCGf	All	0.33	1.53	96
CCGja	All	0.17	0.20	55
EBf	All	0.20	0.58	90
EBja	All	0.47	0.32	32
LNCf	All	0.50	1.40	89
LNCja	All	0.31	0.36	57
RBf	All	0.18	0.89	96
RBja	All	0.22	0.06	7

Table 32. Estimates of sampling and process error in log(Abundance) and % of total variation due to process error for Barnes Reach B3.

Species	Habitat	Sampling SD	Process SD	%Process Error
CCGf	All	0.40	1.66	95
CCGja	All	0.20	0.28	67
EBf	All	0.24	0.82	92
EBja	All	0.39	0.42	54
RBf	All	0.23	0.19	42
RBja	All	0.25	0.00	0

A forward projection was made to estimate the total number of years post-construction needed to detect a 20% increase in mean Abundance/Density/Biomass/Biomass-density assuming that the process and sampling errors remain at their current values and the results are presented in Table 33 and Table 34. The results are highly discouraging. Essentially, it will be impossible to detect a 20% increase except for juvenile/adult Eastern Brook Trout (where a change larger than this has already been detected). Table 29 and Table 30 indicate that the change in log(Abundance) and density of juvenile/adult Brook Trout has already occurred.

Table 33. Estimated number of years post-construction needed for monitoring to have 80% power of detecting a 20% increase in Density or log(Abundance).

		Density		log(Abundance)	
		Barnes	Whatshan	Barnes	Whatshan
Species	Habitat	Years Post-Construction	Years Post-Construction	Years Post-Construction	Years Post-Construction
CCGf	All	.	.	.	.
CCGja	All	.	.	15	3
EBf	All	.	.	.	.
EBja	All	.	40	.	.
LNCf	All	.	.	.	.
LNCja	All	.	.	.	.
RBf	All	.	.	4	.
RBja	All	.	.	1	2

Blank entries indicate no amount of monitoring will have sufficient power to detect this effect.

Table 34. Estimated number of years post-construction needed for monitoring to have 80% power of detecting a 20% increase in Biomass-Density or log(Biomass).

		Biomass Density		log(Biomass)	
		Barnes	Whatshan	Barnes	Whatshan
Species	Habitat	Years Post-Construction	Years Post-Construction	Years Post-Construction	Years Post-Construction
CCGf	All	.	.	.	.
CCGja	All	.	.	2	1
EBf	All	.	.	.	.
EBja	All	.	.	.	.
LNCf	All	.	.	.	.
LNCja	All	.	.	.	3
RBf	All	.	.	.	.
RBja	All	.	.	13	3

Blank entries indicate no amount of monitoring will have sufficient power to detect this effect.

Why is this targeted power impossible to reach in most cases? Consider the values from Table 29 for Rainbow Trout fry (RBf) in Barnes Creek. The three years of pre-construction monitoring have log-abundances of 6.56, 7.22, and 6.50 (i.e., they vary by a factor of over 2× in actual abundances (Table 27)). The mean log-abundance prior to construction is 6.76 and a 95% confidence is 6.08 to 7.28. A 20% increase in mean log-abundance would raise the mean to 6.96 = 6.76 + 0.20 which is still inside the 95% confidence interval so even if the post-construction mean was known exactly and had really increased by 20%, it is not possible to detect it.

The power analysis can also be inverted to determine what size of difference is detectable given 3 years pre- and 3 year post-construction monitoring assuming that sampling and process error remain as is and the results are reported in Table 35 and Table 36. Not unexpectedly, process error is so large for most species in both creeks that only large differences will be detectable except for the non-missing corresponding entries in Table 33.

The major reason for the inability to detect reasonably size differences for most species except RBja is the very large process error (refer to Table 31 and Table 32). This gives rise to very large changes in abundance and density across years which are unpredictable, and no amount of sampling will smooth these fluctuations. For example, if the process variation is 90% of the total variation, then a complete census (i.e., no sampling error) will only reduce the standard deviation of the total error by about 5%. If the cause of the year-to-year fluctuation is suspected (e.g., different water temperatures) this could be used as a covariate to remove some of the year-to-year variations and improve power, but the relationship must be fairly strong. If the year-to-year fluctuations are the result of changes in sampling protocols (e.g., different times of the year), then some standardization would be in order.

Table 35. Estimated % changes in Abundance and Density detectable with 3 years pre- and post-monitoring if process and sampling error don't change.

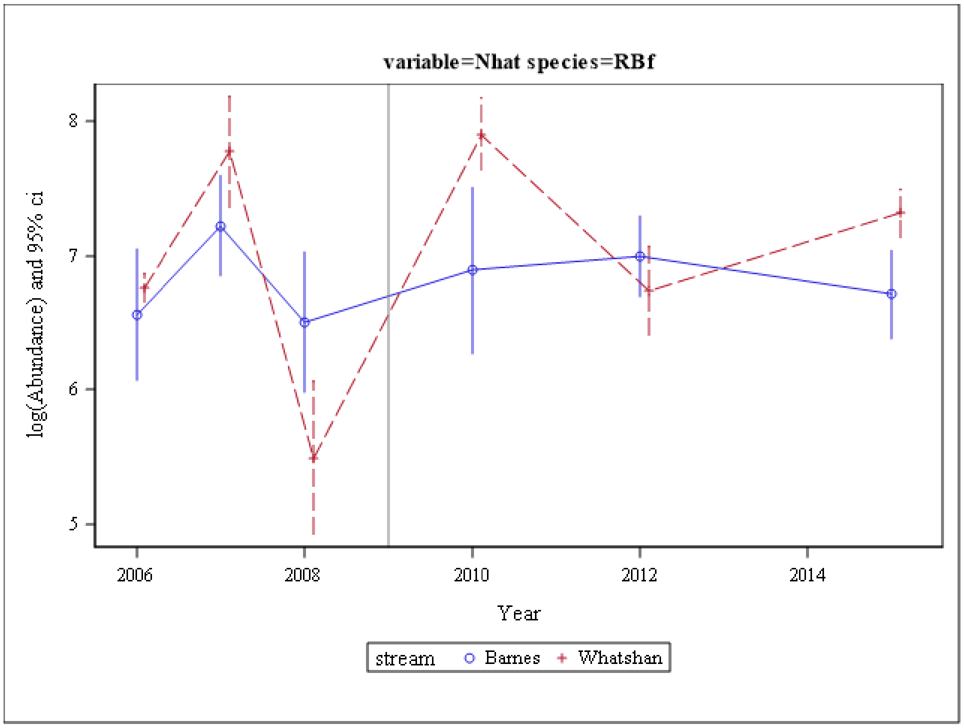
		Density		Abundance	
		Barnes	Whatshan	Barnes	Whatshan
Species	Habitat	% Detectable difference	% Detectable difference	% Detectable difference	% Detectable difference
CCGf	All	4861	6752	727	609
CCGja	All	1735	1133	30	17
EBf	All	198	389	181	94
EBja	All	119	33	82	82
LNCf	All	.	316	.	551
LNCja	All	.	655	.	57
RBf	All	215	796	22	204
RBja	All	58	76	10	12

Table 36. Estimated % changes in Biomass and Biomass-Density detectable with 3 years pre- and post-monitoring if process and sampling error don't change.

		Biomass		Biomass Density	
		Barnes	Whatshan	Barnes	Whatshan
Species	Habitat	% Detectable difference	% Detectable difference	% Detectable difference	% Detectable difference
CCGf	All	1551	2394	771	612
CCGja	All	2637	1027	15	5
EBf	All	1445	1562	212	82
EBja	All	6848	1041	70	101
LNCf	All	.	188	.	1288
LNCja	All	.	647	.	19
RBf	All	848	1840	62	219
RBja	All	2381	2579	29	18

The current analysis assumed a step change between the pre- and post-construction periods, (i.e., there is an immediate increase in mean abundance/density which then remains fixed (subject to year-to-year variability). If the effect of the construction is compounded (e.g., a 10% increase in the first year, a 10%+10% in the second year, etc.), then regression methods would be more appropriate, but the results from Table 35 and Table 36 still give a general idea of the size of the compounded difference needed to exist before being detectable in the short term. In the case of compounded increases, the number of years of post-construction monitoring is the most important predictor of power to detect a trend.

The study design called for habitat enhancement in Whatshan Reach W3.2, with Barnes Reach B3 as a control. Plots of log(abundance over) time for all species and life stages in the two reaches are presented as Figure 12 through Figure 15. Plots of log(Biomass), and log(Biomass-Density) would be similar because there was little variation in the mean weight of species across years. If there was no impact of enhancement, the two lines should be parallel over time, moving in lockstep up and down as both streams are subject to year-specific effects. The difference between the two creeks is related to creek-specific effects (e.g., one channel is larger than the other). If enhancement has had an impact, then presumably the line for Whatshan Creek should start to diverge from that of Barnes Creek after enhancement was completed. For Slimy Sculpin fry there may be some divergence in 2012, but the abundances were comparable in 2015. There appears to be no divergence in the other species and life stages. The sharp drop in abundance of Rainbow Trout fry in 2008 is attributed to a large spill from Whatshan Dam that peaked on May 30 and washed away spawning substrate and incubating eggs. This prompted the addition of spawning gravel as part of enhancement work in 2009, which may have contributed to the spike in fry abundance in 2010. It is interesting that most species and life stages in both reaches seem to have increased and decreased in abundance together and both reaches have increased post-construction compared to pre-construction.



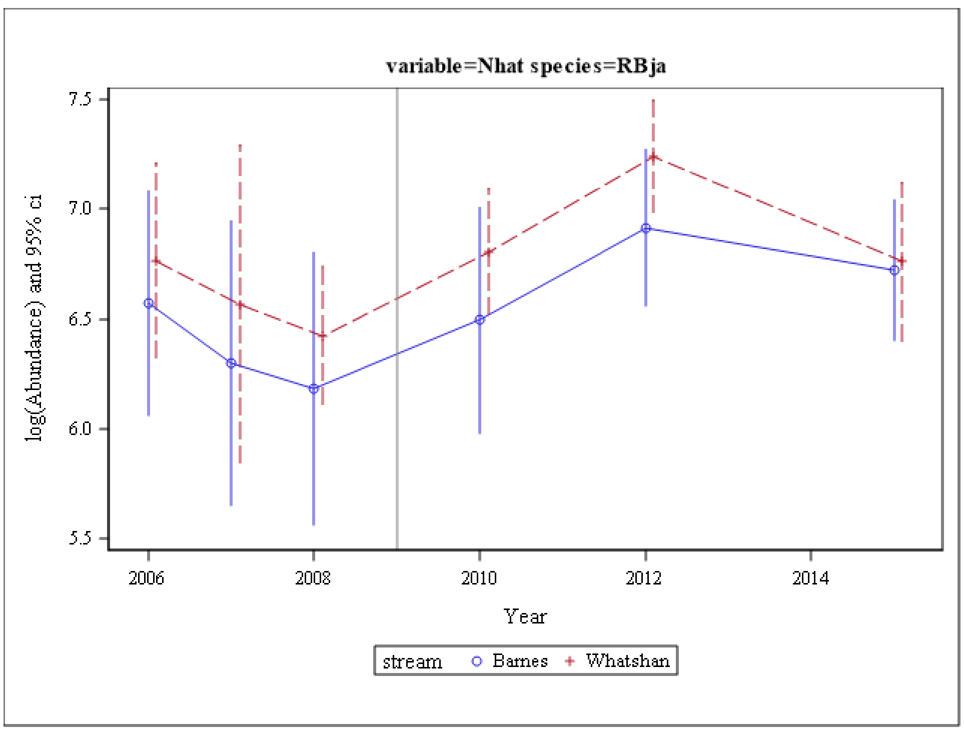
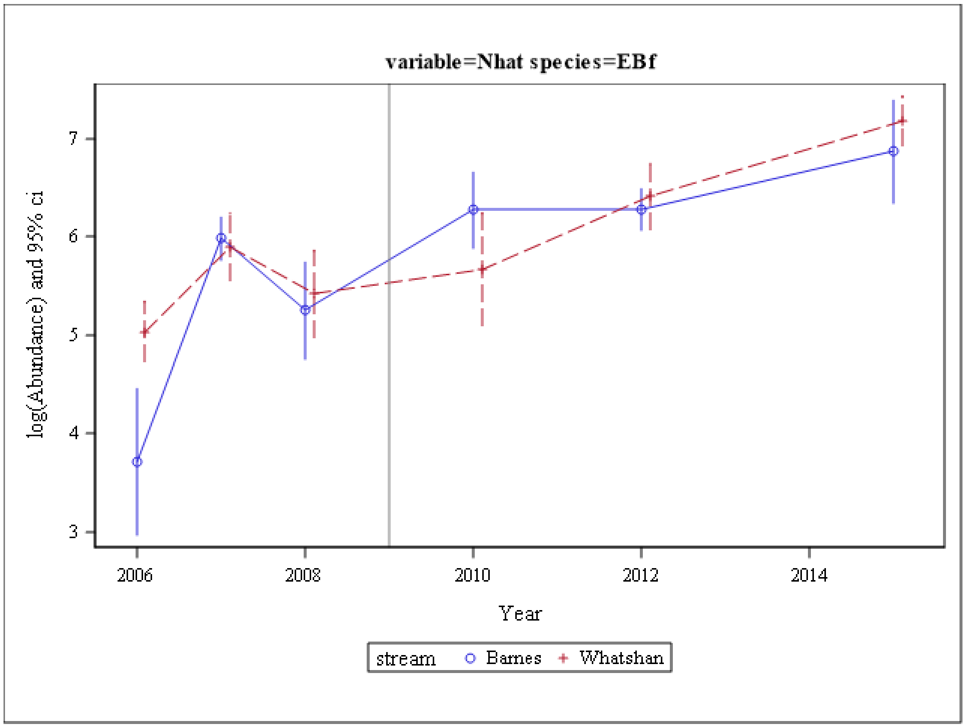


Figure 12. Trends in log(abundance) of Rainbow Trout fry (RBf) and juvenile/adults (RBja) in Whatshan Reach W3.2 and control reach Barnes B3 pre- and post-enhancement. Vertical line separates pre- from post-enhancement periods.



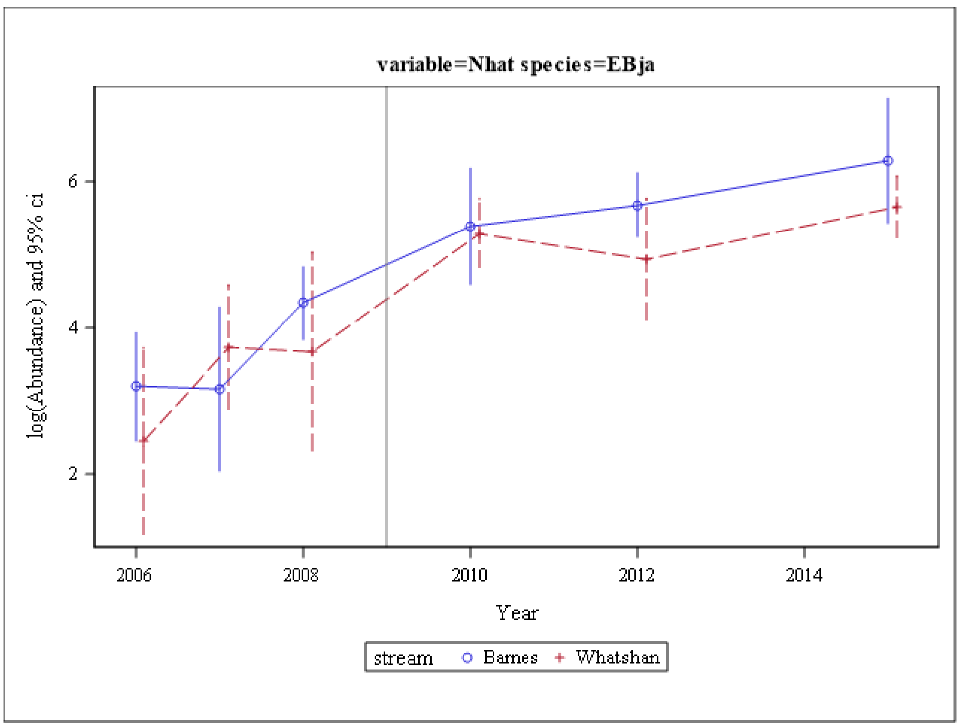
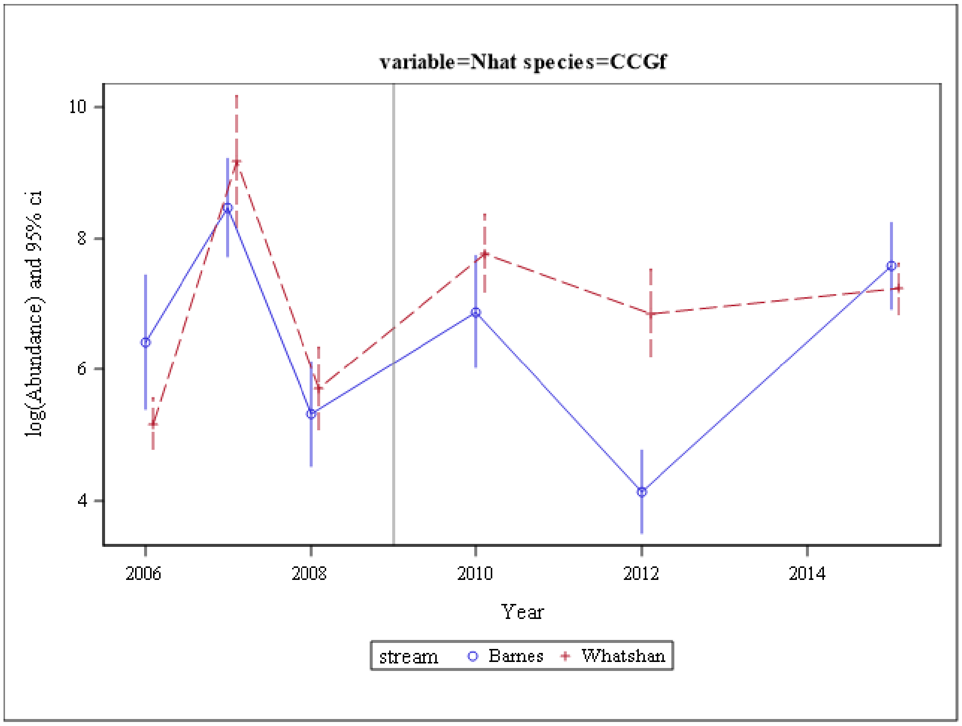


Figure 13. Trends in log(abundance) of Eastern Brook Trout fry (EBf) and juvenile/adults (EBja) in Whatshan Reach W3.2 and control reach Barnes B3 pre- and post-enhancement. Vertical line separates pre- from post-enhancement periods.



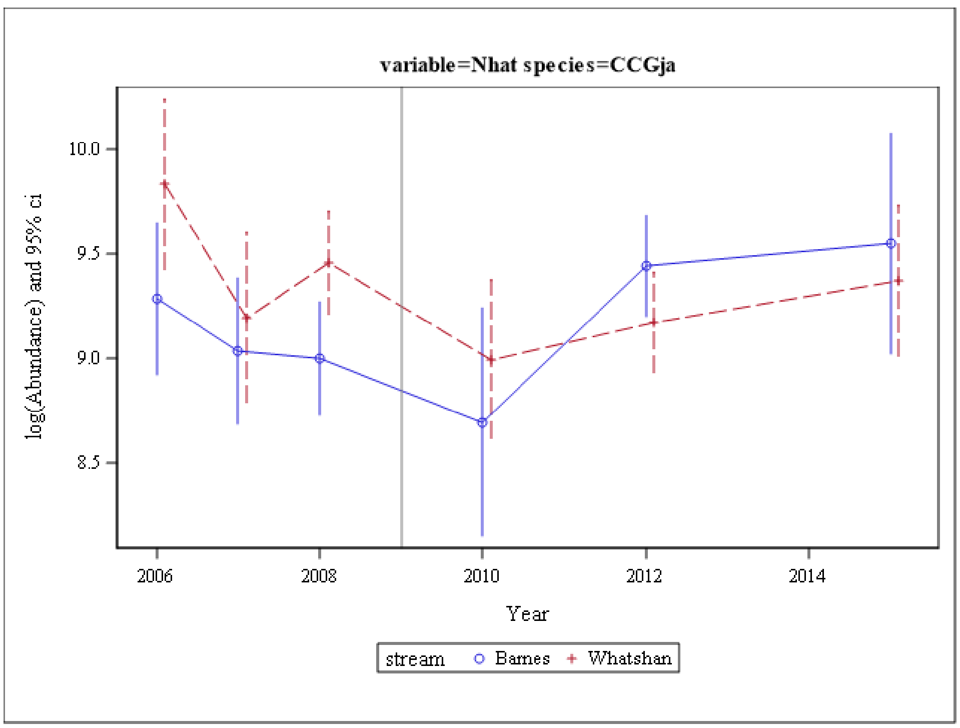
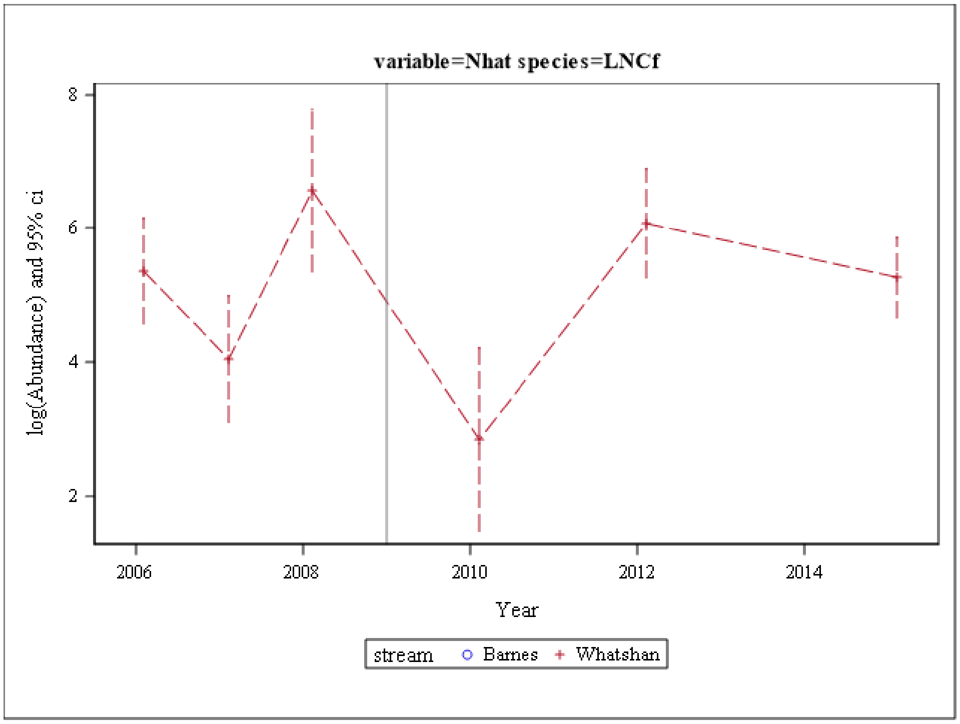


Figure 14. Trends in log(abundance) of Slimy Sculpin fry (CCGf) and juvenile/adults (CCGja) in Whatshan Reach W3.2 and control reach Barnes B3 pre- and post-enhancement. Vertical line separates pre- from post-enhancement periods.



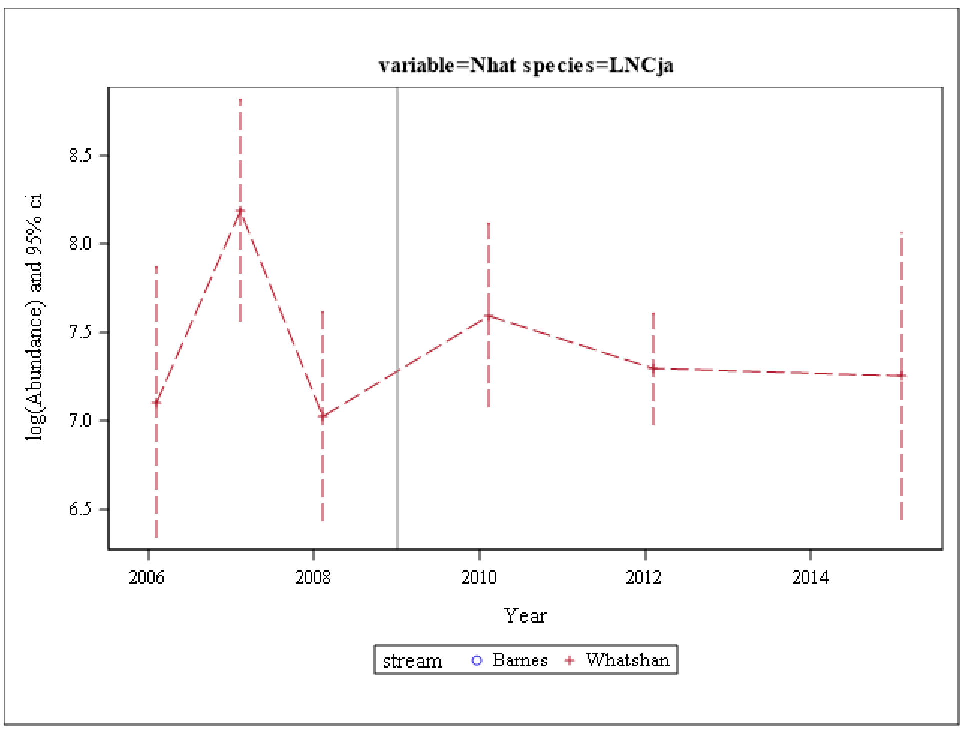


Figure 15. Trends in log(abundance) of Longnose Dace fry (LNCf) and juvenile/adults (LNCja) in Whatshan Reach W3.2 and control reach Barnes B3 pre- and post-enhancement. Vertical line separates pre- from post-enhancement periods.

A formal test to see if the difference between log(Abundance), density, log(Biomass), or Biomass Density in the pre-construction period is the same as in the post-construction period (the BACI effect) is found in Table 37 through Table 40. There was no evidence of a BACI effect for any species, which indicates that there is currently no evidence of an impact of enhancement in the post-construction years.

Table 37. Estimate of BACI effect comparing differential change in log(Abundance) between before and after periods at W3.2 and B3.

Species-Life Stage	Differential Change (W3.2 – B3)	SE	P-value
CCGf	1.14	1.08	0.352
CCGja	-0.44	0.21	0.109
EBf	-0.52	0.52	0.369
EBja	-0.21	0.47	0.680
RBf	0.54	0.60	0.422
RBja	-0.01	0.10	0.926
ALL	-0.35	0.20	0.152

Table 38. Estimate of BACI effect comparing differential change in density between before and after periods at W3.2 and B3.

Species-Life Stage	Differential Change (W3.2 – B3)	SE	P-value
CCGf	1.14	1.08	0.352
CCGja	-0.44	0.21	0.109
EBf	-0.52	0.52	0.369
EBja	-0.21	0.47	0.680
RBf	0.54	0.60	0.422
RBja	-0.01	0.10	0.926
ALL	-0.35	0.20	0.152

Table 39. Estimate of BACI effect comparing differential change in log(Biomass) between before and after periods at W3.2 and B3.

Species-Life Stage	Differential Change (W3.2 – B3)	SE	P-value
CCGf	0.97	0.98	0.378
CCGja	-0.32	0.14	0.091
EBf	-0.64	0.49	0.261
EBja	0.28	0.48	0.596
RBf	0.55	0.41	0.252
RBja	-0.25	0.34	0.499
ALL	-0.33	0.14	0.085

Table 40. Estimate of BACI effect comparing differential change in Biomass Density between before and after periods at W3.2 and B3.

Species-Life Stage	Differential Change (W3.2 – B3)	SE	P-value
CCGf	0.97	0.98	0.378
CCGja	-0.32	0.14	0.091
EBf	-0.64	0.49	0.261
EBja	0.28	0.48	0.596
RBf	0.55	0.41	0.252
RBja	-0.25	0.34	0.499
ALL	-0.33	0.14	0.085

5 CONCLUSIONS

Year 10 of the Lower Whatshan Fish Habitat Enhancement Project provided the third year of post-enhancement fish and fish habitat data for comparison with three years of pre-enhancement data. Answers were determined to the following four questions posed in the Water Use Plan Terms of Reference:

1) Do habitat structures in Reach W3 of the lower Whatshan River increase the availability of suitable habitat for rainbow trout?

2) How long do habitat structures continue to function?

3) Do habitat structures increase available habitat for rainbow trout in a more cost-effective manner than would a minimum flow release from the Whatshan Dam?

4) Does the increase in available habitat benefit rainbow trout in Reach W3.2?

In answer to **Question #1**, there was considerable evidence that habitat enhancement in Reach W3.2 has increased the availability of suitable habitat for Rainbow Trout. Water depth and cover area were the strongest explanatory variables for density of juvenile/adult Rainbow Trout in both reaches, and BACI (Before-After Control-Impact) comparisons showed statistically significant increases in average depth and total cover area in W3.2. In addition, there were significant increases in spawn gravel area and number of pools, which are also likely beneficial to Rainbow Trout.

The answer to **Question #2** is that the habitat structures may be expected to function for at least 25 years before the wood decays to the point that the structures lose integrity. Evidence of submergence and/or over-topping of significant portions of the structures was noted in the field assessment, with very little change or damage to the structures. However, the structures have only experienced short-lived high flows in 2012 and 2013, and higher and/or more prolonged high flows would provide a better test of structure durability and longevity.

As for **Question #3**, it appears that habitat structures do increase available habitat for Rainbow Trout in a more cost-effective manner than a minimum flow release, as the total enhancement cost was in the range of $200,000 compared with the estimated minimum flow release cost of $900,000 annually. In addition, there are other concerns with a flow release, such as high water temperature and introduction of undesirable fish species. It is also unknown whether a minimum flow release would be any more effective than habitat structures at increasing the available habitat for or abundance of Rainbow Trout in the Lower Whatshan River.

Regarding **Question #4**, there is no evidence that the apparent increase in available habitat for Rainbow Trout has benefitted the species. In fact, BACI comparisons showed a significant decrease in length of juvenile/adult Rainbow Trout in W3.2 relative to B3 but it is unknown whether this would be a result of habitat changes (it may be a result of angling harvest). Meanwhile, there was no evidence for an effect on Rainbow Trout abundance, density, or biomass. While there has been a modest increase in Rainbow Trout abundance in Whatshan Reach W3.2 since habitat enhancement was conducted, this increase has been largely mirrored in Barnes Reach B3, such that the differential increase between the two populations is minimal.

An additional hypothesis to be tested for this project was that habitat enhancement in Reach W3.2 of the lower Whatshan River does not negatively affect the density or size of fish species other than Rainbow Trout. The only significant negative BACI effect was a relative 5 mm decrease in fry length for Eastern Brook Trout, a non-native invasive species. Other significant effects were a 3 mm increase in length for Slimy Sculpin fry and a 0.12 increase in condition factor for juvenile/adult Eastern Brook Trout. These effect sizes are not expected to have any biological consequences. No significant differentials were noted in abundance, density, or biomass.

While habitat enhancement in Whatshan Reach W3.2 has increased the average depth, number of pools, amount of cover, and spawning gravel area, all changes that favour Rainbow Trout, the potential indicators of length, weight, condition, abundance, density, and biomass of juvenile/adult Rainbow Trout do not indicate a benefit to the target species.

The lack of a detectable response by the Rainbow Trout population to habitat enhancement in Whatshan Reach W3.2 is perplexing. Possible factors contributing to this lack of response include the following:

1. The key reason why differences in means were not detected between the before and after periods is the large year-to-year variation in each period that is much larger than expected given the uncertainty in the estimates. As noted previously, this year-to-year variability may be related to year-specific effects (e.g., weather). A generic term for this source of variability is process error to distinguish it from variability introduced by sampling.
2. Not all of the proposed enhancement structures were installed. In particular, only 12 of 18 triangular log jams, the primary pool-forming measure, could be constructed due to private property issues. Since maximum depth was the only strong explanatory variable for density of juvenile/adult Rainbow Trout, creation of more pools might have resulted in an increase to Rainbow Trout abundance that was large enough to be detected.
3. Angling may be differentially removing more adult rainbow trout from W3.2 than from B3. Reach W3.2 is highly visible from the road that follows the river and is much more easily accessible than B3. A bag containing several decomposing fish was found in W3.2 during the field survey, and the significant decrease in length of juvenile/adult Rainbow Trout in this reach may be indicative of removal of larger specimens by anglers. The enhancement work may also have generated a predator aggregation response, whereby anglers are attracted to the stream when they become aware of improved angling opportunities provided by more pools with larger and/or more abundant fish.
4. Increased suitability of habitat for Rainbow Trout may be offset by a reduction in total wetted area as the W3.2 channel adjusts to reduced flows by narrowing over time. Reach W3.2 has seen a significant decrease in total habitat area in relation to Barnes B3.

5. Insufficient time may have passed for the habitat structures to fully function, or for the Rainbow Trout population to respond. However, there are already significant improvements in habitat variables associated with higher trout abundance, and the post-enhancement period has exceeded the Rainbow Trout generation time of approximately four years. Therefore, the habitat changes have had time to show a population response regardless of which, if any, life stage was habitat-limited.

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APPENDICES

Appendix 1. Whatshan River Fish Habitat Enhancement Year 10 (2015) Structure and Channel Condition Review by Streamworks Consulting Inc.

Appendix 2. Whatshan W3.2 and Barnes B3 fish sampling photographs, September 2015.

Appendix 3. Physical data for Whatshan W3.2 and Barnes B3 fish sample sites, September 2015.

Appendix 4. Physical data for Whatshan W3.2 and Barnes B3 habitat units, September 2015.

Appendix 5. Fish Collection Form Data and Electrofishing Specifications for Whatshan W3.2 and Barnes B3, September 8-16, 2015.

Appendix 6. Whatshan River and Barnes Creek Fish Aging Results, September 2015.

WHATSHAN RIVER
FISH HABITAT ENHANCEMENT
YEAR 10 (2015)
STRUCTURE AND
CHANNEL CONDITION
REVIEW

February 2016

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TABLE OF CONTENTS

LIST OF TABLES:

LIST OF FIGURES

1.0 INTRODUCTION

Since 2006, BC Hydro has been making efforts to improve fish habitat in the lower Whatshan River northwest of Needles, BC. The goal of the project has been to increase numbers and/or biomass of rainbow trout in the system, offsetting the impact of reduced flows from operation of the Whatshan Generating Station on Arrow Lake Reservoir. The reduced flow regime in the Whatshan River has caused a reduction in the wetted area available to fish in reaches downstream of the reservoir. In addition, the elimination of flood flows may also impact fish habitat by changing the natural morphology of the channel system downstream. Reduced flood flows are less able to sort substrates, scour pools and recruit large woody debris (LWD) from the banks. The lower flows inhibit the ability of the river to initiate substrate movement from a well-armoured bed, and adjust itself over time by incising and adapting to a smaller channel form. Furthermore, the wetted area is withdrawn from the riparian forests, a natural source of cover, shade, detritus and food. All these changes combine to reduce the productivity of the channel affected by the diversion dam.

With the goal of mitigating some of the impacts of the diversion on fish habitat, a 1.3 km section of the Whatshan River downstream of Barnes Creek in the vicinity of the Highway 6 crossing (Reach W3.2) was identified for enhancement by the Whatshan Water Use Plan Consultative Committee. After conducting field reviews, a biologist (Naito Environmental) and a fluvial geomorphologist (Streamworks Consulting Inc) developed a plan for the reach to enhance fish habitat by installing artificial cover elements, and to try and reactivate morphological processes by reducing channel capacity through lateral obstruction and encroachment. Stream power is effectively increased in the vicinity of the artificial constrictions, causing mobilization and sorting of substrates, and encouraging the scour of pool habitat within the constrictions. Encroachment structures were comprised mostly of LWD to help compensate for reduced natural LWD recruitment from the banks and lost riparian connectivity in the present day 'under-fit' channel.

Construction of habitat enhancement measures in Reach W3.2 was completed in the summer of 2009. Since eight structures could not be completed due to lack of consent from private landowners, additional habitat enhancement was completed at other sites. In addition to larger structures, extra boulder habitat was created at four sites, and additional LWD was installed near three sites. The end result was a total of 31 sites. These sites consisted of 12 triangular log jams, 6 lateral log jams, 8 boulder groups, 3 single or double boulder placements, and 2 single or multiple log placements. Twenty-two of the sites were in the original enhancement plan, while the others were added to utilize excess materials. An inspection of the installed structures and channel condition was made in September 2015 by Alan Bates, P.Eng. of Streamworks Consulting. This report summarizes the findings of that assessment. This report is concurrent with an updated Fish Habitat/Biomass Assessment of Reach 3.2 by Naito Environmental.

2.0 ASSESSMENTS

2.1. High Flow Events Since Construction

Since the construction of the Whatshan Dam in 1951 and the diversion of flows through the penstocks directly into Arrow Lake, there remains only local seepage and infrequent spillages in the Whatshan River below the dam. Approximately 2 km below the dam, Barnes Creek joins the Whatshan River, bringing additional unregulated flows and partially refilling the channel. The 1300m long Reach W3.2, immediately downstream of the Barnes Creek confluence was the focus of this enhancement project.

Seven years of streamflow data were collected in the Whatshan River (08NE063) before the construction of the dam, and 55 years of flow data have been collected in Barnes Creek (08NE077) since construction. Assuming that flow in the Whatshan River is minor, and spills over the dam are infrequent, it can be assumed that discharge in Reach W3.2 of Whatshan is now equivalent to the total discharge in Barnes Creek.

Prior to the dam (based on only 7 years of record), daily maximums during freshet exceeded 70 m^3/s in the Whatshan River (near the mouth). Lesser peaks generally exceeded 40 m^3/s prior to diversion for power generation. Barnes Creek generates peak daily discharges of up to 50 m^3/s, with freshet peaks sometimes as low as 5 m^3/s (based on more than fifty years of record). These data provide documentation of the historic natural range of flows and the scale of the flow reduction caused by the diversion.

Typically, channel adjustments occur in creeks and rivers during events at or greater than bank full flow, approximated by a 2 year return period (often termed channel-forming flows). Using a Barnes Creek 5 year flood flow of 45 m^3/s as a test case (design discharge), a HEC-RAS model was run to evaluate bed stability in artificially constricted sections within Reach 3.2. Constrictions were designed to increase local velocities to a point that initiated mobilization/scour of surveyed substrate sizes. The design flow was selected with the goal of generating bed mobilization and channel reforming, on average, once every five years.

The following table lists annual flow peaks in Barnes Creek recorded by Water Survey of Canada (08NE077) since construction.

Table 1: Annual Peak Discharge in Barnes Creek (and Reach 3.2) since 2009.

Year	Date	Maximum Annual Instantaneous Discharge (m^3/s)
2010	May 19	34.4
2011	June 6	34.6
2012	Jun 23	55.7
2013	May 22	66.2
2014	May 18	27.5
2015	June 3	22

Note: Flows for 2014 and 2015 are preliminary daily mean values from Water Survey of Canada

Annual peak flows exceeded the design flow of 45 m^3/s in 2012 and 2013. According to the previously completed modeling analysis, those flows should have been capable of doing channel-forming ‘work’ in Reach 3.2.

Figure 1 on the following page provides a hydrograph of Barnes Creek daily mean flows since construction (Sep 1 2009 to Sep 1 2015). Mean daily peaks only show one event exceeding the 45 m^3/s threshold since construction (59 m^3/s May 22,

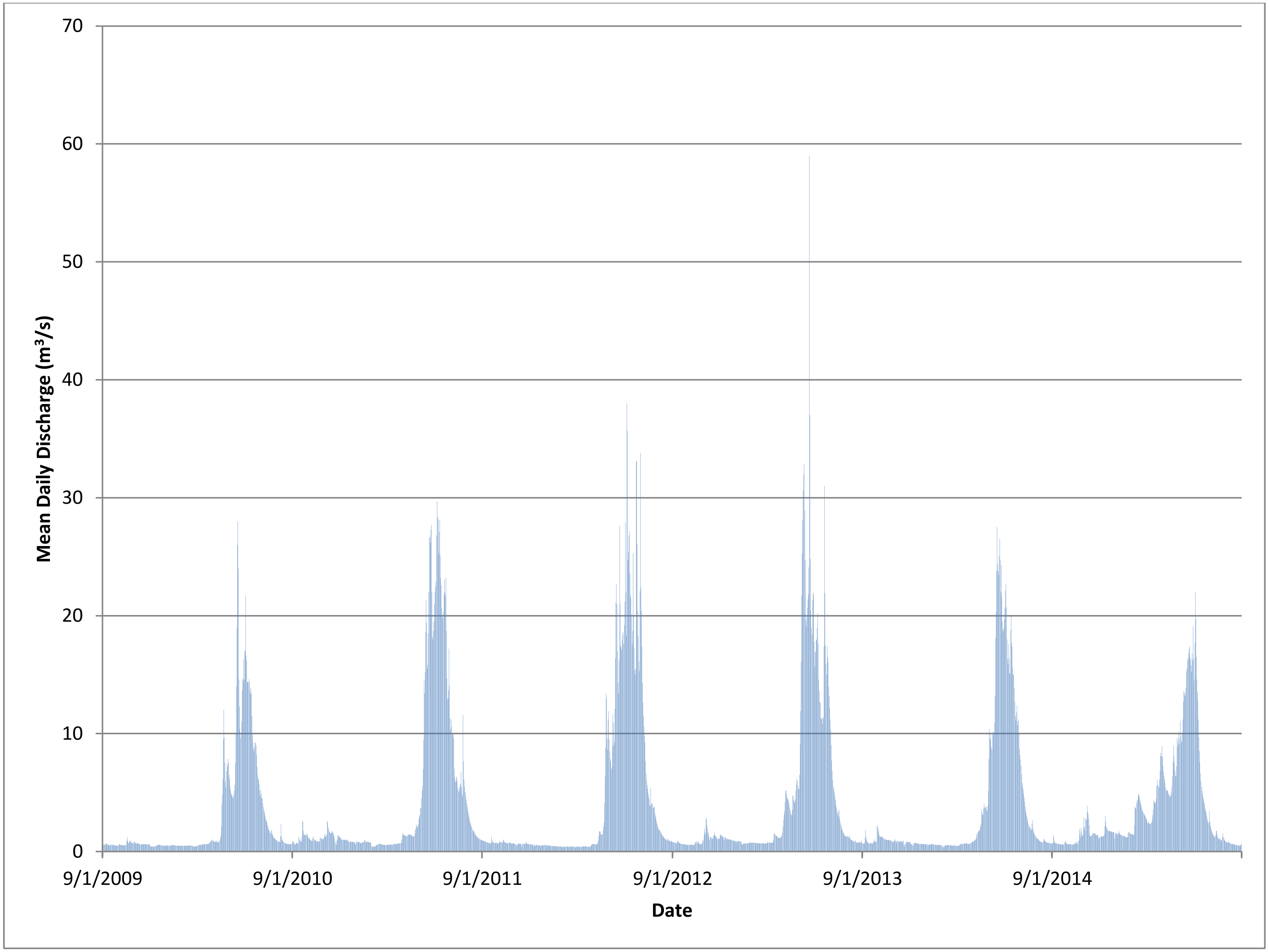


Figure 1 – Mean Daily Flows for Barnes Creek recorded by Water Survey of Canada (08NE077) September 1st 2009 to September 1st 2015

2013). Instantaneous and/or hourly values are generally higher. For example, the instantaneous peak flow for that May 2013 event was 66.2 m^3/s. The difference is significant in 2012 where the peak instantaneous flow was 55.7 m^3/s (June 23) whereas the maximum mean daily flow was only 38 m^3/s (June 5). This suggests that the 2012 peak flow was not sustained for more than a few hours (certainly less than a day). The 45 m^3/s threshold was likely only exceeded for a short time in 2012, giving limited time for channel reforming.

2.2. Field Assessments and Findings

A field survey of Reach 3.2 was conducted by Alan Bates, P.Eng. of Streamworks Consulting on September 11, 2015. Mr. Bates has been was involved in the project since 2006, conducted the original cross section surveys, and carried out the channel modeling and design of the structures. He is therefore familiar with the channel condition prior to the installation of the structures, and immediately post-construction. During the 2015 site visit, numerous photographs were taken of each structure/installation for comparison with photo-documentation from 2009. No cross sections were re-surveyed to assess channel dimensional change. A handheld GPS was used to confirm structure locations. Selected site photographs can be found following the report in Appendix A.

Structure figures in Appendix A provide photo comparisons for each structure site using photos from 2009 and 2015. Common identifiable reference points are labelled on the photo pairs to help the viewer line up features where camera position and angle are different. Visible physical changes are indicated on the 2015 photographs. Other changes and observations from the field are noted on the bottom of the page.

All of the constructed rock and debris structures remain in place and structurally sound with little change to their original configurations. Two bent eyebolts were noted, however that damage could have occurred during construction. Most debris jam structures had successfully recruited small woody debris, and in some cases, larger logs had been captured. Smaller boughs and branches (with needles) placed as 'preload' debris on the structures in 2009 were mostly stripped clean.

In most cases, some degree of bed scour was noted near the tip of the encroachment structures (Photo A). Scour was likely due to increased velocity of flow around the tip, or by high flows pouring over the submerged log ends. Stream armour had often been excavated near the structure tips during construction to initiate/promote scour. Fish were often observed in and around structures, utilizing the cover provided by the debris and deeper water.

The complex velocities in and around the debris structures caused localized scour and deposition resulting in substrate sorting (Photo B). Eddies, formed downstream of the structures, collected sediments precipitated by lower local velocities. This process resulted in the accumulation of sand and gravel bars downstream of many of the bank structures (Photo C). In some cases, vegetation was beginning to colonize the deposits. The debris structures, lateral bars and boulder placements worked well together to narrow the effective channel width, force meanders within the oversized channel and increase channel complexity (Photos B, C, D and E).

In addition to the debris structures, instream boulder placements were used to increase velocity complexity and augment fish habitat (Photos F, G). Positions of boulders were not surveyed, however it was apparent that some have likely moved or at least sunk lower into existing substrates (Photo H). Individually, boulders created small eddies and pour-overs that were intended to cause scour and sort substrates. The amount of scour and sorting accomplished by the boulders was minimal. Most boulders did exhibit a 'shadow' of finer material deposited on their downstream side, however it did not represent a significant change in fish habitat quality (Photo I and J).

During 2009 construction, several truckloads of washed spawning gravels were placed in the channel aimed at increasing substrate diversity (See Sites 5 and 16). Gravel was mobilized through the project area. Available spawning gravel in Reach 3.2 is described in more detail in the accompanying report by Naito Environmental.

Site 29 was intended as a bar stabilization measure at an aggraded inside bend to force the channel into a narrower form. Ballasted logs and debris were spread across the point bar and the preferred channel route was slightly excavated to remove the existing armour layer and encourage downcutting. It appears that high flows have rearranged some of the ballasted logs and exposed some buried boulders. The bar stabilization structure was likely too open, allowing flood flows to pass through relatively unobstructed. Some debris was recruited, but not enough to plug up the thin network of logs. The wetted channel does however appear to have narrowed significantly and downcut slightly in the preferred location, so there has been some success (See Site 29 – Appendix A)

At the lower end of Reach 3.2, the river takes a sharp bend through a bedrock constricted section. At Site 30, woody debris was anchored into the bedrock to augment cover for fish holding in deep water. A natural log jam has formed on the outside bend (right bank) near the downstream end of the reach. Photo K shows the artificial jam and the natural jam it was intended to mimic.

3.0 SUMMARY AND CONCLUSIONS

3.1. Structure Performance and Durability

Based on the above described assessments, all of the installed rock and debris structures (triangular log jams, ballasted log jams, lateral debris placements) have performed as intended. In the six years since construction, there has been little movement and no failure of the debris structures. The structures were tested by high flows, although short-lived, in 2012 and 2013. Evidence of submergence and/or over-topping of significant portions of the structures was noted in the field assessment, with very little change or damage to the integrity of the structures. Most installations have been successful at recruiting additional woody debris, augmenting their effectiveness and longevity. The bar stabilization structure (Site 29) is the one exception where it failed to encourage the collection of sediments on the existing bar. The structure will need to recruit more debris to help reduce through-flows, before it will function to recruit sediment.

No significant decay of the logs used in the installed structures was noted in the assessment. Some bark had been eroded off of the more exposed stems. Cedar and fir, especially larger diameter logs like the ones used in this project, can be expected to last for 25 years before losing significant any structural integrity[1]. Few deciduous stems were used and smaller diameter debris will likely be replaced by recruitment as it decays. The structures are held together by galvanized chain and eyebolts which can be expected to outlast the logs.

Boulder placements have been less effective at initiating channel change and/or creating fish habitat. Many of the boulders remain in relatively shallow uniform riffle sections, limiting their benefit to fish. The armour layers around the boulders likely resist mobilization by the slight increase in local velocity caused by the boulders, and scour pools are not developing. Some limited sorting/accumulation of finer sediments was evident downstream of the boulders. The report by Naito Environmental may provide comment of the fisheries benefits of these cover elements.

3.2. Channel Response

Since construction, only twice have discharges entered the range where channel-forming 'work' can be expected to occur (above the 45 m^3/s design threshold). Neither event appeared to be sustained for more than a day. Some scour, mobilization, sorting and deposition of substrates have occurred in the vicinity of the structures since installation. Looking at the bigger picture, the active channel appears to be narrowing in some areas due to the constrictions caused by the structures, and the meander pattern forced by the structures within the oversized channel. This can be expected to continue over time, and accelerate given future high water events in excess of the design threshold. Whether the augmented fish habitat and channel adaptations so far have translated into increased fish productivity/biomass is being assessed concurrently by Naito Environmental under separate cover.

3.3. Recommendations

The following recommendations are made with regards to the findings of these assessments:

- Structure and channel condition monitoring should be conducted again in 5 years' time, or following any major high water discharge event.
- Channel form and structure positioning (including boulder gardens) may be better documented using low level aerial photography taken along the channel. The costs and feasibility of this type of data collection are decreasing, stemming from technological developments with camera-mounted drones, and may make this a viable monitoring technique in the future.
- Since 2006, another decade of data recording current climate trends has been collected and will continue to be collected for Barnes Creek. If future monitoring is undertaken, the hydrologic profile and flood frequency for Barnes Creek should be updated.

[1] Cederholm et. al. 1997 *Rehabilitating Stream Channels and Fish Habitat Using LWD*, Chapter 8 Fish Habitat Rehabilitation Procedures, Watershed Technical Circular No.9, BC MELP and MOF)

Photo A – Scour and substrate sorting off the tip of a triangular log jam (Site 6). Scour likely caused by water pouring over the logs.

Photo B – Triangular rock and debris jam (Site 22) causing substrate sorting and deposition of sands, gravels and fines. Debris jams were set to force channel

Photo C – Sand and gravel bar depositing downstream of Site 26. Structures and lateral bars are forcing stream meanders within the oversized channel.

Photo D – Channel narrowed by a debris jam structure (Site 6) working in conjunction with large boulders to increase channel complexity.

Photo E - Debris jam (Site 22) and boulders causing substrate sorting and deposition of sands, gravels and fines. Debris jams were set to force channel meanders.

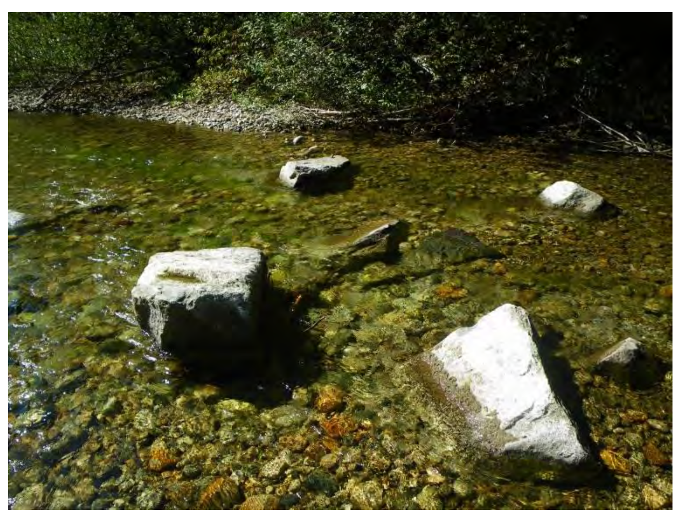


Photo F – Instream boulder placements downstream of Site 17. Minimal scour and deposition of fines.

Photo G – Instream boulder placements downstream of Site 16. Minimal cover, scour and deposition of fines.

Photo H – Instream boulder placements near Site 7. Minimal scour and deposition of fines.

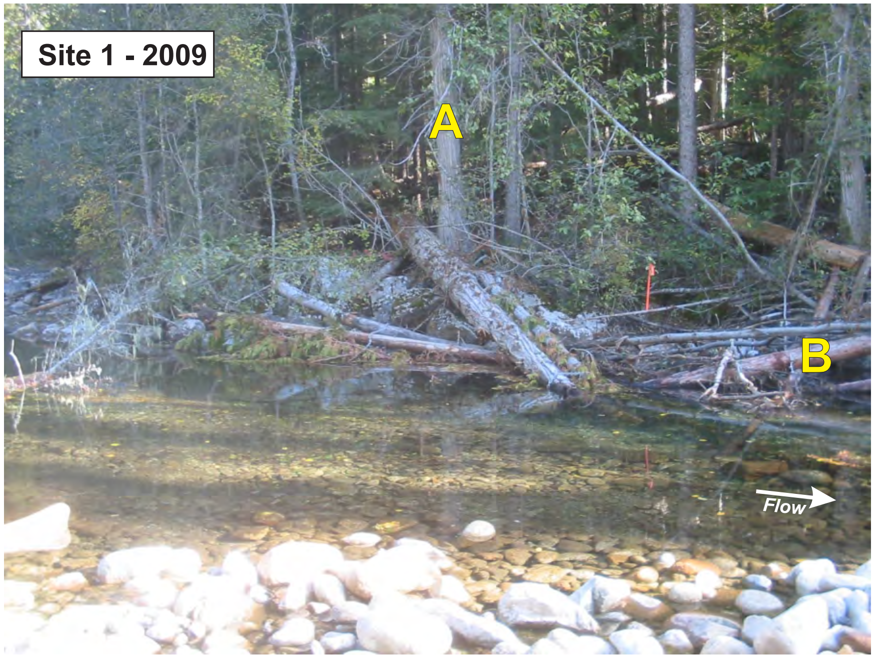
Photo I – Coarse sand deposits downstream of an instream boulder between Sites 24 and 26.

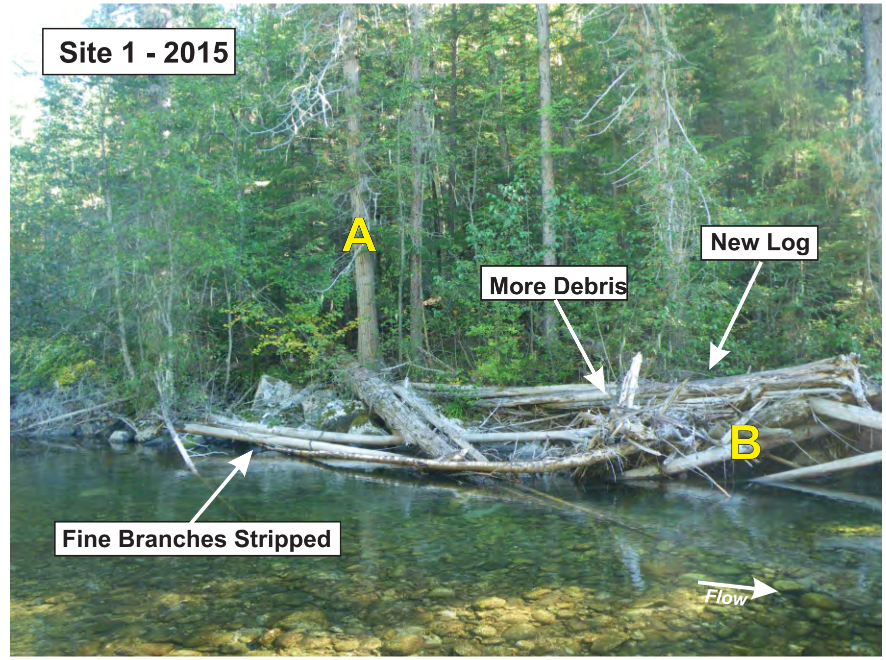
Photo J – 'Shadow' of finer materials deposited downstream of an instream boulder between Sites 19 and 22.

Photo K – Looking upstream from the bedrock constriction at Site 30. The near log jam is constructed and the far log jam is natural.

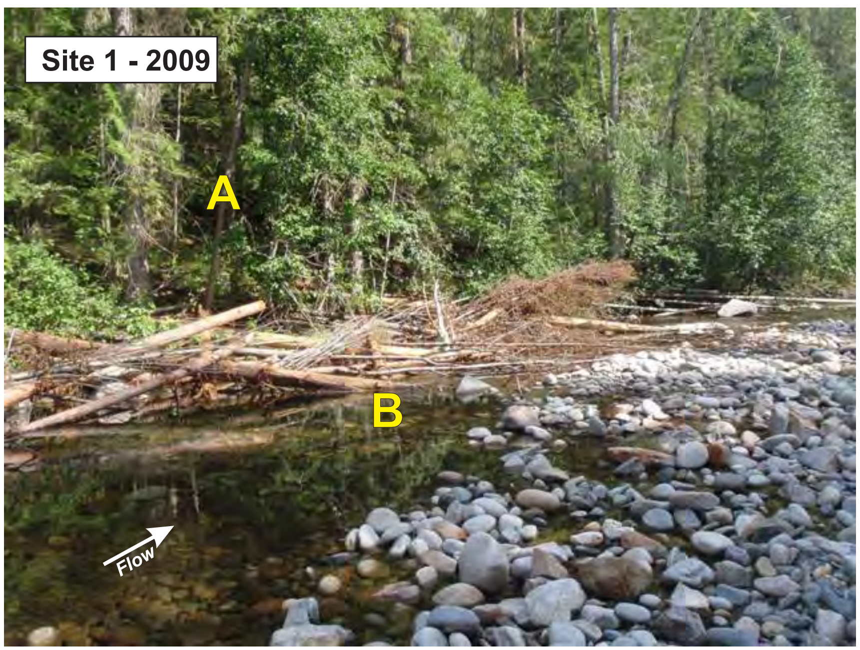
APPENDIX A.

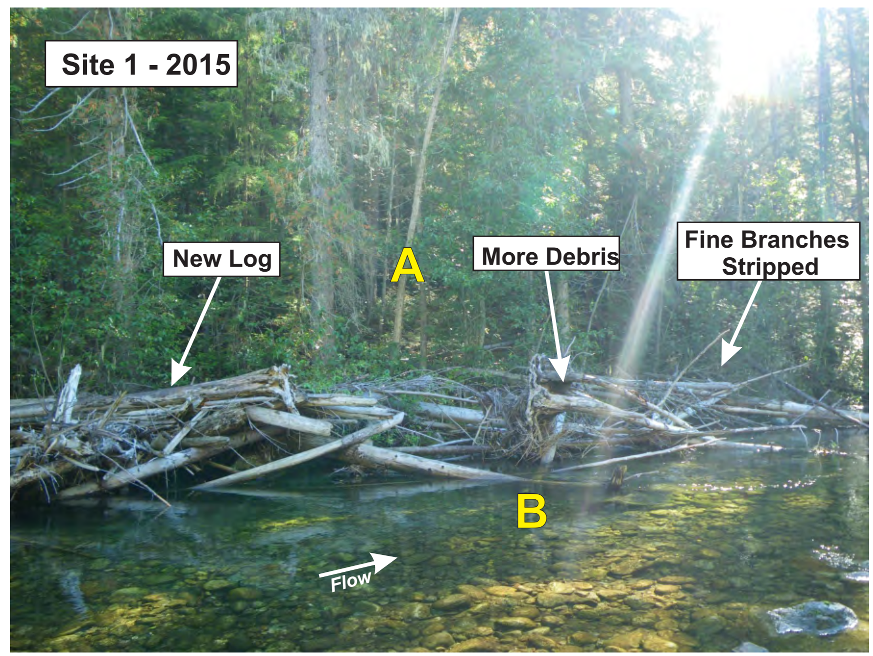
PHOTO COMPARISONS OF STRUCTURE SITES BETWEEN 2009 AND 2015





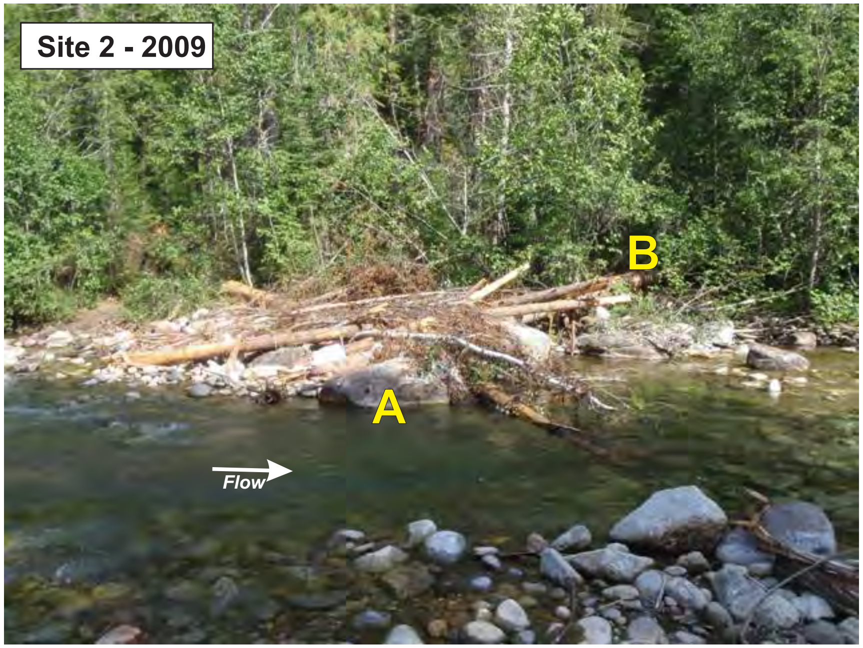
A and B demark identifiable reference points in each photo pair

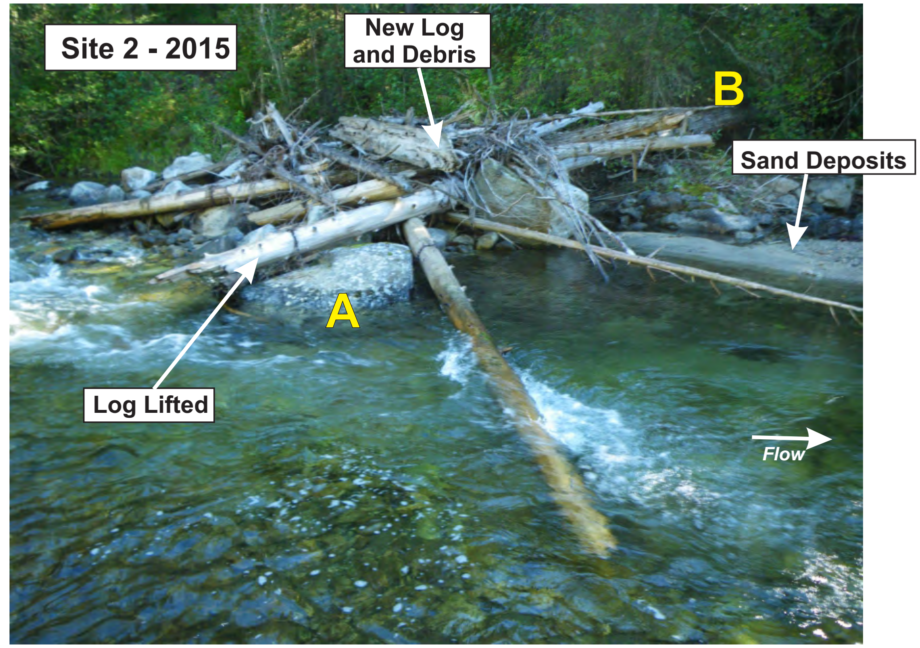




Notes:
Pool increased to maximum 1m depth
Good woody debris recruitment
Some sand deposits in eddies
Fish observed using cover

Lower Whatshan River Fish Habitat Enhancement Year 10 (2015)	
Site 1	Streamworks Unlimited / NAITO ENVIRONMENTAL





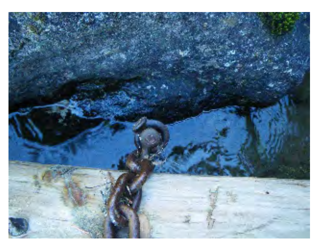
A and B demark identifiable reference points in each photo pair

Photo A: Looking upstream at Structure 2. Note narrowed channel and sand and gravel deposit downstream.

Photo B: Looking downstream at Structure 2. Note narrowed channel and increased velocity/scour off structure tip.

Photo C: Looking upstream at Structure 2 showing large recruited log and smaller debris. High water was close to top of structure.

Photo D: Damaged eyebolt still holding chain
.

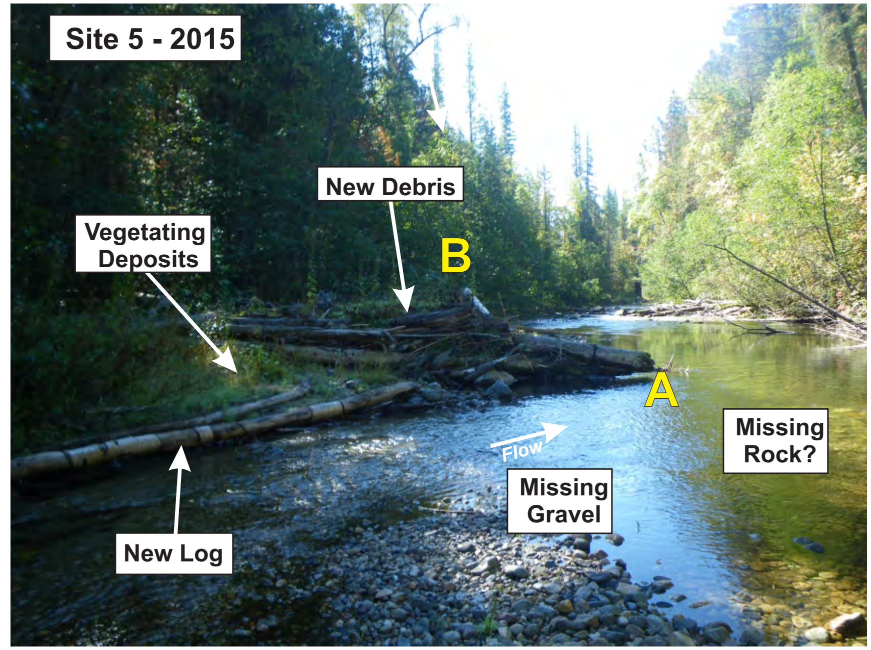


Notes:
Pool increased to maximum 1m depth
Good woody debris recruitment
Sand and gravel deposit downstream
One damaged eyebolt but structure intact.

Lower Whatshan River Fish Habitat Enhancement Year 10 (2015)

Site 2

NAITO ENVIRONMENTAL



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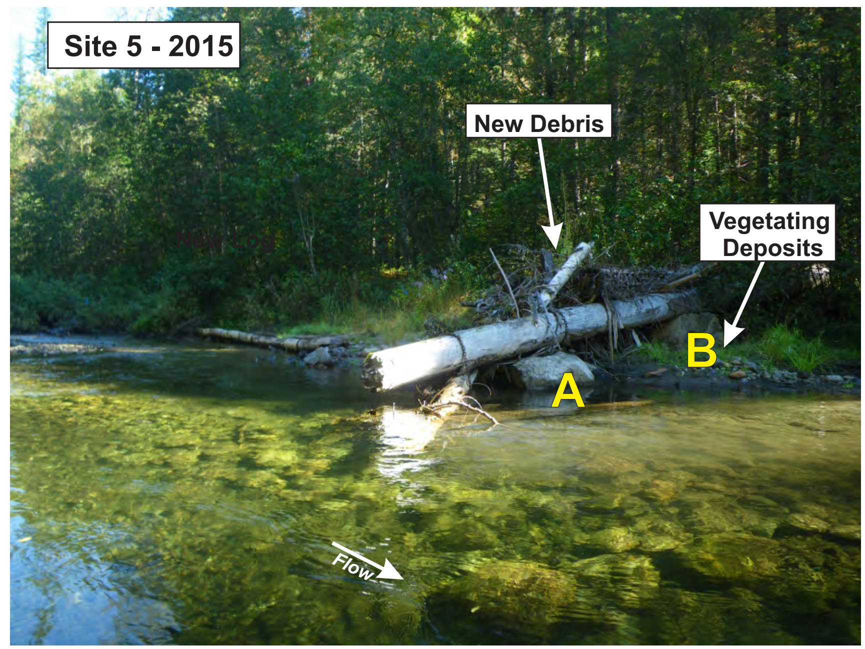
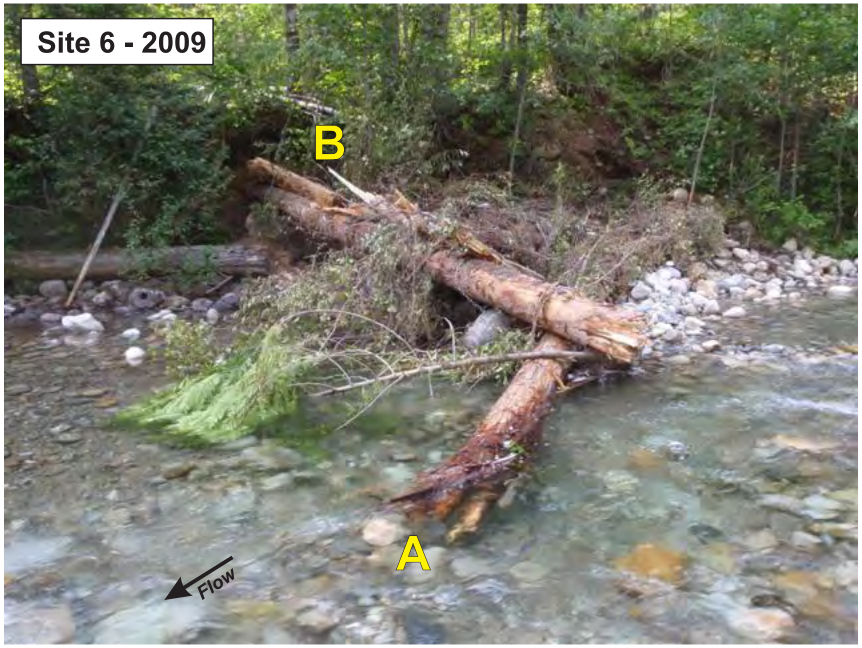
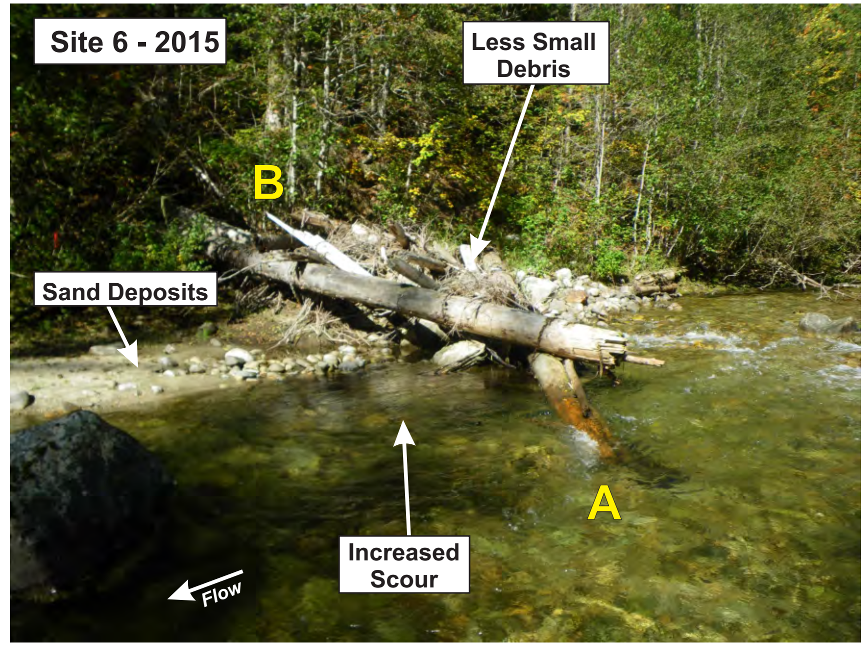


Notes:
Causing good scour to 1m depth
Good woody debris recruitment
Deposits upstream and downstream re-vegetating
Spawning gravel and boulder large rock missing.

Lower Whatshan River Fish Habitat Enhancement Year 10 (2015)	
Site 5	Streamworks Unlimited / NAITO ENVIRONMENTAL





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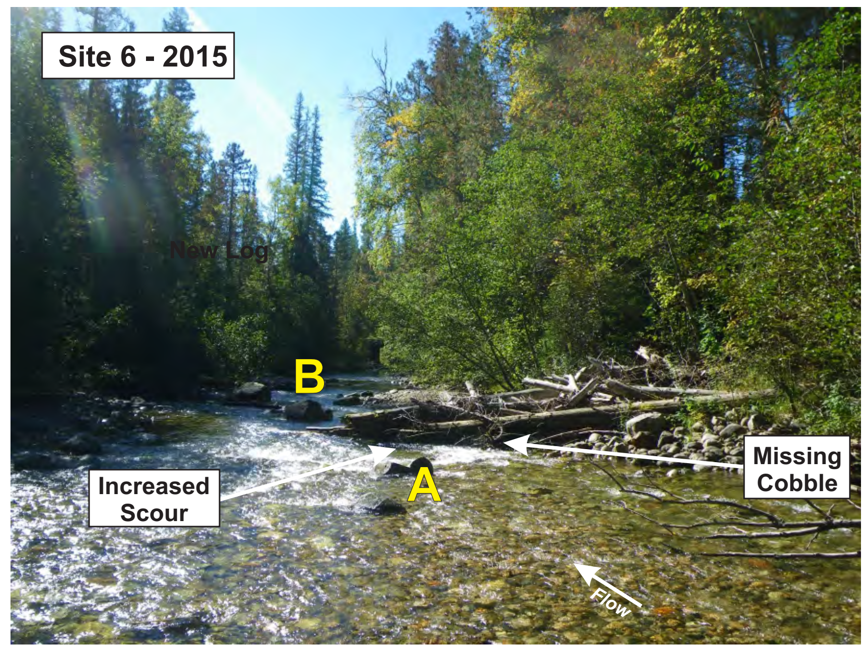
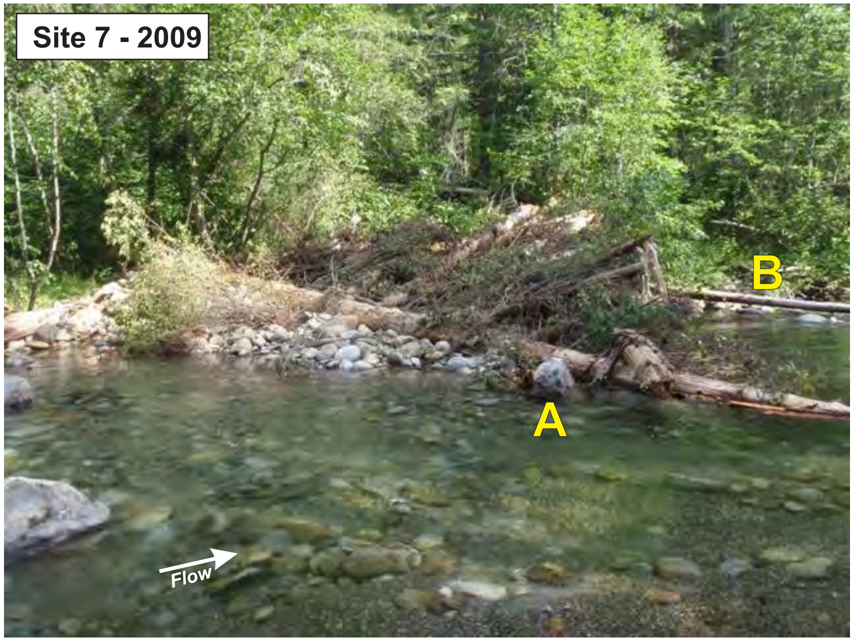
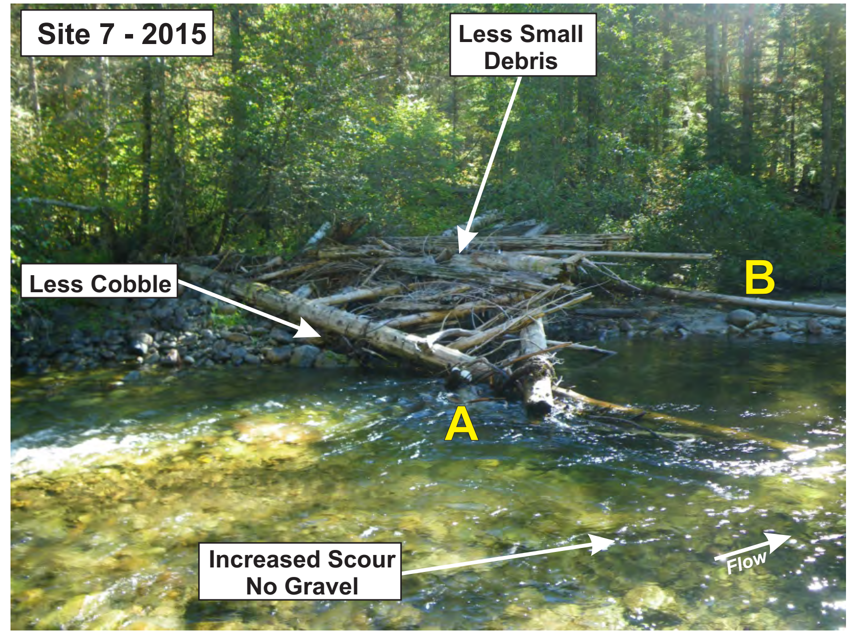


Notes:
Some scour off structure tip
Good woody debris recruitment
Sand and gravel deposit downstream
Diagonal bar forming upstream

Lower Whatshan River Fish Habitat Enhancement Year 10 (2015)

Site 6





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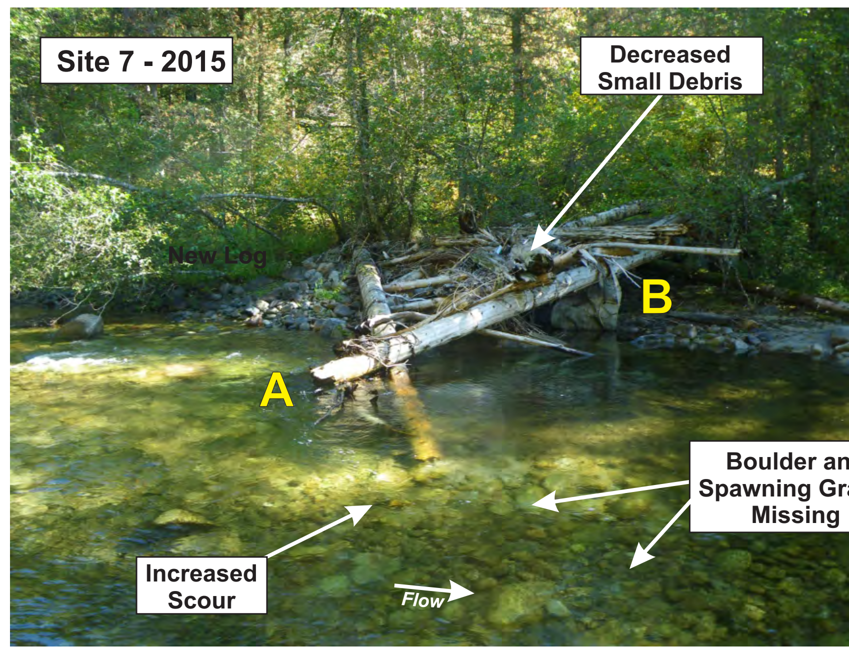
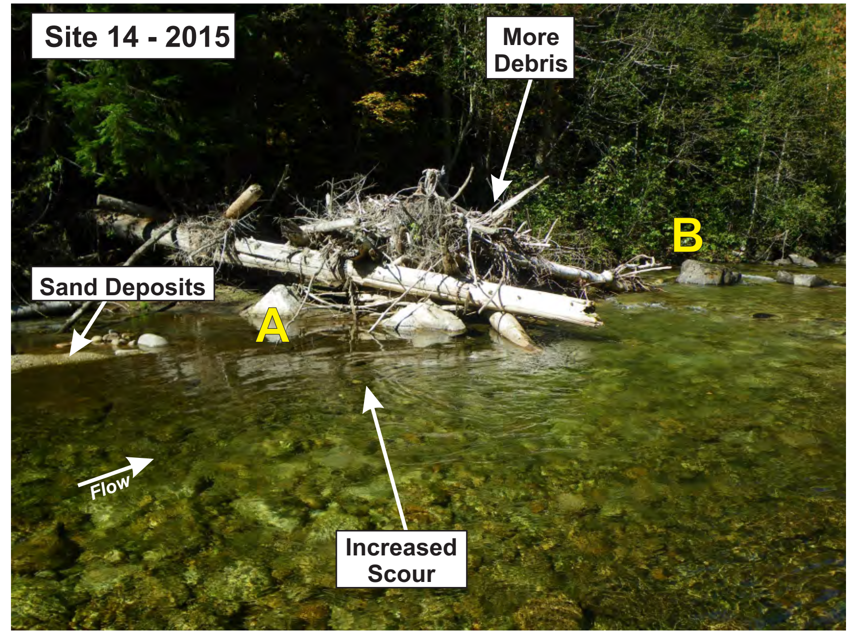


Notes:
Pool increased to maximum 1m depth
Good woody debris recruitment
Boulder and spawning gravel washed away
Fish observed using cover

Lower Whatshan River Fish Habitat Enhancement Year 10 (2015)
Site 7



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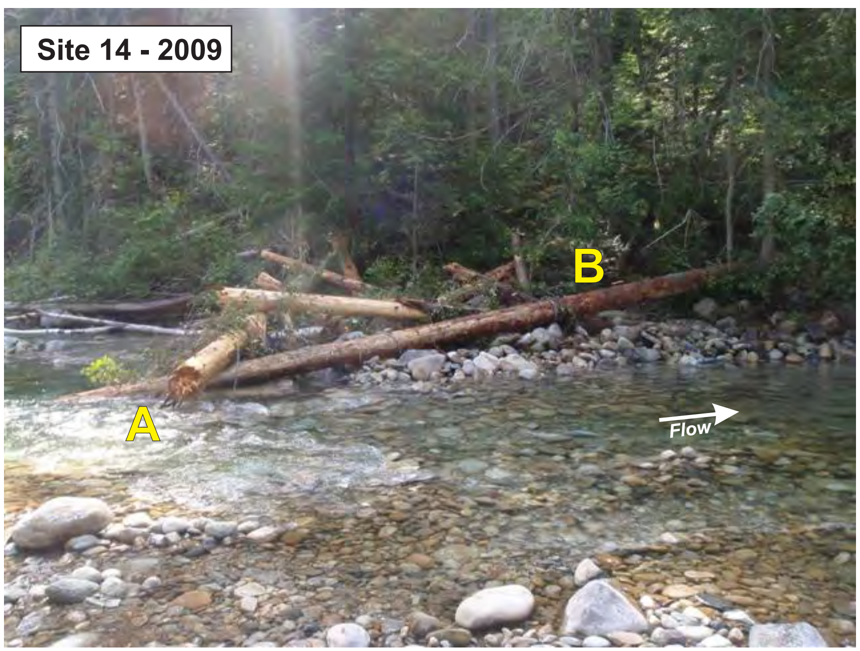
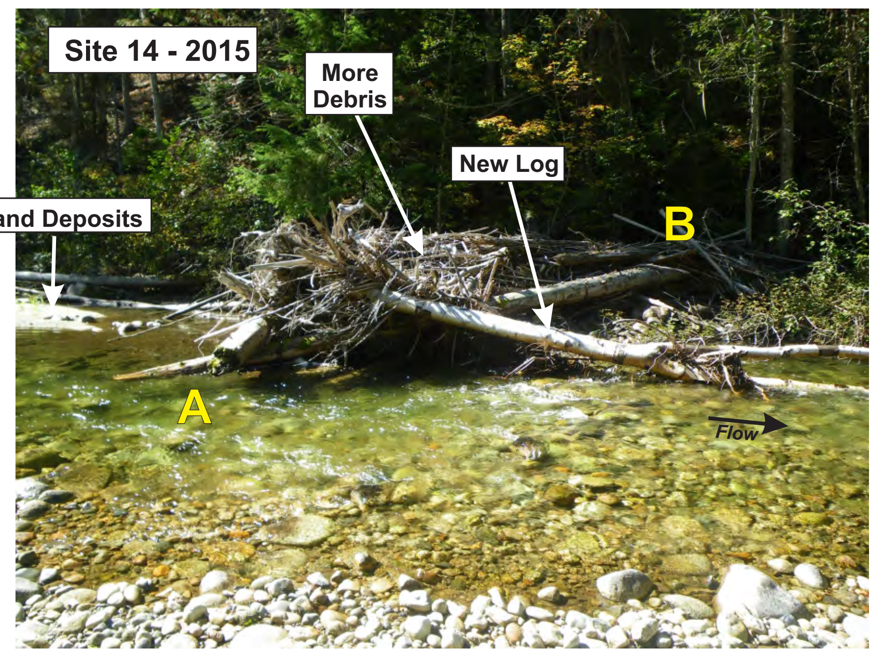


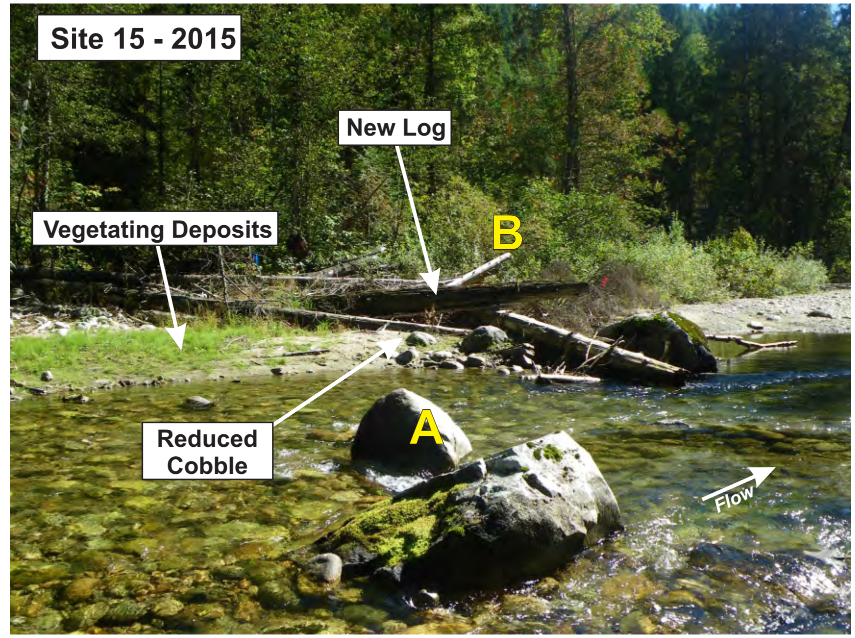


Notes:
Some scour off structure tip
Good woody debris recruitment
Sand deposits downstream
Fish observed using cover

Lower Whatshan River Fish Habitat Enhancement Year 10 (2015)

Site 14

Streamworks Unlimited NAITO ENVIRONMENTAL



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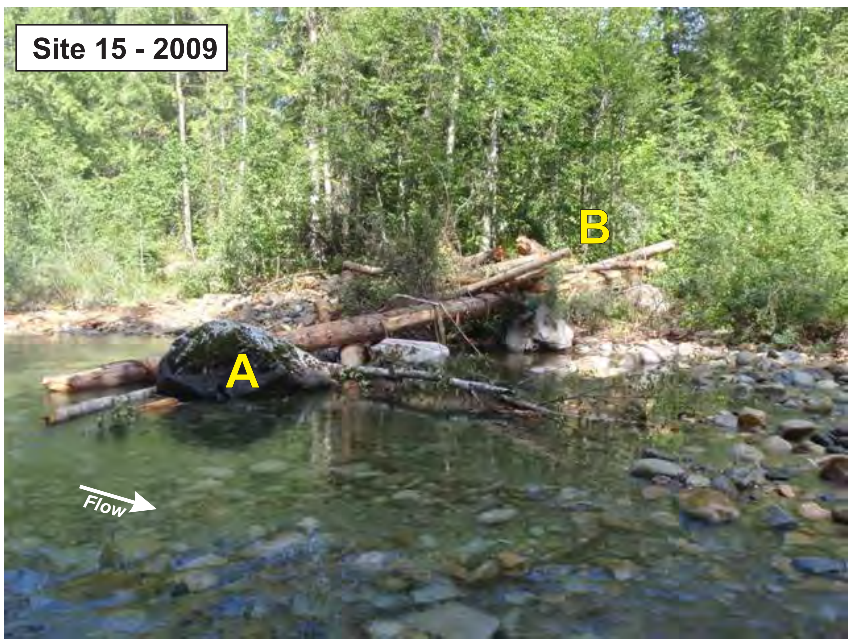
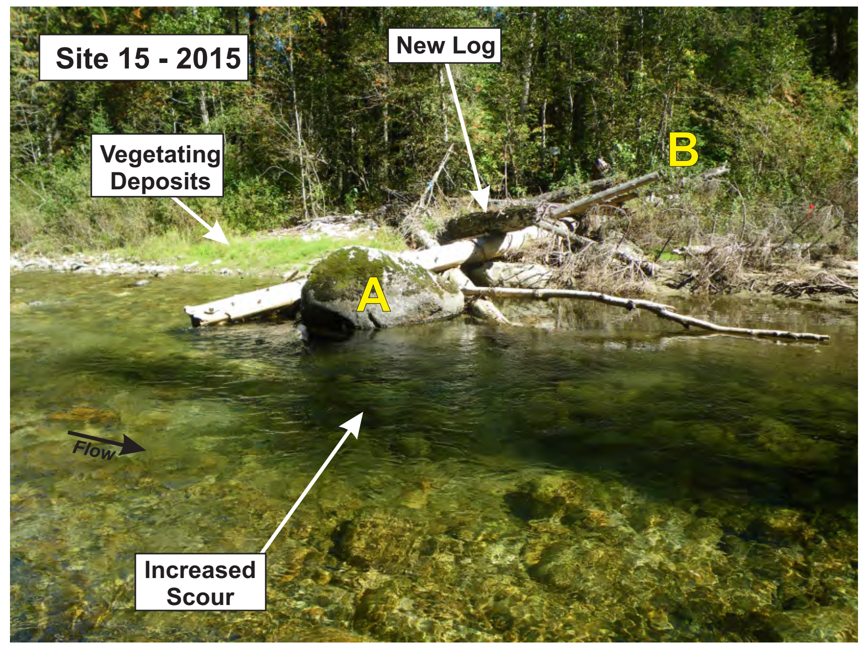
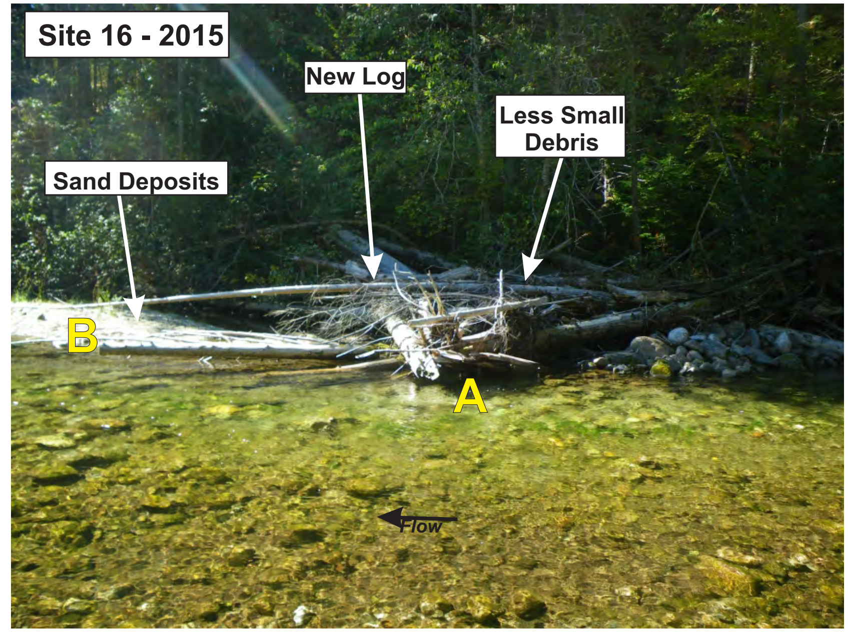




Notes:
Natural boulder causing scour
Some woody debris recruitment
Coarse sand deposits downstream
Thalweg closer to opposite bank

Lower Whatshan River Fish Habitat Enhancement Year 10 (2015)

Site 15



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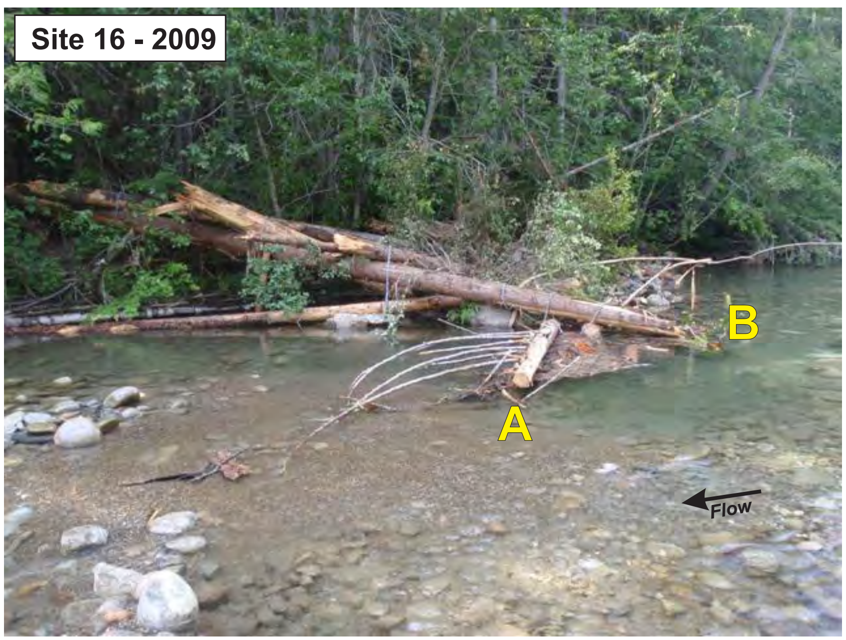
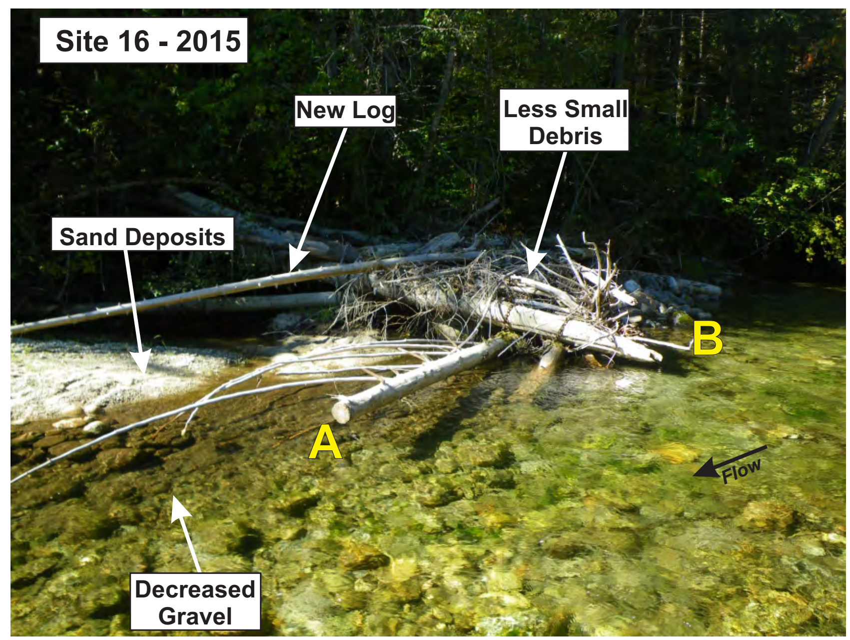
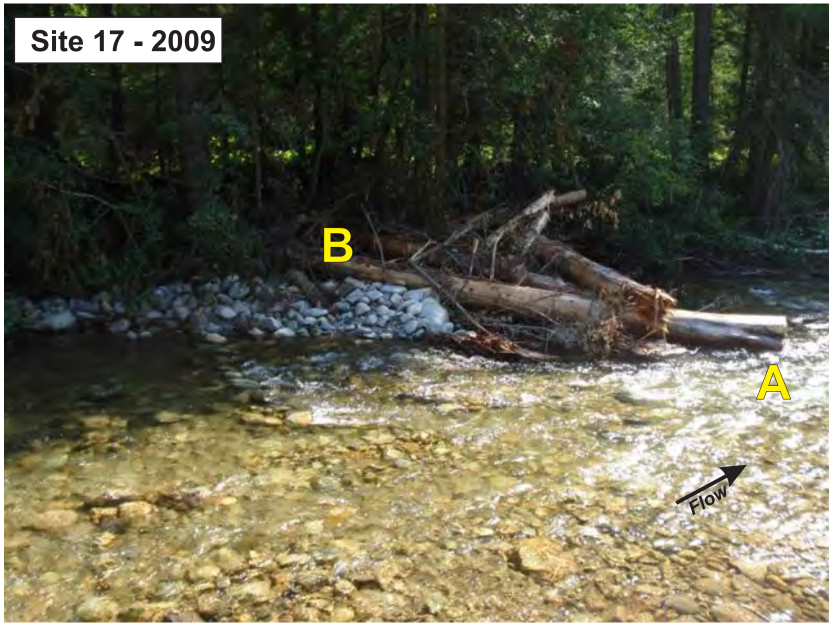
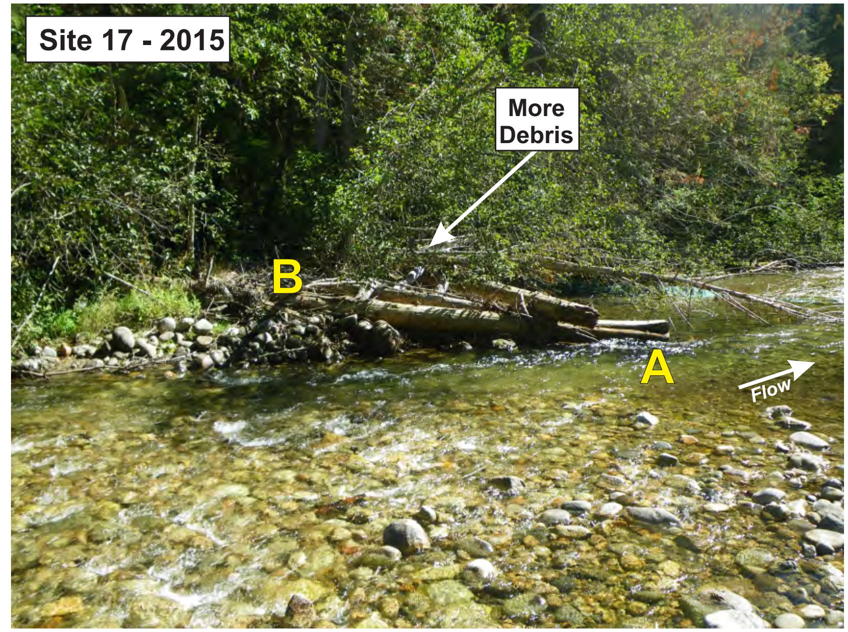




Notes:
Pool off structure tip
Good function and preventing bank erosion
Sand and gravel deposits downstream
Spawning gravel washed away

Lower Whatshan River Fish Habitat Enhancement Year 10 (2015)	
Site 16	Streamworks Unlimited NAITO ENVIRONMENTAL





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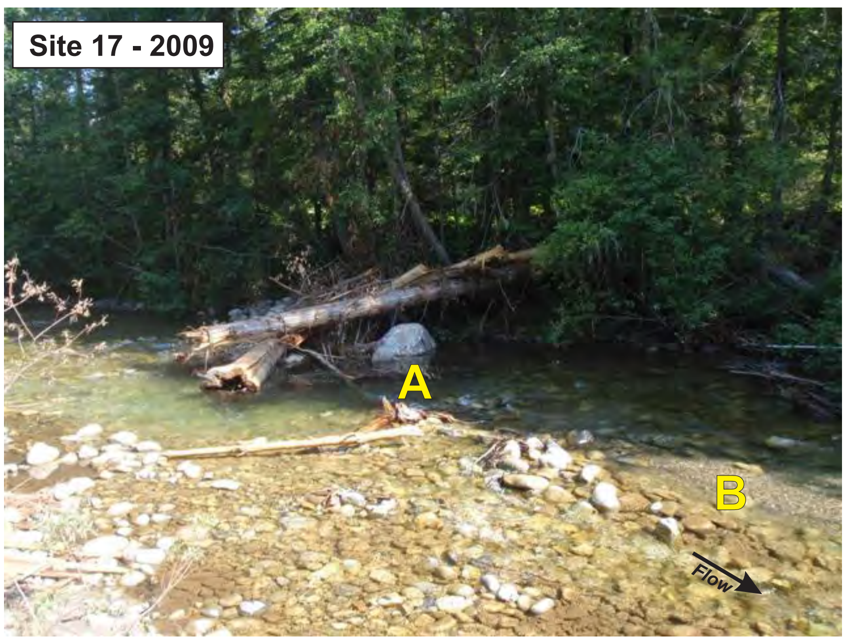
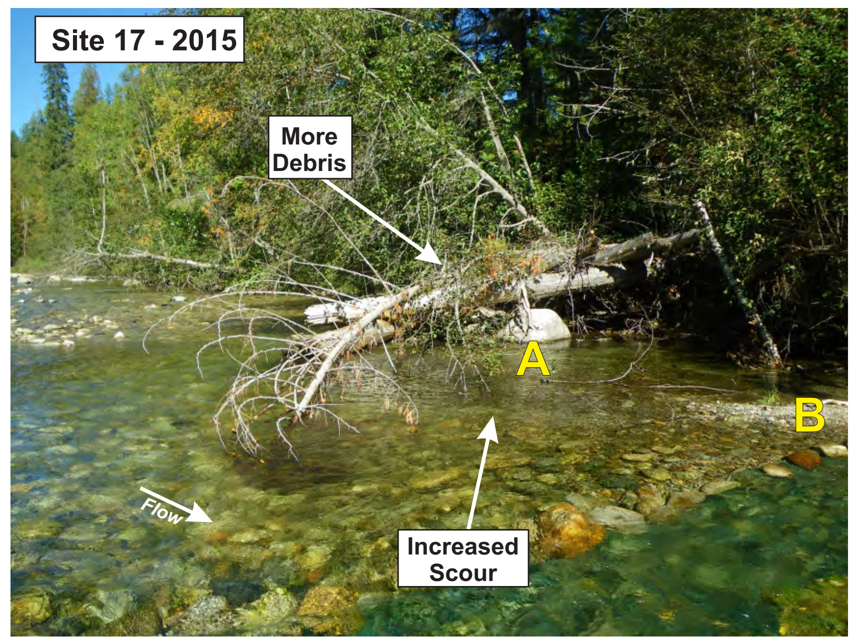
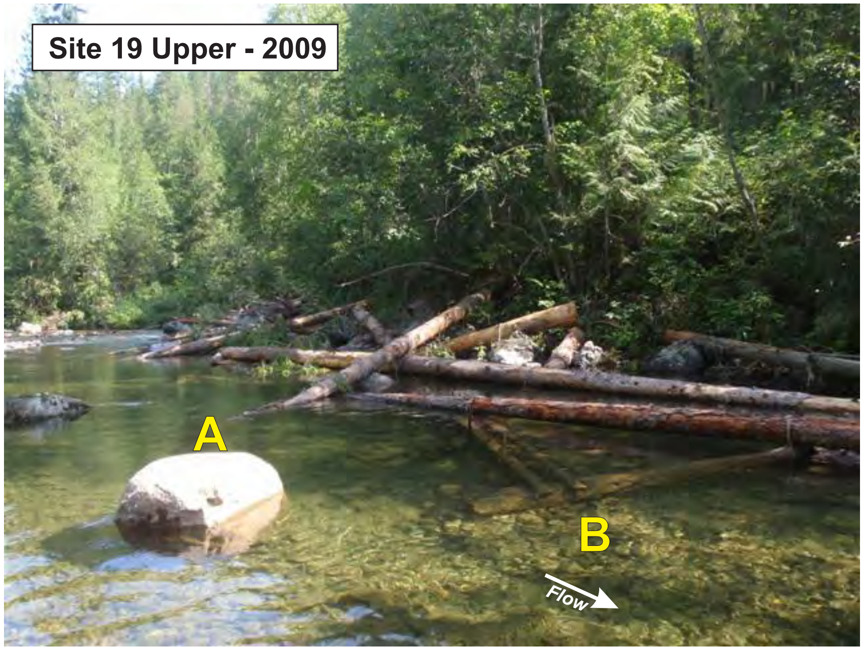
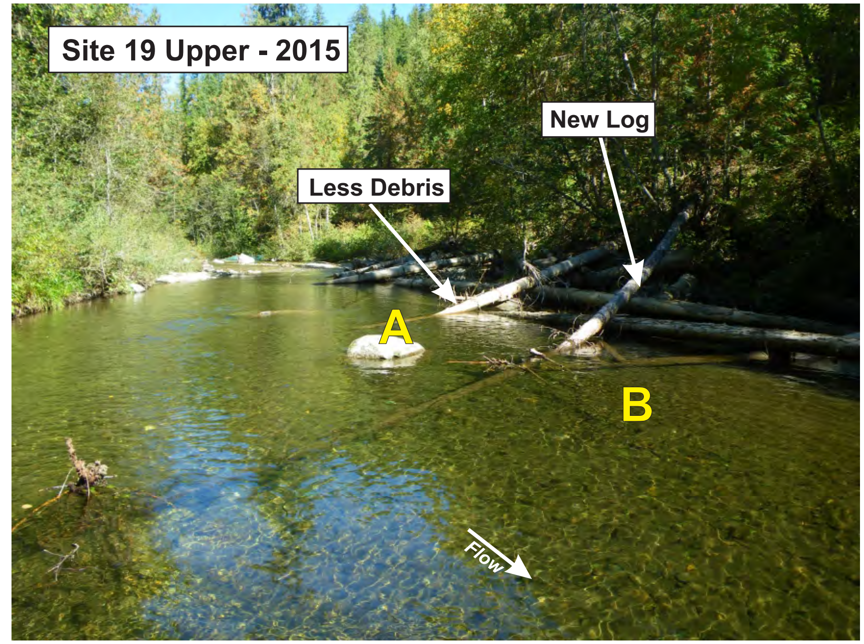




Notes:
Good scour off structure tip
New fallen trees and woody debris recruitment
Small gravel bar downstream
Through-flows have scoured pool downstream





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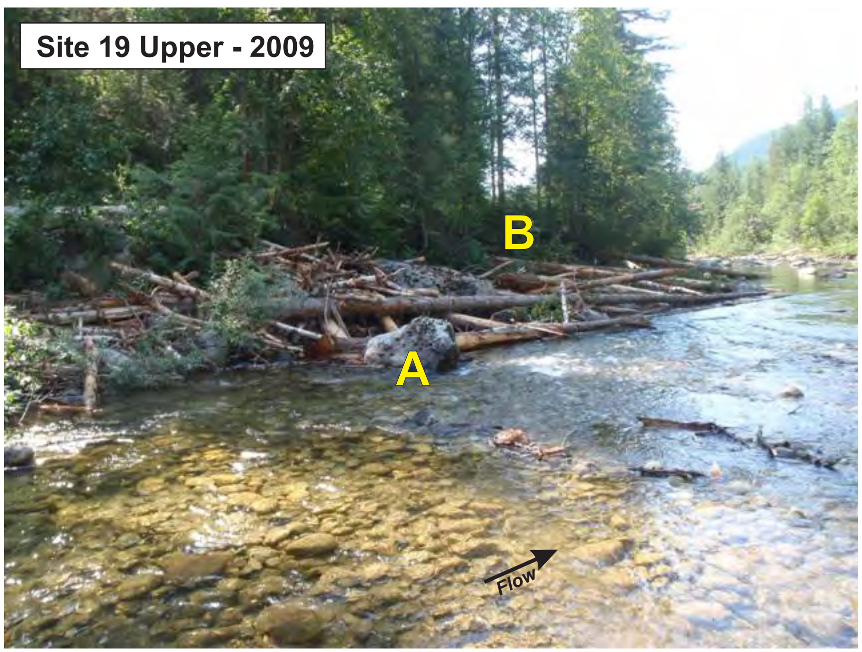
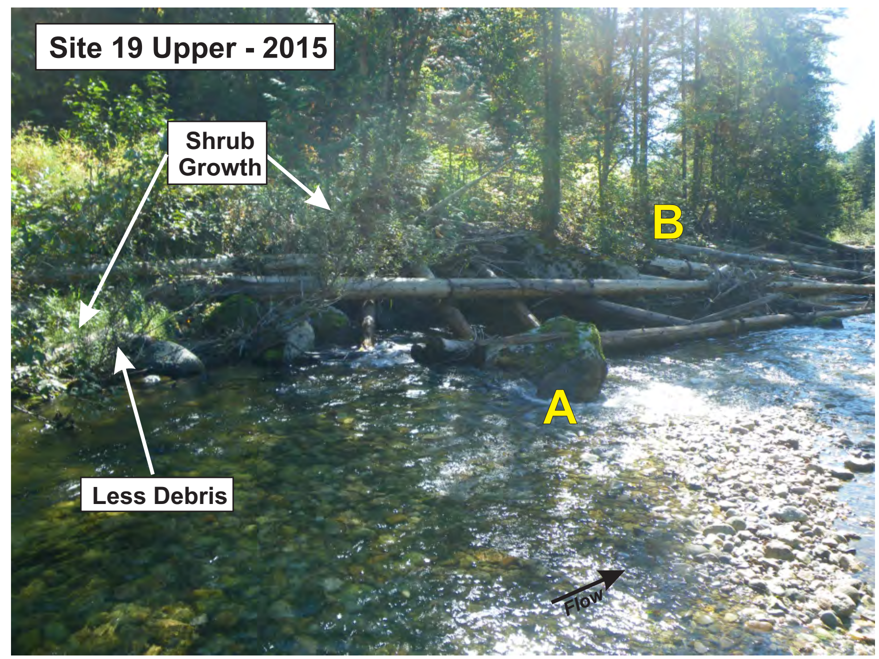
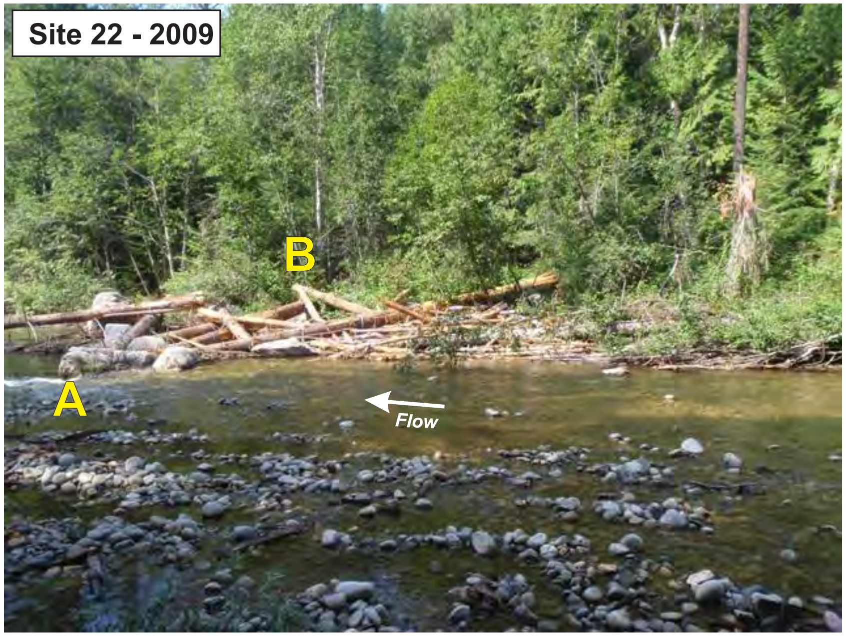


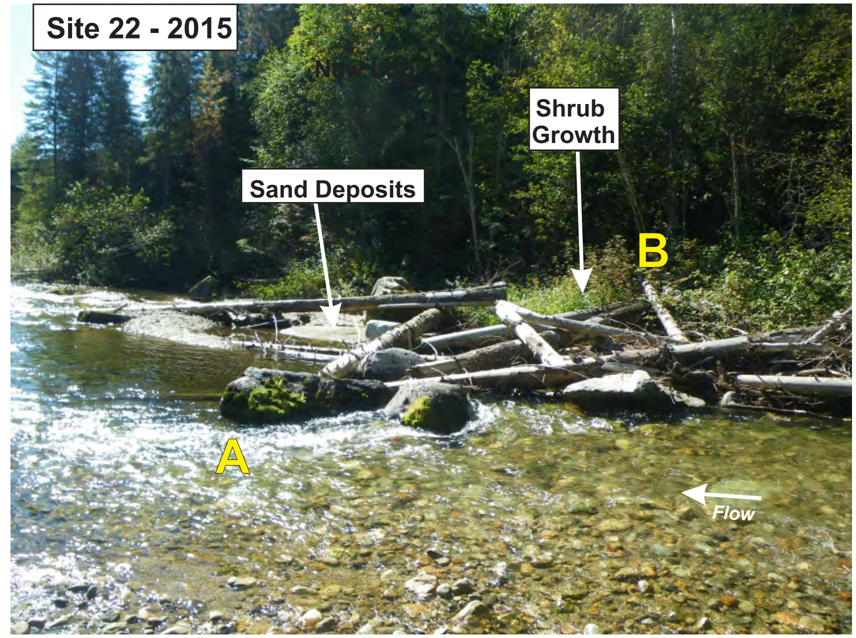


Notes:

Good habitat provided by low velocity, deep cover
Some loss of small debris but little change since installation
Some shrub growth and coarse sand deposits
Fish observed using cover

Lower Whatshan River Fish Habitat Enhancement Year 10 (2015)	
Site 19 Upper	Streamworks Unlimited / NAITO ENVIRONMENTAL





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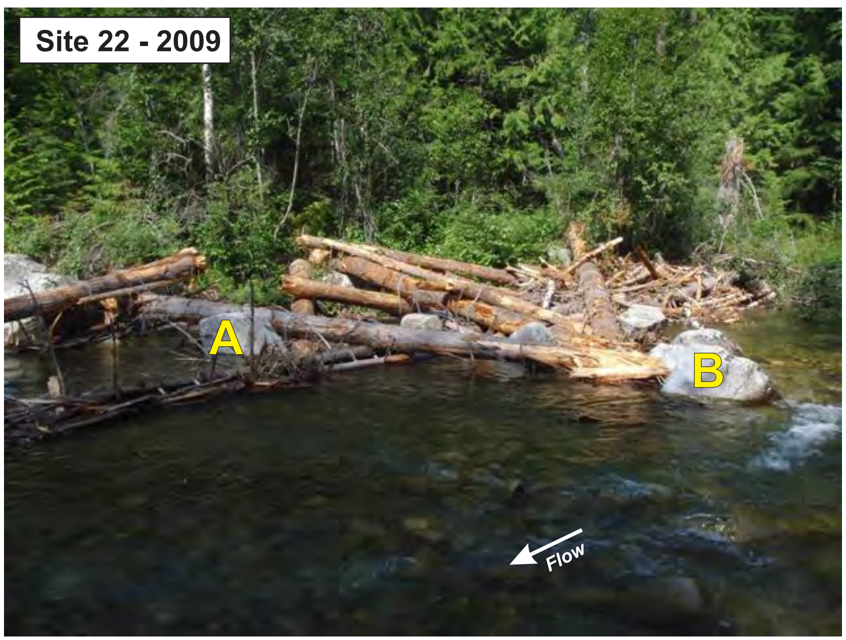
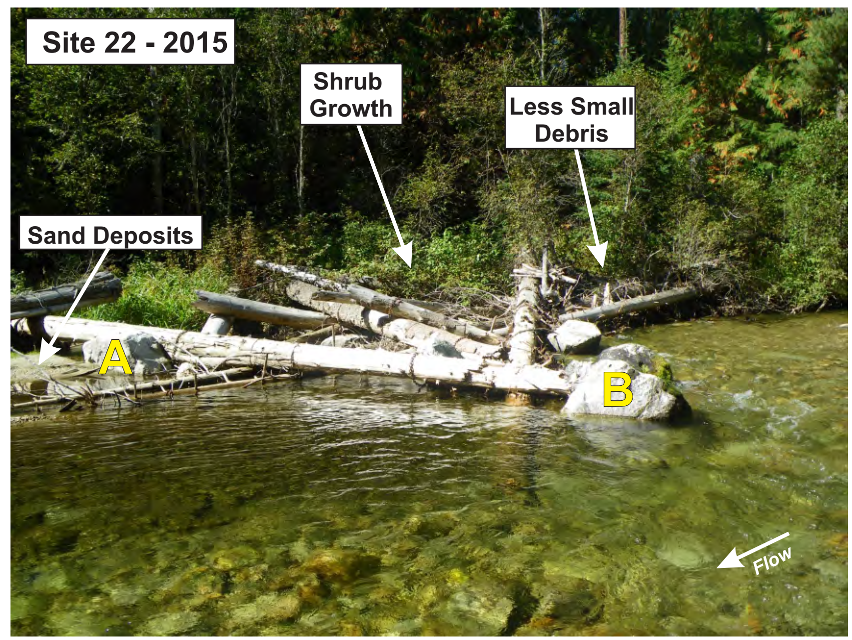
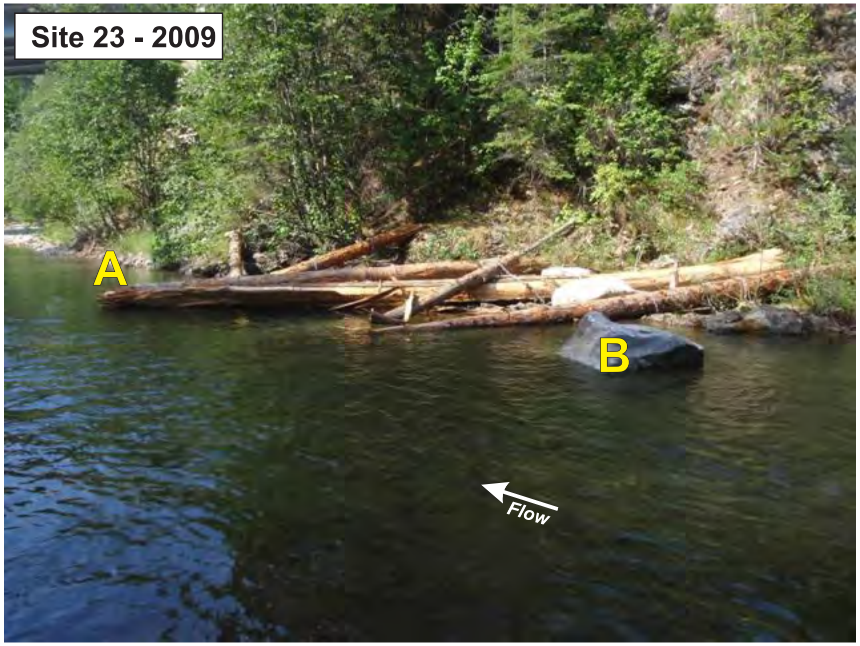
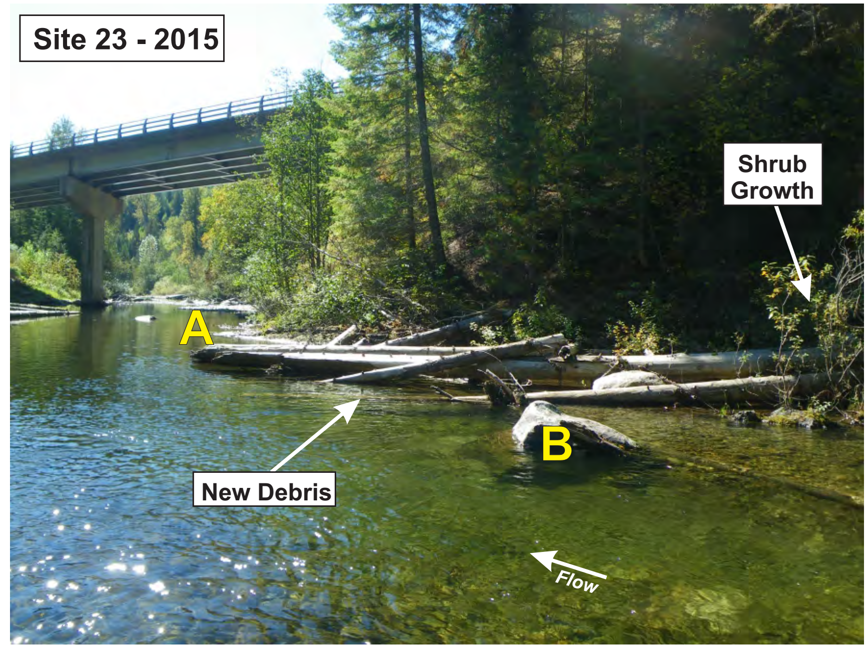




Notes:
Good function forcing channel to left
Mid-channel bar upstream with bright substrates
Sand and gravel deposits downstream
Finer material settleing behind larger rocks





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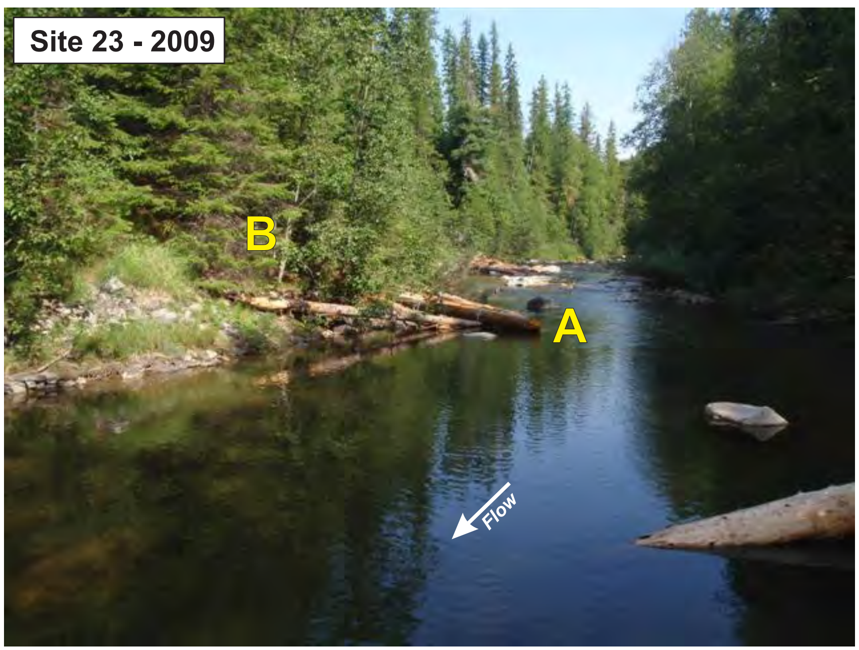
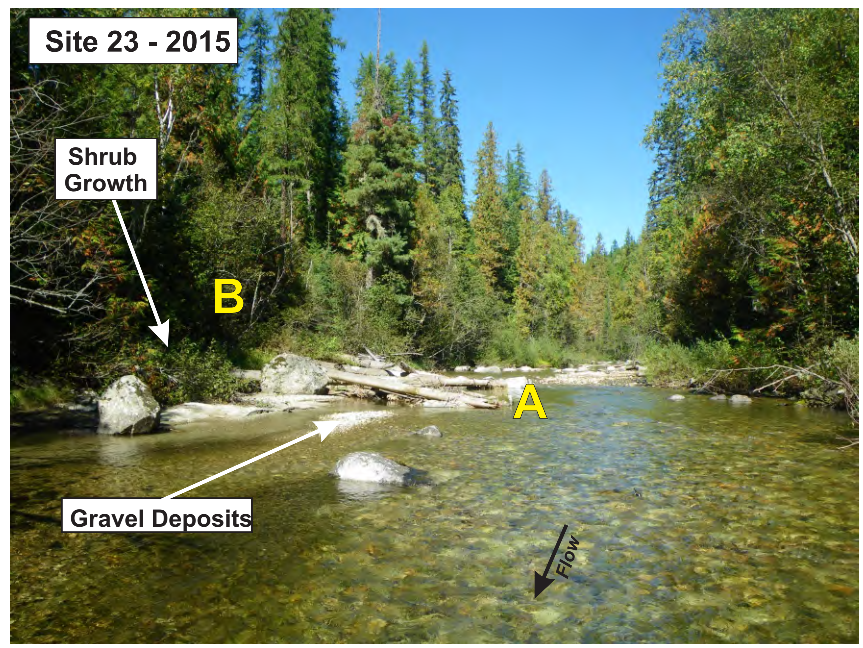
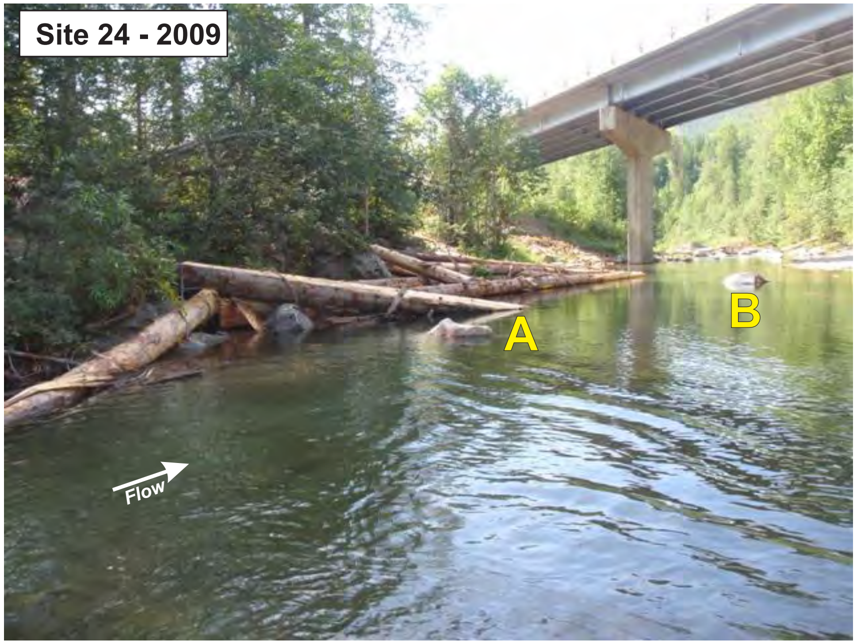
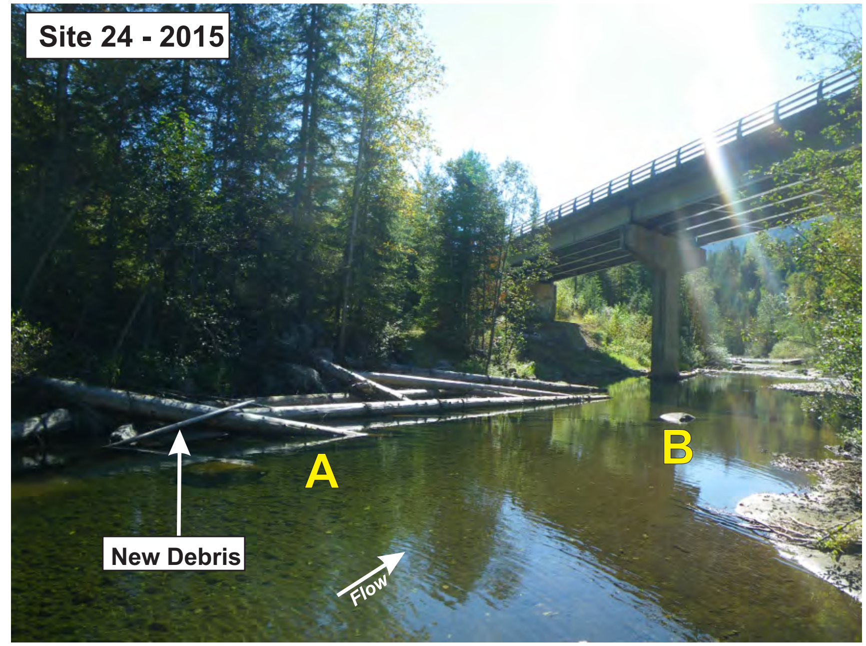




Notes:
No scour due to bedrock
Possible minor movement of logs
Gravel bar developing downstream
Good deep cover for fish

Lower Whatshan River Fish Habitat Enhancement Year 10 (2015)	
Site 23	Streamworks Unlimited / NAITO ENVIRONMENTAL





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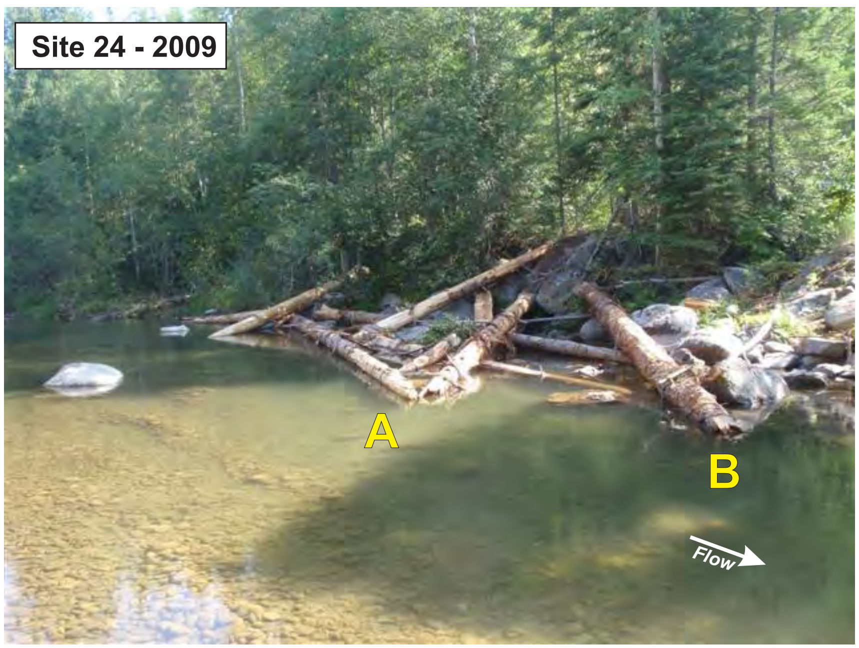
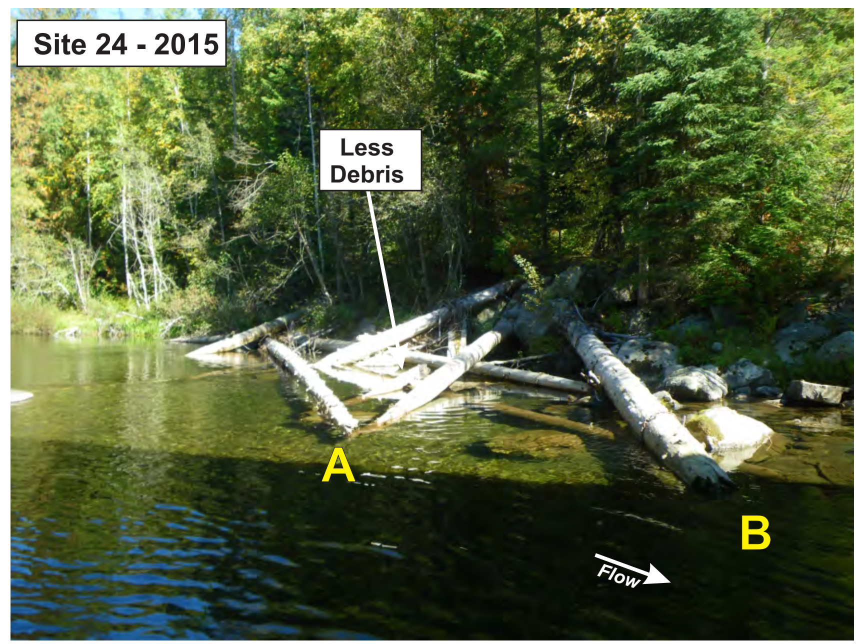




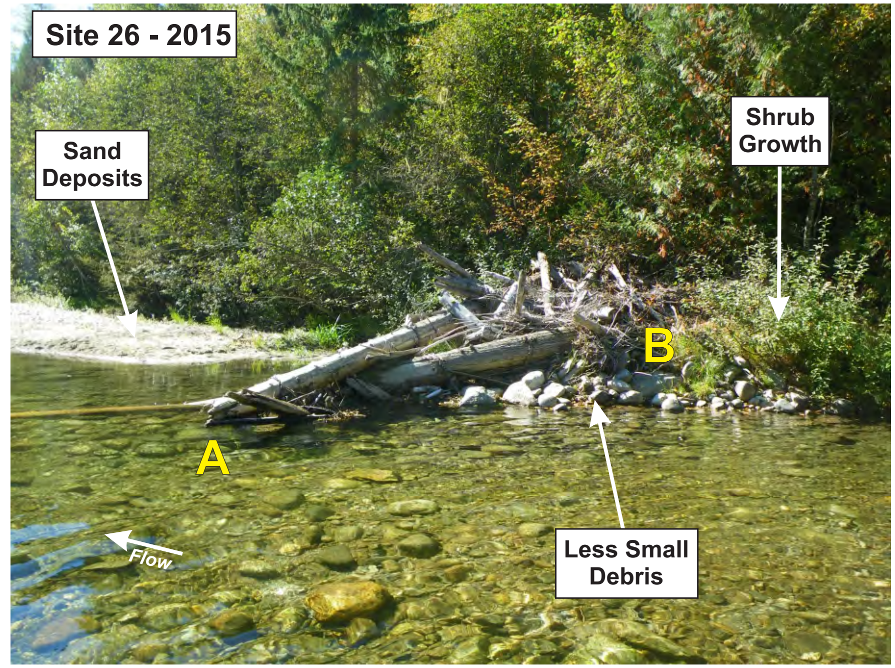
Notes:
Little change in low velocity channel section
Fish observed in deep cover
Some minor movement of logs possible
Some minor losses/gains to small debris

Lower Whatshan River Fish Habitat Enhancement Year 10 (2015)

Site 24

Streamworks Unlimited

NAITO ENVIRONMENTAL



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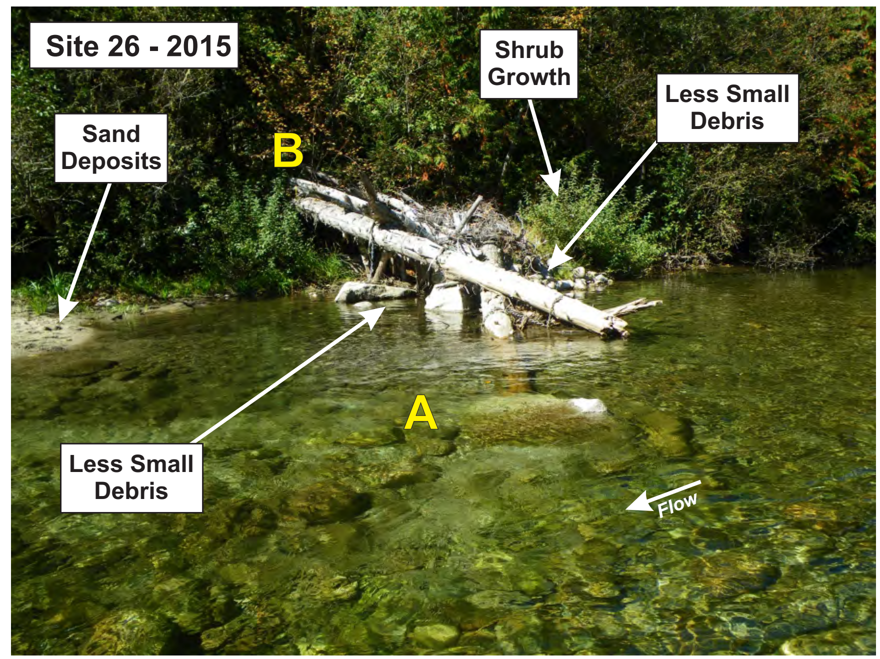
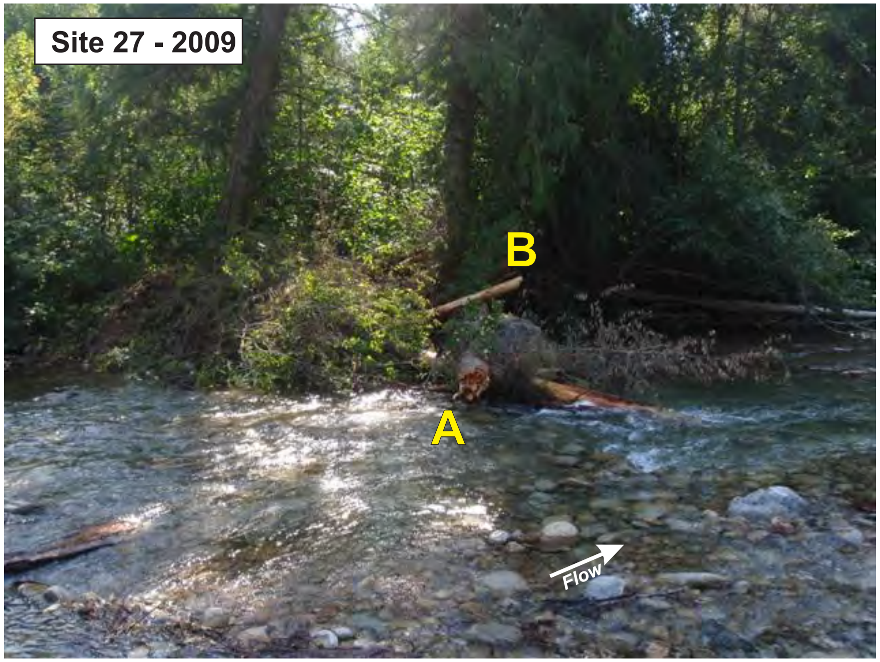
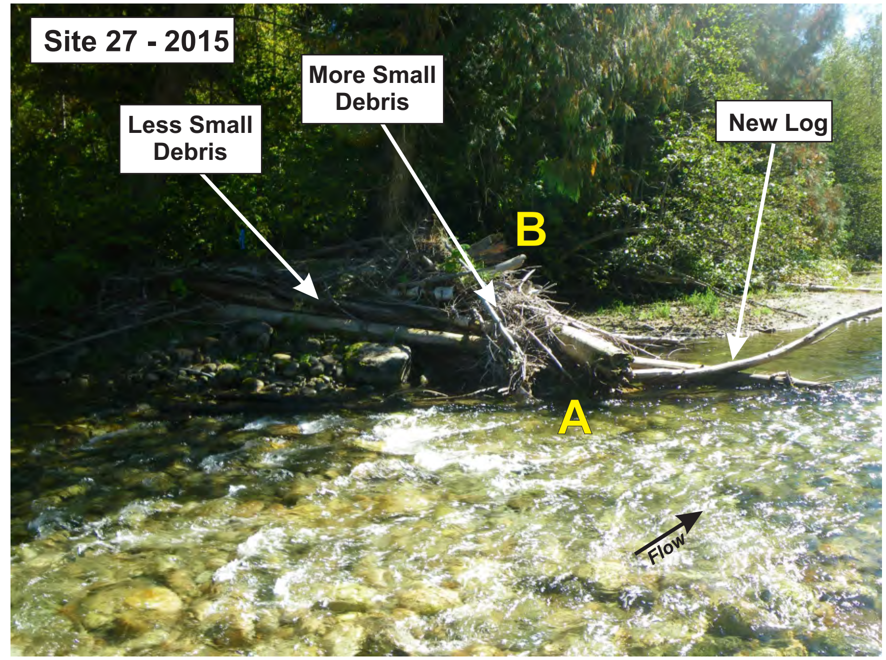


Notes:
Some scour off structure tip
Good woody debris recruitment
Sand deposits and enlarging bar downstream
Shrubs growing through debris upstream

Lower Whatshan River Fish Habitat Enhancement Year 10 (2015)	
Site 26	Streamworks Unlimited / NAITO ENVIRONMENTAL





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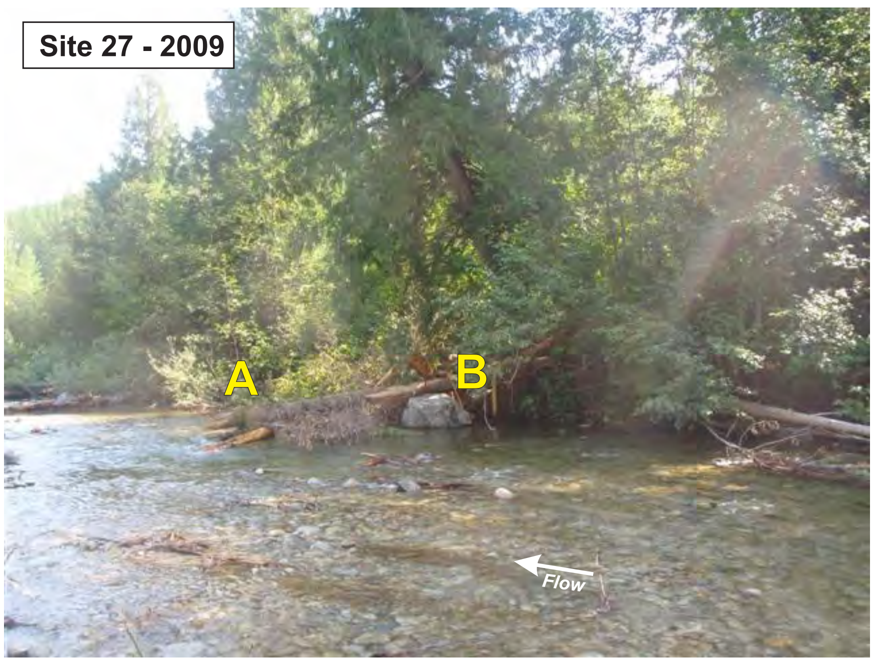
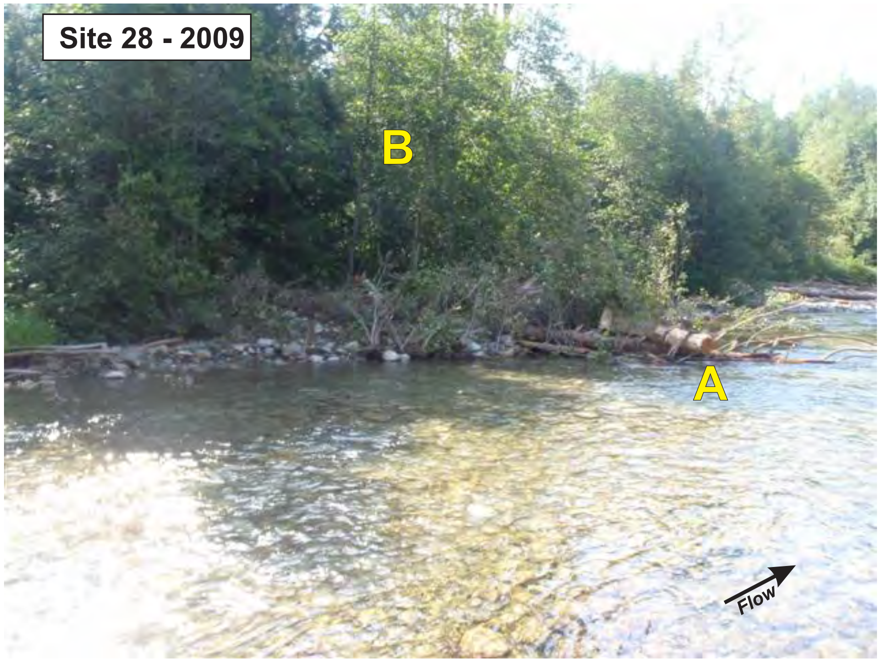


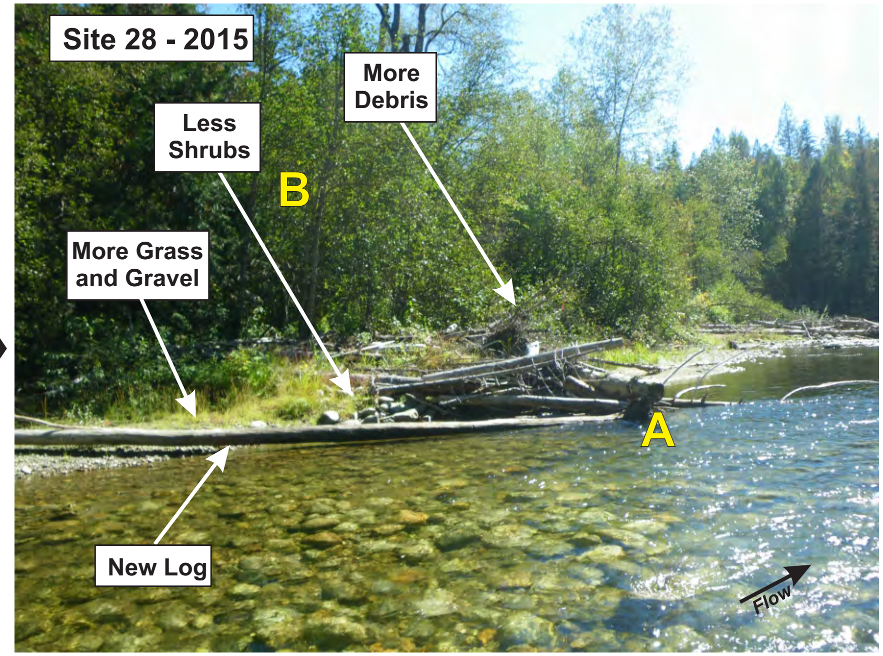
Notes:
Some scour off structure tip
Well-sealed with cobble and debris
Sand and gravel deposits downstream
New small log recruited

Lower Whatshan River Fish Habitat Enhancement Year 10 (2015)

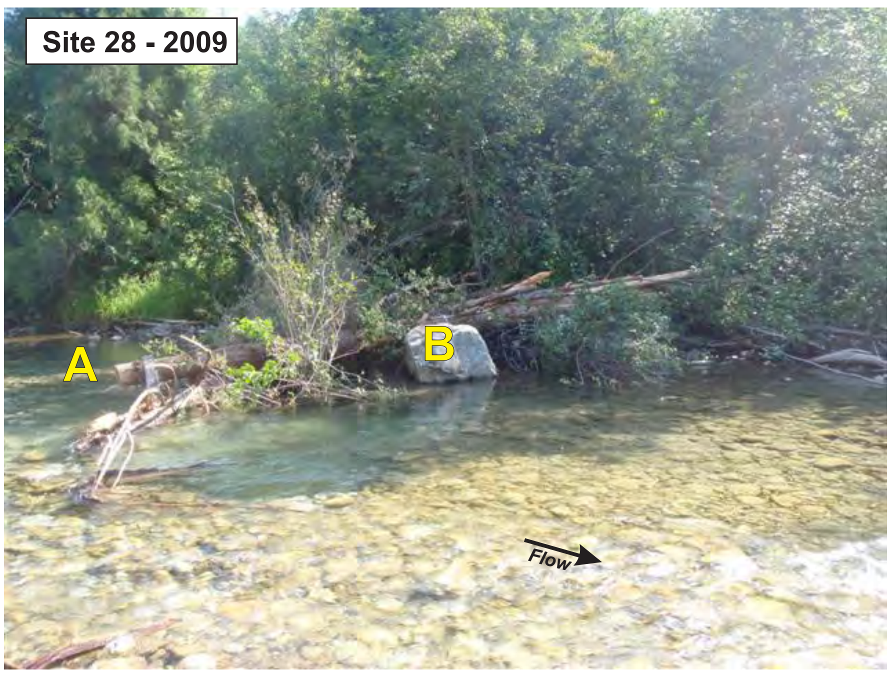
Site 27

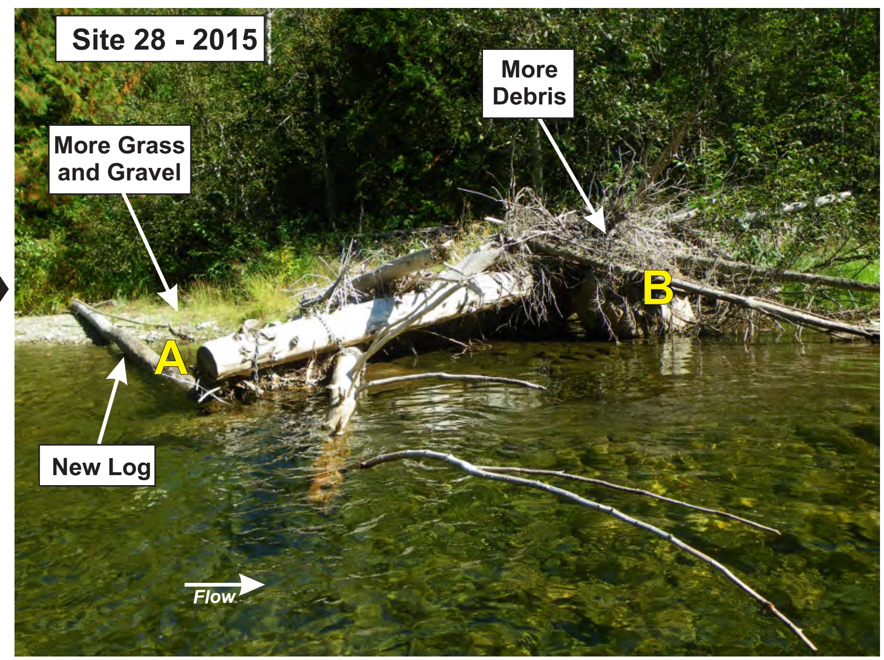
Streamworks Unlimited | NAITO ENVIRONMENTAL





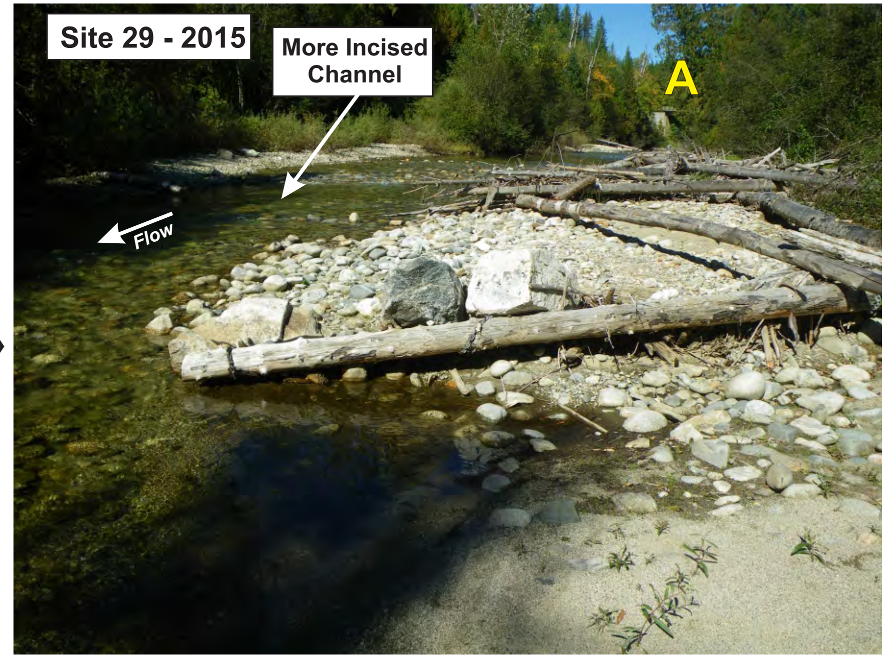
A and B demark identifiable reference points in each photo pair



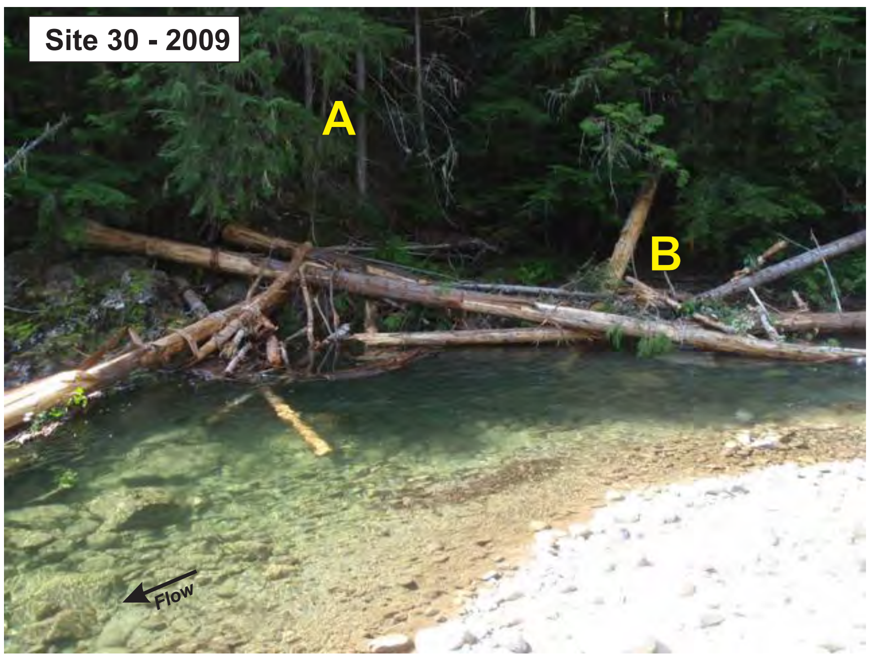


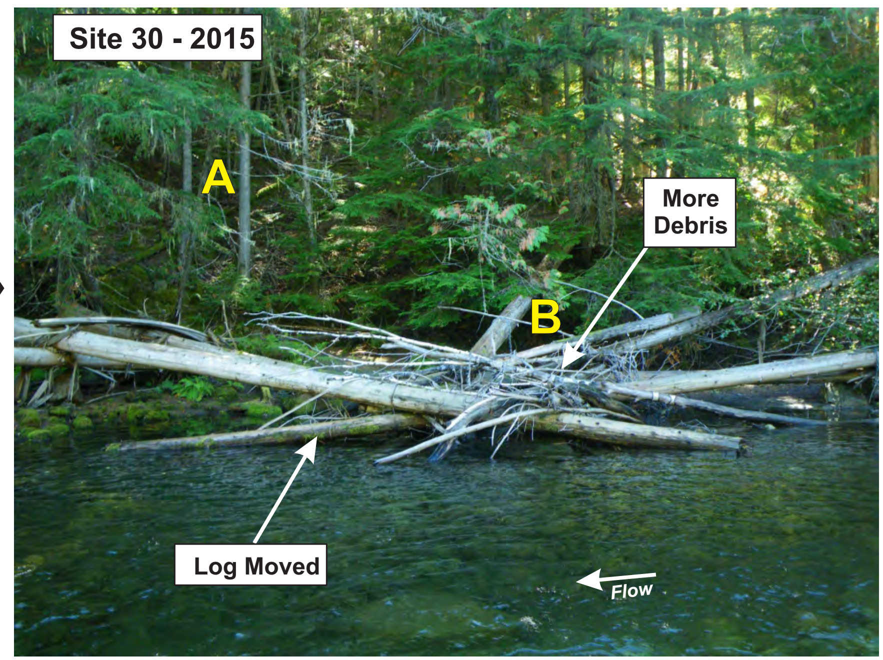
Notes:
Good scour pool off structure tip
Aggressive spur functioning well.
Sand deposits upstream and downstream
New log recruited upstream

Lower Whatshan River Fish Habitat Enhancement Year 10 (2015)	
Site 28	Streamworks Unlimited NAITO ENVIRONMENTAL



A and B demark identifiable reference points in each photo pair





Site 29 Notes:
Some logs and boulders have moved
Some debris recruitment and localized scour
Some sand deposits and substrate sorting
Channel has incised relative to cobble bar

Site 30 Notes:
No scour due to bedrock
Good deep water cover
Minor changes in log positions
Some debris recruitment

Lower Whatshan River Fish Habitat Enhancement Year 10 (2015)

Sites 29 and 30

APPENDIX 2

Whatshan W3.2 and Barnes B3 fish sampling photographs, Sept. 2015.

1. Whatshan P01 – Sta. 0+7.
2. Whatshan R02 – Sta. 0+57.
3. Whatshan G05 – Sta. 100+82.
4. Whatshan P04 – Sta. 200+10.
5. Whatshan R06 – Sta. 400 + 63.
6. Whatshan P07 – Sta. 500 + 26.
7. Whatshan SC1R – Sta. 500 + 16.
8. Whatshan G09 – Sta. 600 + 9.
9. Whatshan R10 – Sta. 900+ 2.
10. Whatshan P10 – Sta. 900 + 85.
11. Whatshan G13 – Sta. 1000 + 43.
12. Whatshan R17 – Sta. 1100+33.
13. Whatshan G17 – Sta. 1100+98
14. Barnes R03R – Sta. 0 + 41.
15. Barnes P02 – Sta. 100+70.
16. Barnes G04 – Sta. 200+1.
17. Barnes SC4L – Sta. 200+76.
18. Barnes R10 – Sta. 400+85.
19. Barnes G11 – Sta. 600+4.
20. Barnes P08 – Sta. 600 + 61.
21. Barnes SC74 – Sta. 600+74.
22. Barnes G17 – Sta. 900+79.
23. Barnes P13R – Sta. 1100+00.
24. Whatshan – Rainbow Trout fry.
25. Whatshan – Rainbow Trout adult.
26. Whatshan – Slimy Sculpin.
27. Whatshan – Eastern Brook Trout fry.
28. Barnes – Eastern Brook Trout adult
29. Whatshan – Longnose Dace
30. Whatshan – discharge transect.


Photo 1. Whatshan P01 – Sta. 0+7.


Photo 2. Whatshan R02 – Sta. 0+57.


Photo 3. Whatshan G05 – Sta. 100+82.


Photo 4. Whatshan P04 – Sta. 200+10.


Photo 5. Whatshan R06 – Sta. 400+63.


Photo 6. Whatshan P07 – Sta. 500+26.

Photo 7. Whatshan SC1R – Sta. 500+16.

Photo 8. Whatshan G09 – Sta. 600+9.

Photo 9. Whatshan R10 – Sta. 900+2.

Photo 10. Whatshan P10 – Sta. 900+85.

Photo 11. Whatshan G13 – Sta. 1000+43.

Photo 12. Whatshan R17 – Sta. 1100+33.


Photo 13. Whatshan G17 – Sta. 1100+98.


Photo 14. Barnes R03R – Sta. 0+41.


Photo 15. Barnes P02 – Sta. 100+70.


Photo 16. Barnes G04 – Sta. 200+1.


Photo 17. Barnes SC4L – Sta. 200+76.


Photo 18. Barnes R10 – Sta. 400+85.


Photo 19. Barnes G11 – Sta. 600+4.


Photo 20. Barnes P08 – Sta. 600+61.


Photo 21. Barnes SC7R – Sta. 600+74.


Photo 22. Barnes G17 – Sta. 900+79.


Photo 23. Barnes P13R – Sta. 1100+0.


Photo 24. Whatshan – Rainbow Trout fry.

Photo 25. Whatshan – Rainbow Trout adult.

Photo 26. Whatshan – Slimy Sculpin.

Photo 27. Whatshan – Eastern Brook Trout fry.

Photo 28. Barnes – Eastern Brook Trout adult.

Photo 29. Whatshan – Longnose Dace.

Photo 30. Whatshan – discharge transect.

APPENDIX 3. Physical Data for Whatshan W3.2 and Barnes B3 Fish Sample Sites, September 2015.

Reach	Site No.	Name	Type	Length	Width	Area	W1	W2	W3	W4	W5	W6	W7	MaxDep	R	B	C	G	F	LWD
W3.2	1	P01	pool	10.3	12.0	123	11.0	10.5	14.4					1.15	5	10	85	0	0	13.9
W3.2	2	R02	riffle	22.0	10.5	232	7.7	8.9	15.0					0.60	0	25	74	1	0	2.6
W3.2	3	G05	glide	26.9	15.1	406	15.3	14.2	17.1	13.8				0.85	0	15	55	30	0	6.2
W3.2	4	P04	pool	21.9	14.5	316	15.2	13.7						0.96	0	1	29	70	0	17.3
W3.2	5	R06	riffle	38.8	15.8	613	17.1	14.9	15.8	15.4				0.45	0	5	80	15	0	7.4
W3.2	6	P07	pool	12.5	10.4	130	12.1	11.8	7.4					0.85	0	30	40	30	0	4.2
W3.2	7	SC1R	side chnl	20.0	3.5	71	3.3	2.8	4.6	3.4				0.20	0	20	75	5	0	0.0
W3.2	8	G09	glide	14.2	11.8	168	12.7	12.0	11.5	11.1				0.70	0	40	55	5	0	8.3
W3.2	9	R10	riffle	18.7	14.0	261	14.8	12.9	14.3	13.9				0.53	0	15	80	5	0	3.0
W3.2	10	P10	pool	12.0	11.1	133	11.1	13.2	8.9					1.15	0	20	65	10	5	6.0
W3.2	11	G13	glide	16.6	14.2	235	12.5	15.8						0.70	0	40	50	10	0	2.8
W3.2	12	R17	riffle	16.3	13.2	216	16.0	12.4	11.3					0.41	0	25	72	3	0	3.4
W3.2	13	G17	glide	16.0	14.3	228	14.2	15.6	13.0					0.58	0	10	85	5	0	3.4
B3	1	R03R	riffle	29.5	8.6	253	10.5	8.9	6.3					0.40	0	10	85	5	0	0.0
B3	2	P02	pool	16.6	11.4	189	12.0	10.9	11.3					0.91	0	1	94	5	0	6.5
B3	3	G04	glide	12.7	8.5	108	8.4	9.0	8.1					0.80	0	5	85	10	0	0.6
B3	4	SC4L	side chnl	24.3	1.6	39	2.8	1.0	2.2	2.0	1.7	0.8	0.6	0.38	0	20	55	25	0	1.7
B3	5	R10	riffle	16.1	8.0	128	7.6	8.3						0.35	0	20	80	0	0	0.0
B3	6	G11	glide	14.2	9.1	129	9.4	9.9	7.9					0.80	0	0	97	3	0	0.0
B3	7	P08	pool	17.3	7.6	132	7.6	8.6	7.4	6.9				1.16	0	0	65	30	5	9.0
B3	8	SC7R	side chnl	25.0	4.5	112	3.6	5.5	4.6	5.2	3.5			0.65	0	0	60	35	5	13.8
B3	9	G17	glide	15.0	9.9	148	10.6	10.4	8.6					0.61	0	20	80	0	0	0.0
B3	10	R17	riffle	17.0	9.5	162	8.6	9.9	10.1					0.31	0	20	80	0	0	0.0
B3	11	P13R	pool	16.0	8.9	143	8.2	10.7	8.5	8.3				0.86	0	40	45	15	0	16.4

APPENDIX 3. Physical Data for Whatshan W3.2 and Barnes B3 Fish Sample Sites, September 2015.

Reach	Site No.	Name	SWD	Bldr	UCB	OH	DP	CovTot1	CovTot2	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14
W3.2	1	P01	2.0	5.6	0.0	0.0	40.0	21.5	61.5	0.1	0.15	0.30	0.50	0.87	0.85	0.68	1.05	0.97	0.92	0.81	0.15		
W3.2	2	R02	0.0	15.5	0.0	0.0	0.0	18.1	18.1	0.15	0.38	0.30	0.48	0.43	0.36	0.30	0.31	0.16	0.16	0.10	0.06	0.03	
W3.2	3	G05	1.0	20.0	0.0	1.0	0.0	28.2	28.2	0.18	0.33	0.39	0.52	0.54	0.65	0.71	0.56	0.54	0.56	0.65	0.55	0.48	0.51
W3.2	4	P04	0.5	2.0	0.8	2.0	2.0	22.6	24.6	0.02	0.11	0.13	0.31	0.41	0.59	0.70	0.46	0.38	0.40	0.40	0.55	0.69	0.74
W3.2	5	R06	8.0	34.0	0.0	12.0	0.0	61.4	61.4	0.12	0.1	0.09	0.15	0.20	0.19	0.19	0.18	0.21	0.26	0.26	0.25	0.31	0.05
W3.2	6	P07	1.5	5.5	0.0	2.0	9.0	13.2	22.2	0.15	0.31	0.37	0.50	0.80	0.38	0.47	0.35	0.25	0.24	0.15			
W3.2	7	SC1R	2.0	4.0	0.0	6.0	0.0	12.0	12.0	0.07	0.11												
W3.2	8	G09	2.5	12.0	0.1	0.5	1.0	23.4	24.4	0.14	0.19	0.21	0.35	0.41	0.36	0.37	0.61	0.36	0.25	0.16			
W3.2	9	R10	0.1	5.5	0.0	2.0	0.0	10.6	10.6	0.09	0.13	0.15	0.21	0.24	0.23	0.31	0.33	0.35	0.38	0.30	0.41	0.17	
W3.2	10	P10	1.0	10.0	0.0	0.0	25.0	17.0	42.0	0.25	0.5	0.63	0.81	0.71	0.64	0.46	0.54	0.52	0.55	0.37	0.12		
W3.2	11	G13	2.0	10.0	0.8	2.0	0.0	17.6	17.6	0.10	0.15	0.31	0.30	0.37	0.52	0.60	0.55	0.46	0.42	0.36	0.35		
W3.2	12	R17	0.5	23.0	0.1	0.6	0.0	27.6	27.6	0.04	0	0.05	0.08	0.06	0.07	0.07	0.14	0.14	0.05	0.08	0.16	0.15	0.17
W3.2	13	G17	4.0	4.6	0.0	0.1	0.0	12.1	12.1	0.05	0.12	0.14	0.18	0.27	0.31	0.35	0.27	0.45	0.42	0.45	0.43	0.35	0.13
B3	1	R03R	3.5	0.0	0.0	15.0	0.0	18.5	18.5	0.08	0.07	0.11	0.20	0.21	0.27	0.31							
B3	2	P02	2.5	1.3	1.0	0.5	10.0	11.8	21.8	0.13	0.16	0.25	0.28	0.34	0.31	0.50	0.69	0.80	0.93				
B3	3	G04	0.8	3.4	0.7	0.2	4.0	5.7	9.7	0.08	0.15	0.27	0.40	0.58	0.55	0.43	0.33						
B3	4	SC4L	0.5	1.2	0.5	2.4	0.0	6.3	6.3	0.14													
B3	5	R10	0.0	15.0	0.0	0.5	0.0	15.5	15.5	0.03	0.05	0.10	0.16	0.31	0.22	0.11							
B3	6	G11	1.0	0.3	3.4	1.0	0.0	5.7	5.7	0.06	0.05	0.15	0.23	0.31	0.46	0.56	0.55	0.51					
B3	7	P08	2.0	0.5	5.0	1.0	25.0	17.5	42.5	0.38	0.53	0.66	0.81	0.74	0.40	0.06							
B3	8	SC7R	2.0	0.0	6.0	1.5	0.0	23.3	23.3	0.22	0.25	0.19	0.34	0.25									
B3	9	G17	0.0	12.4	0.0	0.0	0.0	12.4	12.4	0.15	0.25	0.43	0.48	0.45	0.42	0.34	0.15	0.03					
B3	10	R17	0.0	10.0	0.0	1.0	0.0	11.0	11.0	0.08	0.15	0.18	0.25	0.22	0.23	0.18	0.15	0.11					
B3	11	P13R	1.0	9.0	4.0	0.0	30.0	30.4	60.4	0.23	0.37	0.61	0.75	0.73	0.65	0.51							

APPENDIX 3. Physical Data for Whatshan W3.2 and Barnes B3 Fish Sample Sites, September 2015.

Reach	Site No.	Name	D15	D16	D17	D18	D19	D20	Davg	Dmax	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14
W3.2	1	P01							0.61	1.05	0.00	0.07	0.34	0.32	0.22	0.12	0.00	0.00	0.00	0.00	0.00	0.00		
W3.2	2	R02							0.25	0.48	0.24	0.02	0.07	0.62	0.73	0.41	0.16	0.54	0.53	0.62	0.71	0.21	0.33	
W3.2	3	G05	0.33	0.20	0.00				0.45	0.71	0.01	0.11	0.19	0.27	0.29	0.19	0.29	0.09	0.38	0.08	0.05	0.01	0.10	0.02
W3.2	4	P04	0.58						0.43	0.74	0.01	0.02	0.02	0.03	0.05	0.01	0.07	0.18	0.29	0.13	0.16	0.25	0.41	0.06
W3.2	5	R06							0.18	0.31	0.34	0.14	0.16	0.41	0.25	0.17	0.17	0.43	0.08	0.47	0.65	0.48	0.12	0.00
W3.2	6	P07							0.36	0.80	0.02	0.00	0.16	0.42	0.25	0.05	0.01	0.02	0.01	0.00	0.01			
W3.2	7	SC1R							0.09	0.11	0.02	0.00												
W3.2	8	G09							0.31	0.61	0.18	0.40	0.38	0.32	0.49	0.55	0.02	0.21	0.22	0.06	0.02			
W3.2	9	R10							0.25	0.41	0.00	0.04	0.08	0.18	0.18	0.29	0.24	0.42	0.48	0.06	0.34	0.03	0.02	
W3.2	10	P10							0.51	0.81	0.04	0.11	0.08	0.09	0.02	0.02	0.02	0.54	0.40	0.19	0.05	0.02		
W3.2	11	G13							0.37	0.60	0.12	0.15	0.04	0.12	0.16	0.18	0.14	0.20	0.28	0.23	0.13	0.02		
W3.2	12	R17	0.05						0.09	0.17	0.09		0.08	0.25	0.21	0.42	0.45	0.05	0.64	0.25	0.55	1.05	0.61	0.87
W3.2	13	G17							0.28	0.45	0.00	0.05	0.18	0.15	0.14	0.31	0.36	0.34	0.23	0.22	0.08	0.07	0.06	0.01
B3	1	R03R							0.18	0.31	0.21	0.25	0.68	0.62	0.58	0.40	0.63							
B3	2	P02							0.44	0.93	0.00	0.01	0.01	0.11	0.01	0.01	0.13	0.24	0.19	0.23				
B3	3	G04							0.35	0.58	0.07	0.14	0.18	0.23	0.28	0.32	0.21	0.03						
B3	4	SC4L							0.14	0.14	0.01													
B3	5	R10							0.14	0.31	0.15	0.06	0.30	0.77	0.37	0.31	0.45							
B3	6	G11							0.32	0.56	0.00	0.00	0.02	0.05	0.31	0.23	0.24	0.02	0.00					
B3	7	P08							0.51	0.81	0.02	0.11	0.26	0.12	0.01	0.00	0.00							
B3	8	SC7R							0.25	0.34	0.00	0.00	0.00	0.00	0.00									
B3	9	G17							0.30	0.48	0.06	0.24	0.17	0.22	0.21	0.15	0.05	0.01	0.00					
B3	10	R17							0.17	0.25	0.04	0.35	0.01	0.40	0.46	0.29	0.52	0.35	0.26					
B3	11	P13R							0.55	0.75	0.00	0.04	0.19	0.03	0.00	0.02	0.08							

APPENDIX 3. Physical Data for Whatshan W3.2 and Barnes B3 Fish Sample Sites, September 2015.

Reach	Site No.	Name	V15	V16	V17	V18	V19	Vavg	Vmax
W3.2	1	P01						0.09	0.34
W3.2	2	R02						0.40	0.73
W3.2	3	G05	0.01	0.00				0.13	0.38
W3.2	4	P04	0.01					0.11	0.41
W3.2	5	R06						0.28	0.65
W3.2	6	P07						0.09	0.42
W3.2	7	SC1R						0.01	0.02
W3.2	8	G09						0.26	0.55
W3.2	9	R10						0.18	0.48
W3.2	10	P10						0.13	0.54
W3.2	11	G13						0.15	0.28
W3.2	12	R17	0.15					0.41	1.05
W3.2	13	G17						0.16	0.36
B3	1	R03R						0.48	0.68
B3	2	P02						0.09	0.24
B3	3	G04						0.18	0.32
B3	4	SC4L						0.01	0.01
B3	5	R10						0.34	0.77
B3	6	G11						0.10	0.31
B3	7	P08						0.07	0.26
B3	8	SC7R						0.00	0.00
B3	9	G17						0.12	0.24
B3	10	R17						0.30	0.52
B3	11	P13R						0.05	0.19

APPENDIX 4a. Habitat unit physical data for Whatshan W3.2, September 2015.

2015 Unit	Type	Description	Stn1	Stn2	Distance	Area	sc/bc	Length	WidAvg	W1	W2	W3	W4	W5	W6	W7	W8	LWD	SWD	B	UC	OH	DP	CovTot1	CovTot2	Spawn	R
G01	glide	pool tailout	0	0	0	98		7.0	14.0	16.9	11.0							0	0	1	0	0	0	1	1	2	85
P01	pool	bedrock corner	0	7	7	123		10.3	12.0	11.0	10.5	14.4						13.9	2	5.6	0	0	40	21.5	61.5	0	5
R01	riffle		0	17	17	79		10.5	7.6	7.6	7.5							0	1	1.5	0	1	0	3.5	3.5	0	0
G02	glide	pool tailout	0	28	28	45		6.3	7.2	7.5	6.8							0	0	0.4	0	0	0	0.4	0.4	0	0
P02	pool	large log jam pool	0	34	34	195		22.6	8.6	6.8	8.7	12.5	7.9	7.3				68.3	2	1	5	0.5	39	76.8	115.8	6	0
R02	riffle		0	57	57	435		43.2	10.1	7.9	10.9	7.7	8.9	15.0				5.1	0	19.5	0	0	0	24.6	24.6	6	0
G03	glide		0	89	89	313		22.4	14.0	15.8	14.0	12.1						0	0.5	36	0	0.5	0	37	37	50	0
P03	pool	triangular log jam	100	11	111	313		22.4	14.0	15.8	14.0	12.1						6.6	4	4.5	0.3	5.5	15	20.9	35.9	15	0
G04	glide	very riffle-like	100	22	122	406		29.2	13.9	18.4	13.7	11.5	12.0					4.7	2.5	31	0	0	0	38.2	38.2	50	0
R03	riffle		100	49	149	469		32.6	14.4	12.0	15.7	15.8	13.1	15.3				5.8	1	14	0	6	0	26.8	26.8	7	0
G05	glide	rt bank triangular log jam	100	82	182	406		26.9	15.1	15.1	15.3	14.2	17.1	13.8				6.2	1	20	0	1	0	28.2	28.2	29	0
P04	pool		200	10	210	495		36.1	13.7	13.8	9.8	13.1	14.5	17.3				23.9	2	4	1.4	10.5	35	41.8	76.8	60	0
G06	glide		200	46	246	152		9.4	16.2	17.1	17.6	13.8						0.8	0.5	4.8	0.0	2.0	0.0	8.1	8.1	3.5	0
R04	riffle		200	55	255	105		7.2	14.7	14.8	14.5							1.3	1.0	3.8	0.0	0.5	0.0	6.6	6.6	1	0
G07	glide	d/s side of highway bridge	200	62	262	135		9.1	14.8	15.4	14.8	14.2						1.7	0.0	0.8	0.0	0.0	0.0	2.5	2.5	0	0
P05	pool	u/s side of highway bridge	200	71	271	912		64.8	14.1	14.2	15.1	16.4	13.5	12.8	12.4			62.1	3.0	20.0	0.0	3.0	128.0	88.1	216.1	0	0
R05	riffle	rt bank triangular log jam	300	36	336	961		59.4	16.2	14.4	16.2	13.0	18.5	18.8				24.0	3.5	10.0	0.0	7.0	0.0	44.5	44.5	90	0
G08	glide	boulder garden	300	95	395	415		23.2	17.9	18.8	17.8	17.1						9.2	1.0	20.0	0.5	4.5	0.0	35.2	35.2	45	0
P06	pool	corner with LWD addition	400	18	418	665		45.0	14.8	17.1	14.8	14.0	13.2					73.4	6.5	55.0	1.0	2.0	123.0	137.9	260.9	13	0
R06	riffle		400	63	463	900		62.5	14.4	15.0	16.4	14.1	15.0	13.8	12.1			7.4	8.0	34.0	0.0	12.0	0.0	61.4	61.4	23	0
P07	pool	lt bank triangular log jam	500	26	526	130		12.5	10.4	12.1	11.8	7.4						4.2	1.5	5.5	0.0	2.0	9.0	13.2	22.2	6	0
R07	riffle		500	39	539	806		61.7	13.1	8.0	11.4	10.8	11.1	15.9	21.2			11.8	3.0	30.0	0.0	20.5	0.0	65.3	65.3	11	0
G09	glide	tri LJ 20 m from d/s end	600	9	609	1416		86.4	16.4	21.2	20.4	19.8	15.4	10.6	10.9			43.6	4.0	42.0	0.0	22.0	0.0	111.6	111.6	52	0
P08	pool	lt bank triangular log jam	600	95	695	123		8.3	14.9	14.2	15.3	15.1						7.9	1.0	8.0	0.0	3.0	14.0	19.9	33.9	5	0
R07	riffle		700	1	701	468		33.7	13.9	15.1	13.3	12.1	16.0	12.9				8.1	0.5	16.0	0.0	1.0	0.0	25.6	25.6	75	0
SC1R	s/b chnl		500	16	516	232	86.0	86.0	2.7	3.4	0.8	1.2	2.6	3.8	4.4			10.1	2.0	3.0	0.0	13.0	0.0	28.1	28.1	14	0
P09	pool	rt bank triangular log jam	700	35	735	215		20.8	10.4	12.9	9.6	8.7	10.2					8.5	2.5	19.0	0.0	6.0	20.0	36	56	8	0
G10	glide		700	56	756	447		41.6	10.8	10.2	9.2	10.0	12.4	10.0	12.7			0.0	0.0	28.0	0.0	7.0	0.0	35	35	1	0
R08	riffle	uniform	700	95	795	938		72.4	13.0	12.7	11.9	12.0	15.2					2.3	4.0	22.0	0.0	29.0	0.0	57.3	57.3	2	0
G11	glide		800	67	867	492		31.4	15.7	15.2	16.1	15.7						0.0	1.0	13.5	0.0	1.0	0.0	15.5	15.5	3	0
R10	riffle	u/s side of Barnes bridge; very glide-like	900	2	902	891		67.1	13.3	15.7	13.7	13.5	12.8	10.7				4.0	0.5	18.0	0.0	1.0	0.0	23.5	23.5	5.5	0
G12	glide		900	69	969	164		16.0	10.3	10.7	9.0	11.1						20.0	0.0	17.0	0.0	0.0	0.0	37	37	5	0
P10	pool	lt bank triangular log jam	900	85	985	133		12.0	11.1	11.1	13.2	8.9						6.0	1.0	10.0	0.0	0.0	25.0	17	42	0	0
R11	riffle		900	97	997	133		14.5	9.2	8.9	9.3	9.3						2.4	1.5	17.0	0.0	11.0	0.0	31.9	31.9	1	0
P11	pool	rt bank triangular log jam	1000	12	1012	77		7.6	10.1	9.3	11.1	9.8						3.0	1.0	9.0	0.0	0.0	5.0	13	18	4	0
R12	riffle		1000	20	1020	367		23.4	15.7	12.4	16.1	18.6						3.0	1.0	5.0	0.0	6.0	0.0	15	15	4.5	0
G13	glide	pool tailout	1000	43	1043	235		16.6	14.2	12.5	15.8							2.8	2.0	10.0	0.8	2.0	0.0	17.6	17.6	2	0
P12	pool	lt bank triangular log jam	1000	60	1060	177		12.4	14.3	15.8	12.7							5.4	4.0	13.0	1.0	0.5	40.0	23.9	63.9	10	0
R13	riffle	glide-like	1000	77	1077	313		26.6	11.8	12.7	13.8	9.5	11.0					2.1	0.0	3.0	1.7	1.0	0.0	7.8	7.8	20	0
G14	glide		1100	0	1100	204		19.4	10.5	11.0	10.7	9.9						8.7	5.0	0.3	0.3	9.0	0.0	23.3	23.3	4	0
R14L	riffle		1000	88	1088	167		21.0	8.0	9.2	6.7							7.6	4.0	0.5	1.0	100.0	0.0	113.1	113.1	1	0
G15L	glide		1100	0	1100	79		13.1	6.0	5.6	6.1	6.4						3.1	4.0	1.0	0.2	4.0	0.0	12.3	12.3	4	0
R15L	riffle		1100	13	1113	195		33.4	5.9	7.0	5.7	5.1	5.6					6.1	2.0	6.6	0.5	26.0	0.0	41.2	41.2	6	0
G16L	glide		1100	46	1146	112		19.5	5.8	5.1	5.2	7.0						0.3	0.0	1.0	1.0	3.0	0.0	5.3	5.3	11	0
R16L	riffle		1100	66	1166	78		15.9	4.9	4.6	5.1	5.1						0.0	1.0	0.6	0.2	4.5	0.0	6.3	6.3	1	0
P13	pool		1100	19	1119	127		14.4	8.8	9.9	9.2	7.4						9.0	3.0	2.0	0.5	0.5	15.0	15	30	0	0
R17	riffle	relatively high gradient	1100	33	1133	992		64.9	15.3	23.2	21.1	18.0	13.0	8.3	8.1			9.7	1.5	24.2	0.0	10.0	0.0	45.4	45.4	6.5	0
G17	glide	wide and flat	1100	98	1198	1106		61.3	18.0	16.0	17.6	17.8	20.5	18.3				3.4	3.0	10.7	0.0	28.5	0.0	45.6	45.6	3	0
R18	riffle	glide-like	1200	59	1259	544		35.8	15.2	11.8	17.5	17.4	16.8	15.0	12.6			0.2	0.2	22.1	0.0	3.0	0.0	25.5	25.5	12	0
P14	pool	lt bank triangular log jam	1200	95	1295	216		13.7	15.8	20.4	18.3	12.5	11.8					30.1	3.0	22.2	0.0	10.0	18.0	65.3	83.3	9	0
R19	riffle	deep and fast lt, shallow btwn cobble on rt	1300	9	1309	499		21.7	23.0	22.7	24.5	23.3	21.5					12.7	0.2	20.7	0.4	18.0	0.0	52	52	10	0
G18	glide	pool tailout	1300	31	1331	195		10.0	19.5	22.0	21.1	18.5	16.4					3.5	0.5	1.8	0.0	1.5	0.0	7.3	7.3	10	0
P15	pool	LWD addition	1300	41	1341	293		21.0	14.0	14.8	12.4	13.4	15.2					19.5	6.0	1.9	0.2	1.5	30.0	29.1	59.1	9	0
SC2R	s/b chnl	isolated pool, rt bank	1300	32	1332	60	19.0	19.0	3.2	2.8	3.2	3.8	3.0	3.1				2.3	6.0	0.0	0.0	8.0	0.0	16.3	16.3	8	0
		u/s end P11	1300	62	1362																			0	0		
Totals						20247	105																				

Notes:
OH includes instream vegetation
CovTot1 does not include deep pool.
CovTot2 includes deep pool.

APPENDIX 4a. Habitat unit physical data for Whatshan W3.2, September 2015.

2015 Unit	B	C	G	F	Dep1	Dep2	Dep3	DepAvg	DepMax	PoolMax	Crest	Resid	Comments	Photo	Aspect
G01	0	14	1	0	0.48	0.34	0.30	0.37	0.48					17:42	u/s
P01	10	85	0	0	0.65	0.71	1.05	0.80	1.05	1.15	0.30	0.85		17:43	u/s
R01	5	95	0	0	0.18	0.30	0.40	0.29	0.40					17:51	u/s
G02	1	99	0	0	0.30	0.39	0.28	0.32	0.39					17:51	u/s
P02	5	93	2	0	0.63	0.96	0.88	0.82	0.96	1.10	0.38	0.72		17:52	u/s
R02	25	74	1	0	0.14	0.28	0.25	0.22	0.28					18:20	u/s
G03	70	25	5	0	0.34	0.28	0.40	0.34	0.40					18:32	u/s
P03	20	70	10	0	0.46	0.63	0.96	0.68	0.96	0.97	0.30	0.67		18:33	u/s
G04	55	40	5	0	0.25	0.25	0.25	0.25	0.25				Triangular LJ @u/s end	18:52	u/s
R03	15	80	5	0	0.36	0.24	0.18	0.26	0.36					19:03	u/s
G05	15	55	30	0	0.37	0.43	0.37	0.39	0.43					19:13	u/s
P04	1	29	70	0	0.30	0.69	0.86	0.62	0.86	0.96	0.26	0.70		7:21	u/s
G06	3	87	10	0	0.41	0.22	0.19	0.27	0.41					7:37	across fror
R04	2	78	20	0	0.16	0.20	0.10	0.15	0.20					7:44	across fror
G07	1	97	2	0	0.19	0.17	0.50	0.29	0.50					7:45	across fror
P05	10	65	5	20	0.66	1.01	1.28	0.98	1.28	1.30	0.23	1.07		7:45	u/s
R05	5	45	50	0	0.16	0.27	0.16	0.20	0.27				rt bk triangular LJ	8:47	u/s
G08	10	60	30	0	0.28	0.32	0.19	0.26	0.32					8:57	u/s
P06	20	59	20	1	0.62	0.84	1.02	0.83	1.02	1.10	0.24	0.86		9:18	u/s
R06	5	80	15	0	0.10	0.25	0.40	0.25	0.40				trailing moss	9:45	u/s
P07	30	40	30	0	0.39	0.58	0.70	0.56	0.70	0.85	0.28	0.57		10:22	u/s
R07	10	80	10	0	0.22	0.23	0.15	0.20	0.23				trailing moss	10:30	u/s
G09	25	60	15	0	0.30	0.34	0.44	0.36	0.44				trailing moss-green algae ~20% of bottom	10:49	u/s
P08	20	60	10	10	0.28	0.67	0.52	0.49	0.67	0.80	0.34	0.46	only deep in L 1/3 of channel	11:16	u/s
R07	40	50	10	0	0.25	0.30	0.25	0.27	0.30				incl 2-3 m wide chnl in lee of tri LJ	11:22	u/s
SC1R	5	85	10	0	0.08	0.05	0.07	0.07	0.08				ends at G09 boundary	9:54	u/s
P09	50	40	10	0	0.50	0.75	0.83	0.69	0.83	0.95	0.35	0.60		11:44	u/s
G10	20	75	5	0	0.22	0.38	0.48	0.36	0.48				trailing moss	11:58	u/s
R08	10	90	0	0	0.32	0.23	0.21	0.25	0.32				bag of fish heads (photo 12:34); trailing mos	12:25	u/s
G11	2	88	10	0	0.37	0.35	0.45	0.39	0.45					12:37	u/s
R10	15	75	10	0	0.28	0.24	0.31	0.28	0.31				trailing moss	12:44	u/s
G12	40	50	10	0	0.43	0.40	0.38	0.40	0.43					12:51	u/s
P10	20	65	10	5	0.40	0.83	0.93	0.72	0.93	1.15	0.29	0.86	photo 13:03 across from R	13:00	u/s
R11	58	40	1	1	0.25	0.28	0.40	0.31	0.40					13:11	u/s
P11	25	65	10	0	0.35	0.46	0.65	0.49	0.65	0.70	0.40	0.30	photo 13:19 across from L	13:18	u/s
R12	5	90	5	0	0.10	0.23	0.16	0.16	0.23				trailing moss	13:26	u/s
G13	40	50	10	0	0.45	0.64	0.35	0.48	0.64					13:39	u/s
P12	20	65	5	10	0.78	0.9	0.93	0.87	0.93	1.10	0.24	0.86		13:40	u/s
R13	2	93	5	0	0.23	0.30	0.35	0.29	0.35				spawn gravel at outlet of L channel	13:49	u/s
G14	1	88	10	1	0.38	0.27	0.35	0.33	0.38					14:01	u/s
R14L	1	89	10	0	0.09	0.15	0.10	0.11	0.15				photos u/s of u/s mouth, u/s of d/s mouth	14:58	u/s
G15L	5	85	10	0	0.29	0.25	0.17	0.24	0.29				trailing moss	14:49	u/s
R15L	5	90	5	0	0.27	0.19	0.18	0.21	0.27				trailing moss	14:44	u/s
G16L	5	85	10	0	0.25	0.20	0.15	0.20	0.25				used substrate data from G15L	14:31	u/s
R16L	0	95	5	0	0.14	0.21	0.22	0.19	0.22				trailing moss	14:26	u/s
P13	5	92	2	1	0.42	0.71	0.70	0.61	0.71	0.86	0.26	0.60		14:09	u/s
R17	15	80	5	0	0.17	0.20	0.23	0.20	0.23					17:21	u/s
G17	5	80	15	0	0.22	0.36	0.43	0.34	0.43					17:12	u/s
R18	15	75	10	0	0.18	0.36	0.35	0.30	0.36					16:41	u/s
P14	25	50	15	10	0.30	0.70	0.74	0.58	0.74	0.90	0.30	0.60	shallow riffle along R bank	16:32	u/s
R19	7	88	5	0	0.06	0.20	0.35	0.20	0.35				trailing moss around L bank	16:05	u/s
G18	2	73	15	10	0.09	0.35	0.60	0.35	0.60					15:24	across fror
P15	5	80	10	5	0.33	0.78	0.94	0.68	0.94	1.10	0.30	0.80	Barnes-Whatshan confluence; fish rising	15:10	u/s
SC2R	0	15	85	0	0.15	0.18	0.17	0.17	0.18				Barnes-Whatshan confluence	15:12	u/s
Totals															

APPENDIX 4b. Habitat unit physical data for Barnes Reach 3, September 2015.

						m²	Length	(m)				Wetted Widths (m)								Cover Area (m²)						Area	S
2015 Unit	Habitat	Description	Stn1	Stn2	Distance	Area	sc/bc	Length	WidAvg	W1	W2	W3	W4	W5	W6	W7	W8	LWD	SWD	B	UC	OH	DP	CovTot1	CovTot2	Spawn	R
R01	riffle	confluence of 2 channels	0	0	0	438		26.3	16.7	19.1	17.0	15.8	14.7					0.5	0	3	1.6	3	0	8.1	8.1	6	0
SC1L	sc/bc	formerly lt channel	0	0	0	917	196.0	196.0	4.7	4.1	3.6	2.7	7.3	5.7				42	8	20.5	1.3	9	40	80.8	120.8	9	0
R02L	riffle	lt side of large bar/island	0	26	26	509		97.0	5.3	2.3	4.0	5.2	6.1	6.4	7.5			5.1	3.5	12.9	5.1	2	0	28.6	28.6	4	0
G01R	glide	fast-flowing, not very pool-like	0	26	26	91		15.3	6.0	6.8	6.9	5.2	4.9					0	1	0.1	2.5	1.5	3	5.1	8.1	6	0
R03R	riffle	rt side of large island	0	41	41	403		53.6	7.5	10.5	8.9	6.3	4.4					3.2	6.5	4.5	0	19	0	33.2	33.2	0	0
G02R	glide	pool tailout	0	95	95	135		13.5	10.0	9.4	10.6							0	0.5	2.5	0.2	1	0	4.2	4.2	0	0
SC2R	sc/bc	groundwater-fed channel	100	10	110	50	54.0	54.0	0.9	1.3	0.6	0.8	1.1	0.8				0.4	0	0	0	2	0	2.4	2.4	1	0
P01R	pool	log jam, double pool	100	5	105	380		34.2	11.1	9.0	8.0	13.0	14.5					68.3	34	0.9	3	4	25	110.2	135.2	7	0
R04	riffle	relatively uniform	100	39	139	98		20.5	4.8	4.1	3.5	3.8	7.8					2	0	3	0	1	0	6	6	0	0
G03	glide	pool tailout	100	60	160	124		10.0	12.4	12.5	12.2							5	1	1.4	0	4	0	11.4	11.4	3	0
P02	pool	lateral log jam	100	70	170	189		16.6	11.4	12.0	10.9	11.3						6.5	2.5	1.3	1	0.5	10	11.8	21.8	0	0
R05	riffle	uniform	100	87	187	316		28.5	11.1	12.6	13.0	9.2	9.6					3.5	0	7.5	0	0.5	0	11.5	11.5	0.5	0
G04	glide	deep glide, one pool-like section	200	1	201	320		37.7	8.5	7.7	8.3	8.4	9.6					1.2	3	1.5	3.9	4	4	13.6	17.6	6	0
R06	riffle	break btwn pool and glide, transverse bar	200	39	239	101		8.2	12.4	13.0	14.3	9.8						0	0.1	3	0	0.7	0	3.8	3.8	0.5	0
P03	pool	lateral log jam on hairpin corner	200	47	247	265		29.2	9.1	7.7	9.8	10.0	8.8					75	3	1	0	15	50	94	144	0	0
SC3R	sc/bc	perched mouth	200	65	265	125	84.0	84.0	1.5	2.5	0.5	0.8	1.1	1.3	1.7			8	4.1	0	0.6	2	0	14.7	14.7	8	0
R07	riffle	variable	200	76	276	241		20.8	11.6	9.6	11.5	14.7	10.5					6	2.0	5	2	1	0	16.4	16.4	1	0
SC4L	sc/bc	enters SC1L 7 m from u/s end	200	76	276	49	31.3	31.3	1.6	2.3	1.7	0.7						1.7	0.5	1.2	0.5	9.9	0	13.8	13.8	3.5	0
G05	glide		300	0	300	258		31.9	8.1	9.5	10.9	10.4	5.8	3.9				7	1.5	1	0	3	0	12.8	12.8	0	0
SC5La	sc/bc	dominated by tributary flow (80%)	200	93	293	99	28.0	28.0	3.5	3.2	3.7	3.7	3.5					6.1	0	0	0.8	7	0	13.9	13.9	9	0
SC5Lb	sc/bc	u/s of tributary @300+21	300	21	321	52	22.7	22.7	2.3	1.4	2.7	2.8						1.9	3	0	1.2	6	0	12.1	12.1	5	0
R08	riffle	transverse bar, overlaps w/ G05 and G06	300	12	312	142		6.4	22.2	22.2								0	0	3.8	0	0	0	3.8	3.8	0	0
G06	glide	long and flat	300	44	344	301		43.8	6.9	5.6	5.8	7.2	8.9					0.5	2	0.1	0.9	4.7	0	8.2	8.2	0	0
R09	riffle	transverse bar btwn G06 and G07	300	88	388	285		20.4	14.0	15.3	16.3	17.1	7.2					1.6	0.3	3.2	0.4	9	0	14.5	14.5	0	0
SC6R	sc/bc	runs along G06	300	20	320	130	51.6	51.6	2.5	3.1	2.9	2.9	1.4	2.3				3.4	2.5	0	0.3	11.5	0	17.7	17.7	17	0
G07	glide	long, deep glide	400	1	401	495		43.0	11.5	15.3	13.7	10.9	9.1	8.5				4	8	2.4	0	21	0	35.4	35.4	6	0
P04	pool	lateral log jam	400	44	444	122		16.2	7.6	7.7	7.4							8	2	2	0.5	1	20	13.5	33.5	0	0
G08	glide		400	60	460	83		10.5	7.9	7.7	8.0	8.0						0.8	0	3	0	0	0	3.8	3.8	0	0
P05	pool		400	71	471	129		14.4	9.0	8.0	9.1	9.8						4.3	0.7	1	0.5	1	20	7.5	27.5	0	0
R10	riffle	uniform	400	85	485	389		42.0	9.3	10.2	7.6	8.3	10.9					1.2	1	11.5	0	0.5	0	14.2	14.2	0	0
G09	glide	pool tailout	500	27	527	129		11.9	10.8	11.3	10.3							2.3	0.5	0.5	0	1	0	4.3	4.3	0	0
P06	pool		500	39	539	254		27.8	9.2	10.3	8.5	9.0	8.8					6.5	4	3	3	17	35	33.5	68.5	0	0
G10	glide	pool tailout, riffley at d/s end	500	67	567	117		12.7	9.2	7.2	10.7	9.8						4.2	0.2	1.1	1.5	0	0	7	7	1	0
P07	pool	log jam; too difficult to sample so P08 instead	500	80	580	185		23.6	7.8	7.2	9.8	8.4	5.9					17	0.5	3	0	0.5	50	21	71	0	0
G11	glide		600	4	604	169		17.8	9.5	10.7	9.4	9.9	7.9					2.3	1	0.3	3.4	1	0	8	8	1	0
R11	riffle		600	22	622	160		17.5	9.1	7.9	9.9	9.6						5.2	0.5	0.3	0.2	2	0	8.2	8.2	1	0
G12	glide	pool tailout	600	40	640	184		21.1	8.7	9.6	9.0	8.6	7.6					6.5	0.5	0.5	2	0.5	0	10	10	9	0
P08	pool	massive root wad at u/s end	600	61	661	132		17.3	7.6	7.6	8.6	7.4	6.9					9	2	0.5	5	1	25	17.5	42.5	10	0
SC7R	sc/bc	highly variable; former half of main chnl in 2012	600	74	674	530	128.8	128.8	4.1	1.3	9.2	5.1	3.3	5.3	3.4	1.2		36.6	8	0	14.3	15	0	73.9	73.9	62	0
R12	riffle	incl. flooded bar on lt bank	600	74	674	74		8.9	8.3	8.6	9.3	7.0						0.0	0.0	0.3	0.0	0.0	0.0	0.3	0.3	0	0
G13	glide	pool tailout, stillwater finger lt bank	600	74	674	166		14.3	11.6	15.7	10.1		9.0					8.8	3	0.3	0.5	1	0	13.6	13.6	12	0
P09	pool		600	85	685	100		11.7	8.6	9.0	8.1	10.1	7.1					4.7	1	15	6	4	30	30.7	60.7	0	0
R13	riffle	glide-like along log for 15 m at d/s end	600	90	690	423		50.5	8.4	7.1	10.9	8.7	9.5	7.1	7.0			8.2	12	6.3	5.6	1	0	33.1	33.1	7.5	0
G14	glide		700	10	710	176		26.6	6.6	8.7	7.6	5.6	4.5					1	5	2	0	10	0	18	18	0	0
R14	riffle	splits around mid-chnl bar in middle	700	67	767	422		36.2	11.7	8.9	9.1	12.4	14.6	13.3				4.3	1	6.3	5.8	11	0	28.4	28.4	0	0
G15	glide	long and uniform	700	99	799	529		57.3	9.2	13.3	7.3	7.7	8.1	9.8				1.5	11.0	12.5	0.4	38.0	0.0	63.4	63.4	2	0
R15	riffle		800	56	856	153		16.6	9.2	7.3	9.8	10.6						0.5	9	4	0	7	0	20.5	20.5	0	0
G16	glide		800	73	873	332		38.2	8.7	9.8	8.1	7.0	8.7	9.8				2.2	7	5	1.2	17	0	32.4	32.4	8	0
P10	pool	lateral log jam	900	14	914	115		15.2	7.5	8.1	6.6	7.9						10	1	3	4	10	10	28	38	0	0
R16	riffle	split by mid-chnl bar	900	79	979	668		50.0	13.4	6.6	18.0	22.6	9.9	11.5	11.5			10.6	2.5	46	1.5	13.5	0	74.1	74.1	14	0
G17	glide		900	79	979	254		26.0	9.8	8.6	8.7	9.4	12.3					0	0	11	0	1	0	12	12	0	0
R17	riffle	bouldery riffle	1000	1	1001	162		17.0	9.5	8.6	9.9	10.1						0.0	0.0	10.0	0.0	1.0	0.0	11	11	0	0
SC8R	sc/bc	narrow except for pool at d/s end	900	79	979	134	56.0	56.0	2.4	3.6	4.0	1.3	1.7	1.7	2.1			3.3	3	3.5	2	5	0	16.8	16.8	6	0

APPENDIX 4b. Habitat unit physical data for Barnes Reach 3, September 2015.

						m^2	Length	(m)		Wetted Widths (m)								Cover Area (m^2)								Area	
2015 Unit	Habitat	Description	Stn1	Stn2	Distance	Area	sc/bc	Length	WidAvg	W1	W2	W3	W4	W5	W6	W7	W8	LWD	SWD	B	UC	OH	DP	CovTot1	CovTot2	Spawn	R
G18	glide		1000	18	1018	251		28.0	9.0	10.1	8.4	9.0	8.3					0	0.5	18	0	0.5	0	19	19	0	0
R18L	riffle		1000	46	1046	239		42.7	5.6	7.8	4.7	4.9	5.0					1.2	2	11	0.2	10	0	24.4	24.4	11	0
G19L	glide		1000	89	1089	86		12.2	7.0	6.5	6.8	7.8						4.8	2.5	1.1	2.6	2	0	13	13	0	0
P11L	pool	huge log jam	1100	1	1101	130		18.5	7.0	6.5	7.5							50	10	0.5	1	2	60	63.5	123.5	0	0
P12R	pool	very deep; active beaver area	1000	56	1056	212		22.0	9.6	10.5	9.3	8.3	10.2	9.8				9	3	16	10	1	65	39	104	25	0
R19R	riffle		1000	78	1078	195		22.1	8.8	8.2	10.5	9.8	6.8					0.0	0.5	14.0	0.0	0.0	0.0	14.5	14.5	0.5	0
P13R	pool		1100	0	1100	143		16.0	8.9	8.2	10.7	8.5	8.3					16.4	1	9	4	0	30	30.4	60.4	1	0
R20R	riffle		1100	0	1100	129		10.0	12.9	13.2	15.1	10.4						0	1	9	1.6	0	0	11.6	11.6	0.5	0
G20R	glide	pool tailout from huge log jam	1100	0	1100	77		8.2	9.4	10.4	8.7	9.2						0	0	3	0	0	0	3	3	0	0
SC9R	sc/bc	enters R20R from rt	1100	0	1100	24	14.9	14.9	1.6	1.2	2.0	2.3	1.8	0.6				0.3	0.5	0	0	0.5	0	1.3	1.3	0	0
P14R	pool	u/s side of huge log jam	1100	0	1100	343		38.4	8.9	7.7	9.1	9.2	9.1	9.6				31	2	16	0	0	94	49	143	0	0
R21	riffle	long and uniform	1100	10	1110	958		98.4	9.7	10.5	7.7	8.4	8.1	11.0	12.7			7.3	6.5	65	0.8	2	0	81.6	81.6	0	0
G21	glide		1200	30	1230	107		11.3	9.5	10.5	9.5	8.5						0.0	0.0	2.5	0.0	0.5	0.0	3	3	0	0
P15	pool	log jam	1200	41	1241	114		12.9	8.9	8.9	8.8							19	3	2	0.5	2	15	26.5	41.5	1	0
		u/s end P15	1200	54	1254																			0	0		
Totals						15811	667																				

Notes:
OH includes instream vegetation
CovTot1 does not include deep pool.
CovTot2 includes deep pool.

APPENDIX 4b. Habitat unit physical data for Barnes Reach 3, September 2015.

	Substrate Percentage				Depths (m)											
2015 Unit	B	C	G	F	Dep1	Dep2	Dep3	DepAvg	DepMax	Total	PoolMax	Crest	Resid	Comments	Photo	Aspect
R01	10	85	5	0	0.17	0.18	0.17	0.17	0.18	100					9:41	u/s
SC1L	5	88	5	2	0.09	0.09	0.13	0.10	0.13	100				LWD from LJ at u/s end at main chnl	9:45	u/s
R02L	23	75	2	0	0.20	0.24	0.24	0.23	0.24	100					10:28	u/s
G01R	1	67	30	2	0.24	0.48	0.62	0.45	0.62	100				formerly been classed as pool?	11:13	u/s
R03R	10	85	5	0	0.15	0.22	0.38	0.25	0.38	100				some trailing moss	11:26	u/s
G02R	5	80	15	0	0.31	0.37	0.37	0.35	0.37	100					11:34	u/s
SC2R	10	60	30	0	0.06	0.07	0.07	0.07	0.07	100				looked same; used 2012 data	11:44	u/s
P01R	2	86	10	2	0.49	0.80	0.57	0.62	0.80	100	0.98	0.32	0.66		11:52	u/s
R04	10	85	5	0	0.26	0.35	0.50	0.37	0.50	100					12:22	u/s
G03	3	87	10	0	0.21	0.34	0.26	0.27	0.34	100					12:21	u/s
P02	1	94	5	0	0.32	0.48	0.82	0.54	0.82	100	0.91	0.22	0.69		12:54	u/s
R05	20	78	2	0	0.28	0.28	0.34	0.30	0.34	100				photo 13:05 trib entering from R bk	13:04	u/s
G04	1	80	19	0	0.50	0.54	0.26	0.43	0.54	100				organic fines on inside of bend	13:16	u/s
R06	5	85	10	0	0.38	0.15	0.32	0.28	0.38	100					13:30	across from L
P03	2	91	5	1	0.64	1.01	0.78	0.81	1.01	99	1.10	0.20	0.90		13:49	u/s
SC3R	0	10	75	15	0.05	0.10	0.08	0.08	0.10	100				photo 13:41 at mouth, 13:43 u/s	13:41	u/s
R07	5	93	2	0	0.07	0.23	0.33	0.21	0.33	100					14:22	u/s
SC4L	20	55	25	0	0.13	0.18	0.17	0.16	0.18	100				good spawning area	10:16	u/s
G05	1	92	7	0	0.47	0.50	0.44	0.47	0.50	100					14:22	u/s
SC5La	1	5	52	42	0.20	0.18	0.21	0.20	0.21	100				photo 14:56 of tributary inflow	14:22	u/s
SC5Lb	0	40	60	0	0.07	0.10	0.10	0.09	0.10	100					14:56	u/s
R08	12	87	1	0	0.11	0.13	0.18	0.14	0.18	100					14:56	u/s
G06	0	90	10	0	0.35	0.45	0.43	0.41	0.45	100					15:12	u/s
R09	3	96	1	0	0.15	0.15	0.17	0.16	0.17	100				small L bk trib @300+92 photo 16:09	16:00	u/s
SC6R	0	60	40	0	0.07	0.05	0.07	0.06	0.07	100					15:50	u/s
G07	2	87	10	1	0.23	0.48	0.47	0.39	0.48	100				partial beaver dam	16:03	u/s
P04	3	94	3	0	0.31	0.68	0.74	0.58	0.74	100	0.86	0.20	0.66		16:42	u/s
G08	7	92	1	0	0.39	0.29	0.20	0.29	0.39	100					16:43	u/s
P05	2	96	2	0	0.80	0.49	0.16	0.48	0.80	100	0.86	0.37	0.49		16:51	u/s
R10	15	83	2	0	0.21	0.27	0.13	0.20	0.27	100					16:53	u/s
G09	1	89	10	0	0.20	0.30	0.63	0.38	0.63	100				d/s of former LJ across channel	17:13	u/s
P06	2	88	10	0	0.41	0.85	0.88	0.71	0.88	100	0.99	0.20	0.79		17:23	u/s
G10	1	94	5	0	0.13	0.25	0.19	0.19	0.25	100					17:15	u/s
P07	5	85	5	5	0.75	1.18	0.57	0.83	1.18	100	1.31	0.25	1.06		17:51	u/s
G11	0	97	3	0	0.18	0.50	0.57	0.42	0.57	100					18:10	u/s
R11	0	97	3	0	0.13	0.14	0.26	0.18	0.26	100					18:20	u/s
G12	0	90	10	0	0.40	0.42	0.21	0.34	0.42	100					18:23	u/s
P08	0	65	30	5	0.5	0.94	0.76	0.73	0.94	100	1.16	0.19	0.97		18:37	u/s
SC7R	0	40	55	5	0.17	0.22	0.17	0.19	0.22	100				empties into u/s end of P08; 11:23 u/s	11:17	d/s
R12	1	98	1	0	0.20	0.28	0.13	0.20	0.28	100					9:13	across from L
G13	0	93	7	0	0.49	0.49	0.33	0.44	0.49	100				photo 9:37 d/s	9:13	u/s
P09	20	79	1	0	0.85	1.12	0.84	0.94	1.12	100	1.18	0.33	0.85		9:29	u/s
R13	5	90	5	0	0.29	0.23	0.16	0.23	0.29	100					9:39	u/s
G14	5	93	2	0	0.32	0.42	0.32	0.35	0.42	100					10:12	u/s
R14	5	93	2	0	0.14	0.16	0.17	0.16	0.17	100					10:35	u/s
G15	20	75	5	0	0.23	0.34	0.34	0.30	0.34	100					11:39	u/s
R15	10	87	3	0	0.17	0.15	0.23	0.18	0.23	100					11:47	u/s
G16	5	80	15	0	0.25	0.27	0.31	0.28	0.31	100					11:56	u/s
P10	15	83	2	0	0.35	0.48	0.66	0.50	0.66	100	0.80	0.28	0.52		12:26	u/s
R16	20	75	5	0	0.13	0.24	0.24	0.20	0.24	100					12:37	u/s
G17	25	74	1	0	0.33	0.5	0.5	0.44	0.50	100					13:02	u/s
R17	20	80	0	0	0.23	0.30	0.20	0.24	0.30	100					13:12	u/s
SC8R	25	50	20	5	0.10	0.17	0.14	0.14	0.17	100				photo 13:31 u/s from pool	13:24	u/s

APPENDIX 4b. Habitat unit physical data for Barnes Reach 3, September 2015.

	Substrate Percentage				Depths (m)											
2015 Unit	B	C	G	F	Dep1	Dep2	Dep3	DepAvg	DepMax	Total	PoolMax	Crest	Resid	Comments	Photo	Aspect
G18	15	85	0	0	0.27	0.23	0.36	0.29	0.36	100					13:46	u/s
R18L	30	48	20	2	0.20	0.20	0.28	0.23	0.28	100				d/s end abuts pool	14:16	u/s
G19L	10	20	0	70	0.30	0.48	0.43	0.40	0.48	100					14:22	u/s
P11L	5	5	0	90	0.70	1.01	0.90	0.87	1.01	100	1.06	0.25	0.81	LWD amount is estimate	14:32	u/s
P12R	10	75	10	5	1.36	1.25	0.68	1.10	1.36	100	1.46	0.33	1.13	R chnl carries est. 1/3 of flow	14:52	u/s
R19R	30	70	0	0	0.13	0.20	0.25	0.19	0.25	100					15:07	u/s
P13R	40	45	15	0	0.55	0.80	0.69	0.68	0.80	100	0.86	0.24	0.62		15:30	u/s
R20R	10	80	10	0	0.11	0.15	0.12	0.13	0.15	100					15:30	across from L
G20R	10	90	0	0	0.27	0.31	0.25	0.28	0.31	100					15:37	u/s
SC9R	0	0	0	100	0.20	0.25	0.13	0.19	0.25	100					15:44	u/s
P14R	25	75	0	0	0.98	1.10	0.97	1.02	1.10	100	1.50	0.23	1.27		16:15	u/s
R21	25	75	0	0	0.22	0.28	0.27	0.26	0.28	100					16:26	u/s
G21	5	95	0	0	0.24	0.39	0.42	0.35	0.42	100					16:35	u/s
P15	15	70	10	5	0.64	0.86	0.35	0.62	0.86	100	0.90	0.25	0.65		16:36	u/s
										0						
Totals																

APPENDIX 5a. Fish Collection Form Data and Electrofishing Specifications Whatshan River Reach W3.2 - September 8-13, 2015

Fish Permit No. CB15-174838
Agency: C201 (Naito Environmental)
Crew: GN/RL/CU (Gerry Naito, Robyn Laubman, Chad Unser)

Gazetted Name: **Whatshan River** Other Name: (none)
Watershed Code: 300-680400
Waterbody ID: 00000LARL
No Site Card Completed

SITE/METHOD

Site		Date	Map #	Site UTM				Method	Stream Condition		
No.	Name			Zone	Easting	Northing			Temp	Cond	Turb
1	P01	2015-09-08	82E.090	11	419203	5527276		EF	11.2	134	C
2	R02	2015-09-09	82E.090	11	419165	5527323		EF	11.7	114	C
3	G05	2015-09-09	82E.090	11	419207	5527433		EF	11.9	121	C
4	P04	2015-09-10	82E.090	11	419226	5527466		EF	14.0	127	C
5	R06	2015-09-11	82E.090	11	419314	5527715		EF	11.2	130	C
6	P07	2015-09-11	82E.090	11	419303	5527752		EF	14.2	129	C
7	SC1R	2015-09-11	82E.090	11	419298	5527736		EF	13.5	132	C
8	G09	2015-09-12	82E.090	11	419233	5527881		EF	11.5	134	C
9	R10	2015-09-12	82E.100	11	419247	5528124		EF	15.1	138	C
10	P10	2015-09-12	82E.100	11	419254	5528177		EF	14.0	136	C
11	G13	2015-09-13	82E.100	11	419252	5528217		EF	12.3	139	C
12	R17	2015-09-13	82E.100	11	419269	5528334		EF	15.2	135	C
13	G17	2015-09-13	82E.100	11	419296	5528382		EF	14.3	140	C

11.2 114.0 min
Conductivity and water temperature measured using Hanna HI98129 Combo Tester. 15.2 140.0 max
UTM Coordinates measured using Garmin 60CSx GPS receiver.

FISH SUMMARY - Whatshan W3.2

Species Codes:
- CCG slimy sculpin
- EB eastern brook trout
- LNC longnose dace
- RB rainbow trout

Life Stages:
- F fry
- J juvenile
- A adult

Site #	Site Name	Method	Pass	Species	Stage	Stage Name		Total #	Length (mm)	
									Min	Max
1	P01	EF	1	CCG	F	fry		5	21	25
			1	CCG	A	adult		25	42	90
			1	EB	F	fry		11	68	83
			1	EB	A	adult		1	178	178
			1	LNC	A	adult		2	63	66
			1	RB	F	fry		2	46	71
			1	RB	J	juvenile		3	105	110
			1	RB	A	adult		2	137	153

Site #	Site Name	Method	Pass	Species	Stage	Stage Name		Total #	Length (mm)	
									Min	Max
1	P01	EF	2	CCG	F	fry		4	24	28
			2	CCG	A	adult		14	43	75
			2	EB	F	fry		3	60	80
			2	EB	A	adult		3	129	220
			2	LNC	A	adult		2	85	86
			2	RB	F	fry		4	45	52
			2	RB	J	juvenile		3	90	112
			2	RB	A	adult		1	134	134
1	P01	EF	3	CCG	F	fry		4	21	29
			3	CCG	A	adult		10	43	81
			3	EB	F	fry		2	61	83
			3	EB	A	adult		1	172	172
			3	LNC	A	adult		1	68	68
			3	RB	F	fry		1	55	55
			3	RB	J	juvenile		2	89	106
2	R02	EF	1	CCG	F	fry		11	22	35
			1	CCG	A	adult		116	46	90
			1	EB	F	fry		9	66	84
			1	LNC	A	adult		3	71	93
			1	RB	F	fry		14	38	63
			1	RB	J	juvenile		2	103	127
			1	RB	A	adult		3	134	180
2	R02	EF	2	CCG	F	fry		8	20	36
			2	CCG	A	adult		78	46	94
			2	EB	F	fry		1	79	79
			2	LNC	A	adult		6	67	105
			2	RB	F	fry		10	45	66
			2	RB	J	juvenile		2	98	107
2	R02	EF	3	CCG	F	fry		2	22	32
			3	CCG	A	adult		76	47	85
			3	EB	F	fry		5	70	81
			3	LNC	J	juvenile		1	53	53
			3	LNC	A	adult		4	72	86
			3	RB	F	fry		5	36	56
2	R02	EF	4	CCG	F	fry		1	35	35
			4	CCG	A	adult		19	52	85
			4	EB	F	fry		1	84	84
			4	LNC	A	adult		2	68	95
			4	RB	F	fry		1	49	49
			4	RB	A	adult		1	169	169
3	G05	EF	1	CCG	F	fry		6	26	37
			1	CCG	A	adult		70	46	94
			1	EB	F	fry		13	52	85
			1	EB	A	adult		5	123	190
			1	LNC	J	juvenile		8	41	49
			1	LNC	A	adult		1	89	89
			1	RB	F	fry		8	30	59
			1	RB	J	juvenile		4	89	112
			1	RB	A	adult		2	155	197

Site #	Site Name	Method	Pass	Species	Stage	Stage Name		Total #	Length (mm)	
									Min	Max
3	G05	EF	2	CCG	F	fry		6	27	34
			2	CCG	A	adult		47	44	85
			2	EB	F	fry		6	55	77
			2	EB	A	adult		3	124	151
			2	LNC	F	fry		1	28	28
			2	LNC	J	juvenile		1	37	37
			2	RB	J	juvenile		6	86	126
			2	RB	A	adult		2	138	187
3	G05	EF	3	CCG	F	fry		6	27	35
			3	CCG	A	adult		49	42	85
			3	EB	F	fry		7	51	76
			3	EB	A	adult		2	117	176
			3	LNC	F	fry		4	30	33
			3	LNC	J	juvenile		1	43	43
			3	LNC	A	adult		4	69	90
			3	RB	F	fry		6	38	63
			3	RB	J	juvenile		4	102	125
			3	RB	A	adult		2	196	198
3	G05	EF	4	CCG	F	fry		2	30	31
			4	CCG	A	adult		15	54	82
			4	LNC	J	juvenile		1	48	48
			4	RB	F	fry		3	45	57
			4	RB	J	juvenile		1	103	103
4	P04	EF	1	CCG	F	fry		2	26	26
			1	CCG	A	adult		17	49	87
			1	EB	F	fry		6	61	90
			1	EB	A	adult		1	188	188
			1	RB	F	fry		2	41	46
			1	RB	J	juvenile		3	100	110
			1	RB	A	adult		2	133	167
4	P04	EF	2	CCG	F	fry		2	28	30
			2	CCG	A	adult		19	49	87
			2	EB	F	fry		9	63	91
			2	EB	A	adult		4	126	144
			2	LNC	A	adult		1	75	75
			2	RB	J	juvenile		4	103	120
			2	RB	A	adult		1	157	157
4	P04	EF	3	CCG	A	adult		8	47	77
			3	EB	F	fry		3	62	84
			3	EB	A	adult		1	143	143
			3	RB	J	juvenile		2	100	118
			3	RB	A	adult		1	148	148

Site #	Site Name	Method	Pass	Species	Stage	Stage Name		Total #	Length (mm)	
									Min	Max
5	R06	EF	1	CCG	F	fry		9	26	36
			1	CCG	A	adult		97	49	82
			1	EB	F	fry		14	61	85
			1	EB	A	adult		2	123	179
			1	LNC	J	juvenile		2	42	48
			1	LNC	A	adult		5	66	88
			1	RB	F	fry		28	46	68
			1	RB	J	juvenile		7	102	121
5	R06	EF	2	CCG	F	fry		6	30	36
			2	CCG	A	adult		38	48	80
			2	EB	F	fry		5	72	82
			2	EB	A	adult		2	117	179
			2	LNC	J	juvenile		1	52	52
			2	LNC	A	adult		3	64	83
			2	RB	F	fry		17	41	66
			2	RB	J	juvenile		1	98	98
			2	RB	A	adult		1	132	132
5	R06	EF	3	CCG	F	fry		5	30	36
			3	CCG	A	adult		39	49	89
			2	EB	F	fry		5	72	78
			3	EB	A	adult		1	130	130
			3	LNC	J	juvenile		1	46	46
			3	LNC	A	adult		1	64	64
			3	RB	F	fry		14	43	62
			3	RB	J	juvenile		1	95	95
5	R06	EF	4	CCG	F	fry		1	26	26
			4	CCG	A	adult		35	50	88
			4	EB	F	fry		4	76	84
			4	LNC	J	juvenile		2	46	57
			4	LNC	A	adult		2	66	84
			4	RB	F	fry		4	45	56
			4	RB	J	juvenile		3	105	127
			4	RB	A	adult		1	154	154
6	P07	EF	1	CCG	A	adult		7	55	95
			1	EB	F	fry		4	67	85
			1	EB	A	adult		3	132	182
			1	LNC	J	juvenile		1	50	50
			1	RB	F	fry		8	56	70
			1	RB	J	juvenile		6	87	107
			1	RB	A	adult		4	137	179
6	P07	EF	2	CCG	F	fry		1	36	36
			2	CCG	A	adult		6	52	75
			2	EB	F	fry		2	64	77
			2	LNC	A	adult		2	74	85
			2	RB	F	fry		3	60	63
			2	RB	J	juvenile		4	104	116
			2	RB	A	adult		2	161	166
6	P07	EF	3	CCG	A	adult		9	49	72
			3	RB	J	juvenile		2	87	99

Site #	Site Name	Method	Pass	Species	Stage	Stage Name		Total #	Length (mm)	
									Min	Max
7	SC1R	EF	1	CCG	F	fry		3	22	32
			1	CCG	A	adult		5	54	63
			1	EB	F	fry		9	55	78
			1	RB	F	fry		14	34	52
7	SC1R	EF	2	CCG	F	fry		6	27	36
			2	CCG	A	adult		1	57	57
			2	EB	F	fry		4	65	74
			2	RB	F	fry		5	34	56
8	G09	EF	1	CCG	F	fry		14	24	32
			1	CCG	A	adult		56	47	94
			1	EB	F	fry		3	59	83
			1	EB	A	adult		1	133	133
			1	LNC	A	adult		1	96	96
			1	RB	F	fry		7	39	64
			1	RB	J	juvenile		4	102	114
			1	RB	A	adult		1	199	199
8	G09	EF	2	CCG	F	fry		5	27	31
			2	CCG	A	adult		29	46	86
			2	EB	A	adult		1	171	171
			2	LNC	A	adult		3	65	72
			2	RB	F	fry		2	37	67
9	R10	EF	1	CCG	F	fry		10	20	37
			1	CCG	A	adult		83	48	92
			1	EB	F	fry		11	70	93
			1	EB	A	adult		1	203	203
			1	LNC	F	fry		1	26	26
			1	LNC	J	juvenile		2	46	48
			1	RB	F	fry		12	50	69
			1	RB	J	juvenile		1	104	104
9	R10	EF	2	CCG	F	fry		7	20	30
			2	CCG	A	adult		42	45	76
			2	EB	F	fry		9	75	90
			2	LNC	F	fry		1	27	27
			2	LNC	J	juvenile		2	38	42
			2	RB	F	fry		8	44	64
9	R10	EF	3	CCG	F	fry		5	26	32
			3	CCG	A	adult		25	47	88
			3	EB	F	fry		4	69	82
			3	LNC	J	juvenile		1	52	52
			3	RB	F	fry		3	55	57
10	P10	EF	1	CCG	F	fry		1	25	25
			1	CCG	A	adult		18	42	84
			1	EB	F	fry		6	69	83
			1	EB	A	adult		8	114	182
			1	LNC	A	adult		5	68	98
			1	RB	F	fry		5	45	66
			1	RB	J	juvenile		8	94	125
			1	RB	A	adult		3	130	176

Site #	Site Name	Method	Pass	Species	Stage	Stage Name		Total #	Length (mm)	
									Min	Max
10	P10	EF	2	CCG	A	adult		12	47	87
			2	EB	F	fry		1	67	67
			2	EB	A	adult		1	135	135
			2	LNC	F	fry		1	26	26
			2	LNC	A	adult		1	69	69
			2	RB	J	juvenile		8	84	122
10	P10	EF	3	CCG	F	fry		1	37	37
			3	CCG	A	adult		13	52	72
			3	EB	F	fry		2	70	81
			3	LNC	A	adult		2	72	95
			3	RB	F	fry		1	50	50
11	G13	EF	1	CCG	F	fry		32	23	37
			1	CCG	J	juvenile		122	40	84
			1	EB	F	fry		1	75	75
			1	LNC	F	fry		4	20	32
			1	LNC	J	juvenile		18	39	58
			1	LNC	A	adult		3	61	86
			1	RB	F	fry		2	51	56
			1	RB	J	juvenile		1	83	83
11	G13	EF	2	CCG	F	fry		5	27	30
			2	CCG	A	adult		35	44	83
			2	EB	F	fry		1	84	84
			2	LNC	F	fry		1	32	32
			2	LNC	J	juvenile		1	46	46
			2	RB	F	fry		1	62	62
12	R17	EF	1	CCG	F	fry		3	28	35
			1	CCG	A	adult		51	48	86
			1	EB	F	fry		4	59	79
			1	LNC	F	fry		1	28	28
			1	LNC	J	juvenile		15	43	58
			1	LNC	A	adult		11	65	105
			1	RB	F	fry		5	42	65
			1	RB	J	juvenile		7	97	129
12	R17	EF	2	CCG	A	adult		33	51	84
			2	EB	F	fry		4	61	84
			2	LNC	J	juvenile		5	47	56
			2	LNC	A	adult		7	63	107
			2	RB	F	fry		5	56	64
			2	RB	A	adult		1	155	155
12	R17	EF	3	CCG	A	adult		21	52	73
			3	EB	F	fry		3	74	78
			3	LNC	J	juvenile		6	46	55
			3	LNC	A	adult		8	64	99
			3	RB	F	fry		3	49	64
			3	RB	J	juvenile		1	114	114

Site #	Site Name	Method	Pass	Species	Stage	Stage Name		Total #	Length (mm)	
									Min	Max
13	G17	EF	1	CCG	F	fry		5	23	36
			1	CCG	A	adult		40	40	87
			1	EB	F	fry		7	57	91
			1	EB	A	adult		1	153	153
			1	LNC	F	fry		5	24	34
			1	LNC	J	juvenile		4	43	48
			1	RB	F	fry		2	48	53
			1	RB	J	juvenile		2	101	114
			1	RB	A	adult		1	136	136
13	G17	EF	2	CCG	F	fry		7	28	36
			2	CCG	A	adult		21	48	86
			2	EB	F	fry		3	61	79
			2	EB	A	adult		1	133	133
			2	LNC	J	juvenile		2	43	44
			2	RB	F	fry		2	53	54

ELECTROFISHING SPECIFICATIONS - Whatshan W3.2

Site	Pass	Time In	Out	Sec	Length	Width	Area	Encl	Voltage	Freq	Pulse
P01	1	13:30	14:05	1168	10.3	12.0	124	C	400	60	6
	2	14:58	15:39	1289	10.3	12.0			400	60	6
	3	16:05	16:42	1298	10.3	12.0		C	400	60	6
R02	1	10:10	10:49	1171	22.0	8.9	196	C	400	60	6
	2	12:18	12:51	1242	22.0	8.9		C	400	60	6
	3	13:40	14:18	1495	22.0	8.9		C	400	60	6
	4	15:03	15:33	1265	22.0	8.9		C	400	60	6
G05	1	17:30	18:22	2151	26.9	15.1	406	C	400	60	6
	2	18:59	19:42	1903	26.9	15.1		C	400	60	6
	3	9:16	10:13	2185	26.9	15.1		C	400	60	6
	4	11:01	11:41	1724	26.9	15.1		C	400	60	6
P04	1	15:47	16:23	1568	21.9	14.5	318	C	400	60	6
	2	16:54	17:27	1605	21.9	14.5		C	400	60	6
	3	17:43	18:10	1458	21.9	14.5		C	400	60	6
R06	1	9:27	10:30	2077	38.8	15.8	613	C	400	60	6
	2	11:24	12:04	1726	38.8	15.8		C	400	60	6
	3	12:46	13:29	1843	38.8	15.8		C	400	60	6
	4	14:02	14:37	1644	38.8	15.8		C	400	60	6
P07	1	15:38	15:58	748	12.5	10.4	130	C	400	60	6
	2	16:22	16:39	680	12.5	10.4		C	400	60	6
	3	16:51	17:02	608	12.5	10.4		C	400	60	6
SC1R	1	17:24	17:40	583	20.0	3.5	70	C	400	60	6
	2	17:56	18:13	568	20.0	3.5		C	400	60	6
G09	1	9:17	9:50	1211	14.2	11.8	168	C	400	60	6
	2	10:26	10:51	1108	14.2	11.8		C	300	60	6
R10	1	12:36	13:25	1785	18.7	14.0	262	C	300	60	6
	2	14:10	14:52	1482	18.7	14.0		C	300	60	6
	3	15:23	15:51	1160	18.7	14.0		C	300	60	6
P10	1	17:03	17:27	947	12.0	11.1	133	C	300	60	6
	2	17:54	18:10	729	12.0	11.1		C	300	60	6
	3	18:24	18:42	835	12.0	11.1		C	300	60	6
G13	1	9:14	10:06	2134	16.6	14.2	236	C	200	60	6
	2	10:55	11:28	1407	16.6	14.2		C	200	60	6

Site	Pass	Time In	Out	Sec	Length	Width	Area	Encl	Voltage	Freq	Pulse
R17	1	13:02	13:43	1489	16.3	13.2	215	C	300	60	6
	2	14:22	14:54	1254	16.3	13.2		C	300	60	6
	3	15:19	15:48	1201	16.3	13.2		C	300	60	6
G17	1	17:03	17:35	1334	16.0	14.3	229	C	300	60	6
	2	17:59	18:30	1214	16.0	14.3		C	300	60	6

APPENDIX 5b. Fish Collection Form Data and Electrofishing Specifications
Barnes Creek Reach B3 - September 14-16, 2015

Fish Permit No. CB15-174838
Agency: C201 (Naito Environmental)
Crew: GN/RL/CU (Gerry Naito, Robyn Laubman, Chad Unser)

Gazetted Name:	**Barnes Creek**	Other Name:	(none)
Watershed Code:	300-680400-08700		
Waterbody ID:	00000LARL		
No Site Card Completed			

SITE/METHOD - Barnes B3

Site		Date	Map #	Site UTM			Method	Stream Condition		
No.	Name			Zone	Easting	Northing		Temp	Cond	Turb
14	R03R	2015-09-14	82E.100	11	418629	5529843	EF	11.2	132	C
15	P02	2015-09-14	82E.100	11	418649	5529955	EF	12.0	129	C
16	G04	2015-09-14	82E.100	11	418705	5529984	EF	12.6	132	C
17	SC4L	2015-09-14	82E.100	11	418757	5529937	EF	13.2	105	C
18	R10	2015-09-14	82E.100	11	418714	5530142	EF	12.7	146	C
19	G11	2015-09-15	82E.100	11	418618	5530166	EF	10.8	138	C
20	P08	2015-09-15	82E.100	11	418594	5530215	EF	11.2	137	C
21	SC7R	2015-09-16	82E.100	11	418544	5530265	EF	10.2	224	C
22	G17	2015-09-15	82E.100	11	418332	5530218	EF	10.8	119	C
23	R17	2015-09-15	82E.100	11	418315	5530212	EF	10.7	119	C
24	P13R	2015-09-16	82E.100	11	418222	5530193	EF	9.0	110	C

Conductivity and water temperature measured using Hanna HI98129 Combo Tester.	9.0	105	min
UTM Coordinates measured using Garmin 60CSx GPS receiver.	13.2	224	max

FISH SUMMARY - Barnes B3

Species Codes:			Life Stages:	
	CCG	slimy sculpin	F	fry
	EB	eastern brook trout	J	juvenile
	RB	rainbow trout	A	adult

Site #	Site Name	Method	Pass	Species	Stage	Stage Name	Age	Total #	Length (mm)	
									Min	Max
14	R03R	EF	1	CCG	F	fry		14	19	36
			1	CCG	A	adult		73	39	92
			1	EB	F	fry		3	64	82
			1	EB	A	adult		2	141	156
			1	RB	F	fry		9	53	67
			1	RB	J	juvenile		7	101	122
			1	RB	A	adult		1	146	146
14	R03R	EF	2	CCG	F	fry		1	32	32
			2	CCG	A	adult		39	51	101
			2	EB	F	fry		2	79	85
			2	RB	F	fry		1	48	48
			2	RB	J	juvenile		2	111	112

Site #	Site Name	Method	Pass	Species	Stage	Stage Name	Age	Total #	Length (mm)	
									Min	Max
15	P02	EF	1	CCG	F	fry		45	21	35
			1	CCG	A	adult		28	48	71
			1	EB	F	fry		2	68	88
			1	EB	A	adult		4	116	207
			1	RB	F	fry		5	45	66
			1	RB	J	juvenile		6	94	127
			1	RB	A	adult		5	142	183
15	P02	EF	2	CCG	F	fry		12	21	33
			2	CCG	A	adult		17	46	89
			2	EB	F	fry		1	82	82
			2	EB	A	adult		3	134	217
			2	RB	F	fry		2	55	69
			2	RB	J	juvenile		9	95	131
15	P02	EF	3	CCG	F	fry		5	23	33
			3	CCG	A	adult		16	49	90
			3	EB	F	fry		1	74	74
			3	EB	A	adult		2	134	165
			3	RB	F	fry		1	57	57
			3	RB	J	juvenile		2	110	111
			3	RB	A	adult		2	149	150
16	G04	EF	1	CCG	F	fry		28	20	33
			1	CCG	A	adult		23	45	81
			1	EB	F	fry		1	91	91
			1	RB	F	fry		2	49	60
			1	RB	J	juvenile		1	106	106
16	G04	EF	2	CCG	F	fry		3	27	33
			2	CCG	A	adult		15	48	85
			2	EB	F	fry		1	89	89
			2	EB	A	adult		2	139	240
			2	RB	F	fry		1	51	51
17	SC4L	EF	1	CCG	A	adult		2	54	74
			1	EB	F	fry		18	55	90
			1	EB	A	adult		1	135	135
			1	RB	F	fry		2	35	40
			1	RB	J	juvenile		2	83	87
17	SC4L	EF	2	CCG	F	fry		1	24	24
			2	CCG	A	adult		1	79	79
			2	EB	F	fry		3	62	68
			2	RB	J	juvenile		1	105	105
18	R10	EF	1	CCG	F	fry		3	27	32
			1	CCG	A	adult		68	46	91
			1	EB	F	fry		4	68	90
			1	RB	F	fry		8	43	67
			1	RB	J	juvenile		2	105	117
18	R10	EF	2	CCG	F	fry		1	26	26
			2	CCG	A	adult		74	44	83
			2	RB	F	fry		1	50	50
			2	RB	J	juvenile		1	106	106
			2	RB	A	adult		1	167	167
18	R10	EF	3	CCG	F	fry		2	27	31
			3	CCG	A	adult		34	42	94
			3	EB	F	fry		1	93	93

Site #	Site Name	Method	Pass	Species	Stage	Stage Name	Age	Total #	Length (mm)	
									Min	Max
19	G11	EF	1	CCG	F	fry		31	19	33
			1	CCG	A	adult		48	43	86
			1	EB	F	fry		3	67	87
			1	EB	A	adult		5	127	208
			1	RB	F	fry		10	48	60
			1	RB	J	juvenile		7	82	123
			1	RB	A	adult		3	144	188
19	G11	EF	2	CCG	F	fry		17	18	31
			2	CCG	A	adult		36	44	82
			2	EB	F	fry		1	76	76
			2	EB	A	adult		1	105	105
			2	RB	F	fry		3	53	65
20	P08	EF	1	CCG	F	fry		1	22	22
			1	CCG	A	adult		19	42	88
			1	EB	F	fry		2	88	89
			1	EB	A	adult		7	123	203
			1	RB	F	fry		3	53	59
			1	RB	J	juvenile		10	84	110
			1	RB	A	adult		5	138	194
20	P08	EF	2	CCG	A	adult		11	42	71
			2	EB	F	fry		2	75	83
			2	RB	F	fry		2	56	59
			2	RB	J	juvenile		1	86	86
			2	RB	A	adult		3	156	165
21	SC7R	EF	1	CCG	A	adult		21	47	83
			1	EB	F	fry		19	52	88
			1	EB	A	adult		2	133	135
			1	RB	J	juvenile		1	90	90
21	SC7R	EF	2	CCG	A	adult		7	53	82
			2	EB	F	fry		6	61	88
			2	EB	A	adult		2	121	211
22	G17	EF	1	CCG	F	fry		4	22	27
			1	CCG	A	adult		38	42	77
			1	EB	F	fry		2	65	71
			1	RB	F	fry		10	50	61
			1	RB	J	juvenile		6	94	125
			1	RB	A	adult		2	143	166
22	G17	EF	2	CCG	F	fry		4	17	24
			2	CCG	A	adult		21	44	84
			2	RB	F	fry		3	48	58
			2	RB	A	adult		1	142	142
23	R17	EF	1	CCG	F	fry		5	21	32
			1	CCG	A	adult		128	43	93
			1	EB	F	fry		2	74	84
			1	EB	A	adult		1	136	136
			1	RB	F	fry		10	52	65
			1	RB	J	juvenile		1	97	97
			1	RB	A	adult		1	159	159
23	R17	EF	2	CCG	F	fry		4	19	30
			2	CCG	A	adult		81	44	83
			2	RB	F	fry		3	43	71
			2	RB	J	juvenile		1	91	91
23	R17	EF	3	CCG	A	adult		38	48	79

Site #	Site Name	Method	Pass	Species	Stage	Stage Name	Age	Total #	Length (mm)	
									Min	Max
24	P13R	EF	1	CCG	A	adult		6	42	83
			1	EB	F	fry		3	71	88
			1	EB	A	adult		2	123	182
			1	RB	F	fry		1	52	52
			1	RB	J	juvenile		7	80	129
			1	RB	A	adult		1	135	135
24	P13R	EF	2	CCG	F	fry		1	26	26
			2	CCG	A	adult		17	43	88
			2	EB	A	adult		2	116	140
24	P13R	EF	3	CCG	A	adult		4	44	75
			3	EB	F	fry		1	78	78
			3	EB	A	adult		1	136	136
			3	RB	J	juvenile		1	95	95

ELECTROFISHING SPECIFICATIONS - Barnes B3

Site	Pass	Time In	Out	Sec	Length	Width	Area	Encl	Voltage	Freq	Pulse
R03R	1	9:32	10:00	1186	29.5	8.6	254	C	300	60	6
	2	10:32	10:56	1178	29.5	8.6		C	300	60	6
P02	1	12:00	12:29	1465	16.6	11.4	189	C	300	60	6
	2	13:02	13:30	1407	16.6	11.4		C	300	60	6
	3	13:47	14:09	1136	16.6	11.4		C	300	60	6
G04	1	15:02	15:22	1043	12.7	8.5	108	C	300	60	6
	2	15:41	16:00	872	12.7	8.5		C	300	60	6
SC4L	1	16:49	17:06	630	24.3	1.6	39	C	300	60	6
	2	17:20	17:30	400	24.3	1.6		C	300	60	6
R10	1	18:06	18:24	943	16.1	8.0	129	C	300	60	6
	2	18:44	19:04	1000	16.1	8.0		C	300	60	6
	3	19:27	19:39	671	16.1	8.0		C	300	60	6
G11	1	9:27	10:05	1704	14.2	9.1	129	C	300	60	6
	2	10:40	11:09	1345	14.2	9.1		C	300	60	6
P08	1	12:09	12:37	1345	17.3	7.6	131	C	300	60	6
	2	13:05	13:29	1044	17.3	7.6		C	200	60	6
SC7R	1	8:59	9:24	1098	25.0	4.5	113	C	200	60	6
	2	9:42	10:02	827	25.0	4.5		C	200	60	6
G17	1	14:37	15:02	1154	15.0	9.9	149	C	300	60	6
	2	15:23	15:41	830	15.0	9.9		C	300	60	6
R17	1	16:02	16:48	1279	17.0	9.5	162	C	300	60	6
	2	17:13	17:33	948	17.0	9.5		C	300	60	6
	3	17:57	18:13	785	17.0	9.5		C	300	60	6
P13R	1	11:42	12:01	800	16.0	8.9	142	C	200	60	6
	2	12:21	12:39	807	16.0	8.9		C	200	60	6
	3	12:49	13:07	777	16.0	8.9		C	200	60	6
				26674			1544				

APPENDIX 6. Whatshan River and Barnes Creek Fish Aging Results, September 2015.

Stream	Site	Date	Sample	Species	Len (mm)	Weight (g)	Age	COMMENTS
Whatshan	G09	12-Sep-15	20	RB	102	10.3	1+	6002
Whatshan	P01	8-Sep-15	8	RB	103	11.2	1+	5992
Whatshan	G09	12-Sep-15	21	RB	104	10.9	1+	6003
Whatshan	P01	8-Sep-15	5	RB	110	12.2	1+	5989
Whatshan	G09	12-Sep-15	23	RB	111	12.3	1+	6005
Whatshan	P01	8-Sep-15	6	RB	112	13.6	1+	5990
Whatshan	G09	12-Sep-15	24	RB	114	15.3	1+	6006
Whatshan	P10	12-Sep-15	28	RB	114	15.1	1+	6010
Whatshan	P10	12-Sep-15	29	RB	122	21.6	1+	6011
Whatshan	R17	13-Sep-15	30	RB	122	18.2	1+	6012
Whatshan	P10	12-Sep-15	26	RB	125	20.5	1+	6008
Whatshan	R02	9-Sep-15	13	RB	127	17.2	1+	5996
Whatshan	R02	9-Sep-15	12	RB	134	26.8	1+	5995
Whatshan	P10	12-Sep-15	27	RB	140	25.7	1+	6009 ? 2+ ALL REGEN.
Whatshan	P01	8-Sep-15	1	RB	106	11.1	2+	PHOTO 5986
Whatshan	P01	8-Sep-15	7	RB	134	23.3	2+	5991
Whatshan	P01	8-Sep-15	2	RB	137	24.9	2+	5987
Whatshan	R02	9-Sep-15	11	RB	137	29.7	2+	5994
Barnes	P02	14-Sep-15	33	RB	142	28.4	2+	6015
Barnes	P02	14-Sep-15	38	RB	149	32.3	2+	6020
Barnes	P02	14-Sep-15	37	RB	150	38.1	2+	6019
Whatshan	P01	8-Sep-15	4	RB	153	38.9	2+	5988
Whatshan	R17	13-Sep-15	31	RB	155	36.7	2+	6013
Barnes	P08	15-Sep-15	43	RB	156	34.9	2+	6027
Barnes	P02	14-Sep-15	32	RB	157	36.3	2+	6014
Barnes	P08	15-Sep-15	40	RB	157	41.2	2+	6022
Barnes	P02	14-Sep-15	35	RB	160	37.5	2+	6017
Barnes	P08	15-Sep-15	42	RB	160	49.9	2+	6026
Whatshan	P04	10-Sep-15	19	RB	167	56.0	2+	6001 ONLY 3 READABLE
Whatshan	R02	8-Sep-15	10	RB	180	67.5	2+	5993
Barnes	P08	15-Sep-15	44	RB	165	53.1	2+?	6028 BEST SCALE
Barnes	P02	14-Sep-15	34	RB	166	45.2	3+	6016
Whatshan	R02	9-Sep-15	14	RB	169	47.8	3+	5997
Barnes	P02	14-Sep-15	36	RB	183	62.0	3+	6018
Barnes	G11	15-Sep-15	39	RB	188	71.5	3+	6021
Barnes	P08	15-Sep-15	41	RB	194	86.6	3+	6024-25
Whatshan	G05	10-Sep-15	17	RB	196	86.1	3+	6000
Whatshan	G05	9-Sep-15	15	RB	197	68.3	3+	MAYBE 4+, 5998
Whatshan	G05	10-Sep-15	16	RB	198	69.5	3+	4+?, 5999
Whatshan	G09	12-Sep-15	22	RB	199	87.9	3+	6004
Barnes	G18	15-Sep-15	45	RB	166	46.6	C/A	6029
Whatshan	P10	12-Sep-15	25	RB	176	60.8	C/A	6007

Analyses by Hamaguchi Fish Aging Services, Kamloops, BC