Peace Project Water Use Plan

Williston Reservoir Tributary Habitat Review

Study Year 2

Reference: GMSMON-17

Williston Reservoir Tributary Habitat Review - 2011 Summary Report

Study Period: 2012

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GMSMON#17 WILLISTON RESERVOIR TRIBUTARY HABITAT REVIEW

Williston Reservoir Tributary Habitat Review - 2012 Data Summary Report

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Cover Photo

Bay at the mouth of Ole Creek, looking southeast down Williston Reservoir showing wood debris accumulation, May 2012.

Keywords

Williston Reservoir, Fish, Fish Spawning Habitat, Arctic Grayling, Rainbow Trout, Amphibian, Amphibian Habitat, Tributary Enhancement, Adfluvial Fish Migration, Spring Spawning, Water Temperature

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Executive Summary

This report presents the methods and results of the second year (2012) of baseline monitoring at the Williston Reservoir tributaries selected for trial enhancement works to improve fish passage (GMSMON#17). The primary focus of this Peace Project Water Use Plan study is on the success of tributary enhancement in improving fish access and habitat where enhancement works aim to mitigate two types of access impediments: 1) shallow braided channels with little or no cover over the drawdown zone (Six Mile Creek); and, 2) accumulation of floating woody debris (Ole Creek).

Though the monitoring program is principally interested in fish, wildlife (including amphibians and birds) and habitat (vegetation) will also be monitored (a summary of objectives, management questions and hypotheses is found below in Table 1 ES). Sites that BC Hydro selected for this monitoring program include two trial tributaries: Ole Creek - a woody debris blockage site (northern trial site), and Six Mile Creek - a perched mouth site (southern trial site). There are also paired control sites to both Ole Creek and Six Mile Creek. They are Factor Ross Creek and Lamonti Creek, respectively. This study is based on a before-after, control-impact (BACI) design, this being the second year of 'before-test' monitoring.

Baseline data have been collected during 2011 and 2012, with field sessions generally occurring in early spring (May), late spring (late June to early July) and late summer (August) each year. Data collection in 2012 involved fish spawning surveys, fish population surveys, and amphibian surveys. In 2011, songbird surveys, and vegetation surveys were also conducted along each tributary; however, these were discontinued in 2012 as it was agreed, in consultation with BC Hydro, that enhancement works would not have an impact on the existing conditions of these components along the tributaries. Monitoring of these components will therefore be restricted to the actual enhancement areas once they are constructed.

Satellite-linked stream gauging stations equipped with pressure transducers and air and water temperature probes were installed on the test streams (Ole and Six Mile creeks) in late May 2012. These are providing real-time temperature and water level information accessible via the internet. A stream level - discharge relationship is being compiled; however, more data are required to refine this model. Three discharges were measured in 2012 at varying stream stages.

Stream walks were conducted in the spring to enumerate spawning fish and redds. The location and estimated area of suitable spawning substrates were also recorded. Arctic Grayling (*Thymallus arcticus*), and Rainbow Trout (*Oncorhynchus mykiss*) were the target species as they spawn in the spring when reservoir levels are at their lowest and tributary access blockages are most likely to occur. Because Arctic Grayling were not observed during the first year of the study in 2011, spawner surveys focused on Rainbow Trout in 2012. Surveys were conducted in early July 2012 when stream flow and temperature data indicated that conditions were suitable for Rainbow Trout spawning. One Rainbow Trout in spawning colours was observed in Six Mile Creek but no other fish or redds were observed in any of the other streams. In general, there was a limited amount of suitable spawning habitat within the surveyed sections (i.e., lower reaches) of the study streams.

Additionally, during the July survey observations were made near the mouths of the study streams to document any potential barriers to fish movement (i.e., debris jams or perched mouths); none were noted at that time. Reservoir levels in 2012 were higher than average and consequently, tributary access blockages were unlikely and may not have occurred during the spawning migration period.

Amphibian searches were also conducted during the early July field session as per RISC standards (RISC 1998a and 1998b) for time constrained searches. Searches were conducted at what were considered the best of the suitable breeding habitat areas encountered in 2011. In general, amphibian populations appear to be low around the study streams. Between all sites, the following three species were noted: wood frog (*Lithobates sylvatica*), western toad (*Anaxyrus boreas*), and Columbia spotted frog (*Rana luteiventris*) with western toad being the most frequently encountered*.* In 2011, long-toed salamander (*Ambystoma macrodactylum)* (*egg mass only*) were also observed at Six Mile Creek.

Surveys of suitable amphibian breeding areas along the lower reaches of the study streams thus far suggest that enhancement works will not impact amphibian habitat, which is constrained to upland areas (including perched wetlands) adjacent to the study streams; no areas of suitable amphibian breeding habitat have been noted that share potential habitat with fish. It is recommended that future amphibian monitoring be focused within areas where potential impacts to amphibians resulting from the enhancement works are more plausible (i.e., within the drawdown zone at the stream mouths).

A new approach was adopted for fish population estimates to address sampling challenges in 2011 related to low fish density. In August 2012, a mark-resight method was used whereby fish were captured by electrofishing, tagged, and released. A night time snorkel survey ensued whereby the proportion of tagged fish among the total observed allowed for a population estimate. This method was found to be an improvement from the 2011 method and should provide a more reliable means for post-enhancement comparisons of fish community response. Mark-resight abundance estimates were intended primarily for Rainbow Trout because they are the targeted species for enhancement and monitoring. However, the mark-resight method was also used to estimate abundance of other species, when possible, to validate the method and provide the context of other fish populations when interpreting changes before and after enhancement.

Burbot (*Lota lota*), Bull Trout (*Salvelinus confuentus*), sculpin (*Cottus* sp.), Mountain Whitefish (*Prosopium williamsoni*), and Rainbow Trout were observed in Six Mile Creek. Of these, Rainbow Trout was the only species captured in sufficient numbers to allow for an estimate of abundance to be calculated: approximately 10 fish/100 m^2.

Bull Trout, sculpin, and Rainbow Trout were observed in Lamonti Creek. A greater number of Rainbow Trout were caught in 2011 compared to 2012, and Mountain Whitefish were caught in 2011 but not 2012. Abundance estimates were 5 fish/100 m^2 for Rainbow Trout and 11 fish/100 m^2 for Bull Trout.

In Ole Creek, Bull Trout, sculpin, Mountain Whitefish, and Rainbow Trout were observed, with Bull Trout making up the majority (31 individuals). Bull Trout was the only species with sufficient catch to allow for an abundance estimate: approximately 32 fish/100 m^2.

In Factor Ross Creek, Bull Trout, sculpin, Arctic Grayling, Kokanee (*Oncorhynchus nerka*), Mountain Whitefish, and Rainbow Trout were observed. Additionally, a group of three Arctic Grayling was observed at a site upstream of the forestry road bridge, another was observed during the snorkel survey at a site near the mouth of the creek. Catches and species diversity in 2012 were much higher than in 2011, when only sculpin and Mountain Whitefish were caught. Abundance estimates were only possible for Bull Trout: approximately 15 fish/100 m^2.

Reservoir levels were extremely high during the 2012 season (exceeding 75th percentile levels for most of the spring and summer) which had an effect on the morphological and fish passage conditions at the stream mouths (i.e., generally improved access). Additionally, regional snow pillow information suggests an above average snow load was present within the study stream watersheds in 2011 and 2012. This has implications in assessing the effects of enhancement works in improving fish access, as baseline data thus far have only been collected in years where conditions (i.e., high stream and reservoir levels) have allowed unimpeded fish access to the subject streams. This may obscure post-treatment hypothesis testing in detecting ‘no-change’ if no pre-treatment data from a year when a blockage occurred will be available to test the impacts of the enhancement works in an otherwise impeded access scenario.

Permanent photo plots of the stream mouths were set up at each of the trial and control tributaries in order to provide a visual aid in determining the stream mouth conditions through time given seasonal changes, reservoir levels, and varying stream discharge. Photos were taken in July and August 2012.

The following recommendations are made based on the first two years of the monitoring program:

- Spawning surveys should continue to focus on Rainbow Trout but should aim to survey a greater stream length. The real time temperature and level data should be used to schedule the spawning assessment after stream temperatures reach 5-7°C, and shortly after the peak spawning date for Rainbow Trout. Further, snorkelling should also be used during these surveys to improve detection of adult fish.
- Continue to use the mark-resight method to estimate abundance of fish in the study streams.
- Consider changes to the study design to five years of monitoring before tributary enhancement and five years after enhancement in order to increase the likelihood of collecting baseline data during a period when access into the tributaries is actually impeded.
- Refine the enhancement designs to incorporate more woody debris in mounds that would elevate the structures close to the stream mouths to above the full pool level.
- Amphibian sampling should continue using time-constrained searches as a method but effort should be refocused to target areas where impacts from the enhancement works are most likely (i.e., within the drawdown zone at the stream mouths). The use of cover boards may be considered to improve detection of salamanders at the mouth of Six Mile where cover may be limiting.

Table 1 ES: GMSMON#17 Status of Objectives, Management Questions and Hypotheses after Year 1.

Objective	Management Questions	Management Null Hypotheses	Year 1 (2011) Status	Year 2 (2012) Status
Address management questions by collecting data necessary to test null hypotheses.	Does fish abundance and diversity in tributaries increase as a result of enhancement?	Fish abundance and diversity in tributaries does not increase as a result of tributary enhancement.	Based on the limited baseline data available, hypothesis cannot be rejected at this time. More data required to be collected.	Changed methods for evaluating this question with improved results. Baseline data only at this time.
	Is the area and quality of fish habitat created by the tributary enhancement maintained over time?	Total rearing area for fish does not increase following enhancement to tributaries.	Based on the limited baseline data available, hypothesis cannot be rejected at this time. More data required to be collected.	Baseline data only at this time.
	Does riparian vegetation along tributaries increase in abundance and diversity as a result of enhancement?	Riparian vegetation abundance and diversity in and near tributaries does not change following enhancement to tributaries.	Vegetation transects were established and data were collected; however, BC Hydro has agreed that the vegetation program will be suspended until the year of the enhancement works.	Monitoring work in regards to this question is suspended until the implementation of the enhancement works, work conducted thus far provides a good understanding of baseline conditions in the region.
	Does amphibian abundance and diversity in tributaries change as a result of enhancement?	Amphibian abundance and diversity in and near tributaries does not change following tributary enhancement.	Based on only baseline data collected, hypothesis cannot be rejected at this time. More data required to be collected.	Continuing baseline data collection, suggest increasing sampling effort in future years due to generally low populations.
	Does tributary enhancement change the area and quality of amphibian breeding habitat over time? If so, is the area and quality maintained over time?	Total amphibian breeding area does not change following enhancement.	Because only baseline data has been collected to date, hypothesis cannot be rejected at this time. More data required to be collected.	Need more emphasis on measuring habitat quality for amphibian species in future years. Baseline only at this time.
	Does abundance and diversity of songbirds (passerines) around tributaries change as a result of enhancement?	Songbird abundance and diversity near tributaries does not change following tributary enhancement.	Recommend cancellation of bird sampling program. Should the proposed enhancement design call for removal of vegetated berms/delta's and the like, there could have been effects to vegetation and terrestrial habitat worth assessing in MON17. The WUP Committee would not have known what works would be needed to improve the tributary access enhancement, hence the inclusion of the songbird habitat portions of the monitor. Now that BCH has an implementation design showing that songbird habitat areas are not likely to require change, on a measureable scale, the recommendation is to state that H6 has been answered and does not require further study.	Discontinued at this time. Habitat enhancement works are not anticipated to impact avian species regionally. Recommend qualitative assessment of avian use of enhancement works post construction.

Table of Contents

TABLES

FIGURES

APPENDICES

APPENDIX A
Maps

APPENDIX B
Photo Plates

APPENDIX C
Methodological Details and Sampling Protocols

APPENDIX D
Data Tables

APPENDIX E
Model Code

1.0 INTRODUCTION

The Tributary Habitat Review monitoring program is a component of the Peace Project Water Use Plan and its Williston Tributary Access Management Plan aimed to improve access to tributaries for fish and wildlife. Williston Reservoir levels are the lowest during the spring, prior to the reservoir filling phase that occurs during spring freshet. During these low reservoir levels in the spring, fish access to tributaries of the reservoir can be impeded in the drawdown area, primarily through two types of blockages: 1) debris blockages caused by accumulations of woody debris; and, 2) perched mouth, where the mouth of the stream is perched above the reservoir with steep and/or shallow water flow in between. Many fish species in Williston Reservoir have adfluvial life-histories and use tributaries to spawn. Access blockages primarily affect adfluvial species, such as Arctic Grayling (*Thymallus arcticus*), and Rainbow Trout (*Oncorhynchus mykiss*), that spawn in the spring when reservoir levels are at their lowest. Proposed habitat enhancements (discussed below) therefore aim to improve fish access to tributaries during low reservoir levels in the spring, while potentially also providing benefits to wildlife and vegetation. The primary focus of this study is to measure the effectiveness of two trial tributary enhancement projects in improving fish access and habitat.

Williston Reservoir is located west and north of the town of Mackenzie, in the northern interior of British Columbia (BC). It is the largest reservoir in BC, covering a surface area of 1,773 km^2 (BC Hydro 2011). The Peace River is the primary outflow to the reservoir, with water levels in the reservoir controlled by the WAC Bennett Dam located near Hudson's Hope, BC. Water fluctuations in the reservoir due to dam operations along with gentle relief in the littoral zone result in a large drawdown area during low water periods. As a result, shallow channels with excessive braiding often occur where tributaries flow over the exposed drawdown zone, potentially reducing fish access to the tributaries. Lacking habitat complexity from overhanging vegetation or instream cover, these stream segments provide low quality fish habitat through the drawdown zone. Additionally, excessive large woody debris (LWD) present in the reservoir routinely accumulates in some of the bays where tributaries typically occur. After reservoir drawdown occurs, LWD may present a barrier to fish passage, increase scouring and erosion of riparian habitat, or accumulate in the riparian area and prevent plant establishment (BC Hydro 2008). Cubberley and Hengeveld (2010) conducted an aerial reconnaissance of nine tributaries in order to create an inventory of candidate sites for a trial access enhancement works among Williston tributaries. Two trial sites, Six Mile Creek and Ole Creek, were selected for treatment of perched mouth and debris jam barriers, respectively. Engineering designs for Ole and Six Mile Creek enhancement were later developed (KWL 2011) and are expected to be implemented in the 2013-2014 period. Various design options were proposed with the main goals of enhancements being to confine stream flow to a single channel, improve and reinforce channel structure, and prevent additional woody debris from accumulating at the creek mouths. Specifically, proposed enhancements near the mouth of Six Mile Creek included woody revetments, vegetated geoslope banks and an enhanced log jam, all of which are designed to reduce erosion, reinforce channel banks, and prevent channel bifurcation. At Ole Creek, proposed enhancements included woody revetments, gravel berms to confine and reinforce the stream channel, and a woody debris catcher to reduce accumulations of wood at the stream mouth.

This monitoring program consists of a Before-After, Control-Impact (BACI) study design to assess the effectiveness of habitat enhancements. Six Mile Creek (treatment) and Lamonti Creek (control) were selected as sites with potential perched mouth blockages; Ole Creek (treatment) and Factor Ross Creek (control) were selected as sites with potential woody debris blockages. Ole Creek and Factor Ross Creek are located on the northwest shores of Williston Reservoir approximately 40 km south of the First Nation community of

Tsay Keh Dene, and approximately 20 km apart. Six Mile and Lamonti creeks are located approximately 35 km north of Mackenzie, both are within Six Mile Bay and are approximately 1 km apart (Map A1, Appendix A).

Access to tributary streams for spring spawning fish is critical to tributary enhancement objectives. Large-bodied fish that spawn in Williston tributaries during the spring include Rainbow Trout, Arctic Grayling, and suckers (*Catostomus sp.*) Sucker species occurring in Williston Reservoir are Longnose Sucker (*Catostomus catostomus*), Largescale Sucker (*Castostomus macrocheilus*), and White Sucker (*Catostomus commersonii*) (Blackman 1992), all of which are spring spawners and can have adfluvial or stream resident life-histories (McPhail 2007). Longnose Sucker are the most abundant species (Blackman 1992) and typically spawn in spring shortly after ice-out when water temperature is ~5°C but some populations in the Peace watershed are known to delay spawning until mid-June in water temperature of 15-16°C. Arctic Grayling tend to spawn in large tributary streams and may have been absent from the trial tributaries for long enough that stocks may no longer exist (A. Langston, pers. comm., 2011). According to fish distribution records, Arctic Grayling have been recorded in Six Mile Creek (BC Ministry of Environment 2011). Based on species habitat requirements and habitat conditions in the streams, Rainbow Trout and suckers are considered the most likely spring-spawning fish species present within the trial tributaries (A. Langston, pers. comm., 2011). However, with enhanced spring access, it is possible that Arctic Grayling could repopulate the tributary streams. Fish capture results from the 2012 field program indicate that Arctic Grayling are present in Factor Ross Creek. Suckers have not been observed in any of the four tributaries monitored during 2011 or 2012.

This monitoring program is designed to assess the effectiveness of the enhancements in improving fish access to and utilization of the selected tributaries before and after construction. Because the tributary enhancements of the Williston tributaries access plan were acknowledged to have potential to improve habitat for both fish and wildlife, the Terms of Reference (TOR) for this program also stated that amphibians, songbirds and vegetation were to be monitored to assess benefits to wildlife and their habitat. Information from this monitoring program will be used along with other monitoring projects to determine if changes to present operating regimes (e.g., lowering drawdown levels) would be beneficial for both fish and wildlife in Williston Reservoir (BC Hydro 2010).

The primary objectives of this report are to:

- Collect data aimed at addressing the management questions identified below in Section 1.1;
- discuss the findings of data collection in 2012 for fish, amphibian and environmental conditions and compare with 2011, where possible; and,
- provide recommendations for the enhancement program and for future years of the monitoring program.

1.1 Scope, Objectives, Management Questions and Hypotheses

According to the BC Hydro Terms of Reference (TOR) for GMSMON#17, the objective of the monitoring program is to address the management questions identified in the following sections. The study area will include the tributaries selected for enhancement (selected as part of Trial Tributaries implementation project). The monitoring program will occur annually during the 10-year Williston Tributary Access Management Plan. At least one year of baseline data will be collected prior to the commencement of any enhancement activities. Data collection, data analyses, and reporting will be completed annually over the study period and a final study report will be produced in Year 10 that summarizes the results of the entire monitoring program and the conclusions that can be drawn pertaining to the management questions and hypotheses. According to the TOR, the general approach to the monitoring program is a BACI study that will consist of annual fish surveys, fish habitat assessment, riparian vegetation assessment, songbird surveys, as well as amphibian and amphibian-habitat inventory assessments. Based on the findings of the first year of the monitoring program in 2011 (Golder 2012), and in consultation with BC Hydro, it was recommended that songbird surveys not be conducted in subsequent years and vegetation surveys be suspended until the design and detailed location of the habitat enhancements are chosen.

1.1.1 Fish Surveys

Species deemed most suitable as targets of the trial tributary enhancement monitoring program due to their social value, ecology, and life history characteristics include Arctic Grayling and Rainbow Trout. Each of these species are expected to be, at least in part, adfluvial (i.e., migrate between stream and lake habitats and spawn in streams) within the Williston system. Further, Arctic Grayling are listed as G1QS1/critically imperilled in the Williston Watershed (Ballard and Shrimpton 2009).

Arctic Grayling most commonly display a riverine (fluvial) life history; however, adfluvial and lacustrine populations also occur. This species is known for complex migrations between spawning, feeding, and overwintering habitats. In the Williston Reservoir, Arctic Grayling are known to overwinter in embayments and migrate into streams shortly after ice-out for spawning. They typically begin spawning at water temperatures of approximately 4°C. A study of large tributaries of Williston Reservoir found that Arctic Grayling spawning occurred from late-April to late-May in a lower discharge year, and a month later, from late-May to late-June in a higher discharge year (Blackman 2002a). Spawning sites are selected in flowing water over coarse (2 to 4 cm) gravel and cobble substrate, in modest current (0.5 to 1.0 m/s) within shallow (10 to 40 cm) glide or run habitat. Incubation is typically one to three weeks. Fry are weak swimmers and take refuge along the shallow margin of streams (McPhail 2007).

Rainbow Trout are typically adfluvial, though a few introduced populations are known to spawn over gravel substrates along lake shores and many fluvial populations exist. Rainbow Trout spawn in the spring and migration into spawning stream is triggered by water temperatures (5°C) and rising water level. Spawning sites are typically selected over gravelly substrate in variable water depths (15 cm to 2.5 m is typical) with water velocities of 0.3 to 0.9 m/s. Areas with subgravel flow seem to be preferred. Incubation is temperature dependent and ranges from approximately two weeks to two months; alevins remain in the gravel and emerge 32 to 42 days after hatching. Adfluvial fry may migrate back into the lake after their first summer or may overwinter in the stream and migrate the following spring (McPhail 2007).

The key management questions relating to fisheries within the Tributary Habitat Review monitoring program are:

- Does fish abundance and diversity in tributaries increase as a result of enhancement?
- Is the area and quality of fish habitat created by the tributary enhancement maintained over time?

The primary sampling objective of the fish component of the program is to address the management question posed above by collecting data necessary to test the following null hypotheses:

- H_o: Fish abundance and diversity in tributaries does not increase as a result of tributary enhancement; and,
- H_o: Total rearing area for fish does not increase following enhancement to tributaries.

1.1.2 Amphibian Inventory and Abundance

Amphibians in British Columbia can be grouped into aquatic breeding obligates (frogs, toads, newts and mole salamanders/*Ambystomatidae*) and terrestrial breeding obligates (lungless salamanders/*Plethodontidae*) (BC MWLAP 2004). All the amphibian species known within the Project region are aquatic breeding obligates. Aquatic breeding amphibians require an aquatic environment such as ponds, streams, and wetlands for egg laying sites and tadpole rearing. In general, aquatic breeding amphibians select breeding sites that consist of standing or slow moving water (<5 cm/sec [Richter and Azous 1995]). Egg laying habitat and tadpole microhabitat features vary between species but may include ample emergent vegetation, shallow, warm littoral zones and cover objects that provide shelter from predators.

Many adult amphibians, such as frogs, newts and some salamanders, inhabit the terrestrial environment outside of the breeding period. Terrestrial environments are typically moist and are often located in proximity to water bodies including streams, wetlands and ponds, although some species can be found in more arid environments several kilometres from natal sites (i.e., western toad). Amphibians within the terrestrial environment require moist microhabitat sites with cover objects, which provide refuge. Cover objects can include logs, shrubs, tree hollows, and rock crevices, and provide thermoregulatory and shelter sites.

Amphibian breeding in the region of the study area generally occurs between late April and June followed by tadpole rearing and emergence through the remainder of the growing period. Annual timing of amphibian emergence from hibernation and initiation of breeding activity is dictated, in part, by ambient air and water temperatures.

Amphibian abundance can be affected by extraneous factors such as climate, weather, predation, and disease, and may vary annually (RIC 1998). In addition, females may not breed each consecutive year, which can result in natural variation in breeder abundance. This variation is apparent in species such as western toad (*Anaxyrus boreas*) which are considered explosive breeders.

Reconnaissance monitoring of amphibians was completed in 1998 and 1999 (Hengeveld 1999, 2000). Five amphibian species were documented during these surveys (Table 1).

Table 1: Amphibian Species Documented within the Study Area (Hengeveld 1999, 2000).

Species	Federal Rank	Provincial Rank
Western Toad (*Anaxyrus boreas*)	Special Concern	Blue
Columbia Spotted Frog (*Rana luteiventris)*	Not at Risk	Yellow
Boreal Chorus Frog *(Pseudacris maculate)**	Not Assessed	Yellow
Wood Frog (*Lithobates sylvatica*)	Not Assessed	Yellow
Long-Toed Salamander (*Ambystoma macrodactylum*)	Not at Risk	Yellow

*** Identified in Hengeveld (1999, 2000) reports as Striped Chorus Frog (*Pseudacris triseriata*)**

The primary objective of studying amphibians in the Tributary Habitat Monitoring Program is to determine whether or not amphibian abundance and diversity changes as a result of enhancement work and improved fish access. Amphibians could potentially be affected by the enhancement through changes to vegetation and habitat, or by increased predation on aquatic stages by fish.

The key management questions relating to the amphibian inventory and abundance section of the Tributary Habitat Review monitoring program are:

1) Does amphibian abundance and diversity in tributaries change as a result of enhancement?

2) Does tributary enhancement change the area and quality of amphibian breeding habitat over time? If so, is the area and quality maintained over time?

The primary sampling objective of the amphibian inventory and abundance task is to address the management questions posed above by collecting data for the study areas necessary to draw inferences and to test the following null hypothesis:

- H_o: Amphibian abundance and diversity in and near tributaries does not change following tributary enhancement; and,
- H_o: Total amphibian breeding area does not change following enhancement.

1.1.3 Songbird Inventory and Abundance

Waterfowl and bird of prey monitoring was conducted in the reservoir during 2000 and 2003 (Booth and Corbould 2003, Corbould and Hengeveld 2000, respectively). The breeding period for passerines (songbirds) is thought to be from May to July in the area surrounding the Williston Reservoir (RIC 1999). Because there have been limited surveys of songbirds in the Williston Reservoir area, the Tributary Monitoring Program of selected tributaries aimed to complete reconnaissance surveys for songbirds to provide baseline information to test whether proposed enhancement works would affect songbird abundance and diversity. However, based on observations during the first year of study in 2011 and review of the proposed habitat enhancement construction (KWL 2011), it is unlikely that the enhancement will result in a measurable change in songbird abundance or diversity. Proposed enhancement may create a small amount of additional riparian habitat through vegetation re-growth but the majority of bird habitat along the study streams would be unaffected. In addition, the abundance and diversity of migratory songbirds observed during bird surveys can be highly variable and influenced by numerous other factors, which would make linking changes in abundance to habitat enhancements impossible. Therefore, as recommended in the report from the first year of study in 2011 (Golder 2012), songbird surveys were not conducted in 2012 and monitoring efforts were focused on fish and fish habitat where the proposed designed enhancements are most likely to yield a change.

The key management question relating to the songbird inventory and abundance portion of the tributary habitat review monitoring program is:

- Does abundance and diversity of songbirds (passerines) around tributaries change as a result of enhancement?

The primary sampling objective of the songbird inventory and abundance task is to address the management question posed above by collecting data necessary to draw inferences and to test the following null hypothesis:

- H_o: Songbird abundance and diversity near tributaries does not change following tributary enhancement.

Songbird data collected in the study area in 2011 and presented in Golder (2012) provide some of the first baseline data about the songbird species present near the study tributaries. These data contribute to the knowledge base about songbirds in the Williston Reservoir area, but could also be used to help answer the management question above if managers wish to monitor songbirds near the study streams following habitat enhancement. It is recommended that a qualitative assessment of avian use of the enhancement works be conducted post construction in order to address the management question. This would consist of a visual assessment of species usage and behaviour (i.e., breeding, nesting, foraging, perching, etc.).

1.1.4 Vegetation

The key management question relating to the riparian vegetation section of the Tributary Habitat Review monitoring program is:

- Does riparian vegetation along tributaries increase in abundance and diversity as a result of enhancement?

The primary sampling objective of the riparian vegetation task is to address the management question posed above by collecting data necessary to draw inferences and to test the following null hypothesis:

- H_o: Riparian vegetation abundance and diversity in and near tributaries does not change following enhancement to tributaries.

This management question is difficult to answer without clearly defined locations for enhancement works on each of the treatment tributaries. As such, Golder (2012) recommended, in consultation with BC Hydro, that the vegetation portion of the current monitoring program be suspended until enhancement works can be more clearly defined in order to focus monitoring efforts in areas where changes resulting from the works are plausible. For example, once locations are chosen and enhancement works progress, a monitoring program could include vegetation monitoring on and directly adjacent to, the enhancement feature so that changes are more clearly linked to the enhancement works.

1.2 Study Area

In 2011, the sampling program focused on the lower reaches of each tributary, from where each stream flows into Williston Reservoir (mouth) upstream approximately 1.1 km, typically to where the nearest Forest Service Road crossed the stream. In 2012 the same reaches close to the stream mouths were sampled, but efforts were also made to sample further upstream.

An overview of the project area is provided in Appendix A, Map A1 and a map of each stream is provided in Maps A2 through A5 (Appendix A).

Descriptions of the Site's biological environment are based on the Ecoregion system and Biogeoclimatic (BGC) Ecosystem Classification (BEC) system. The Ecoregion classification system provides a systematic review of the small-scale ecological relationships in the province. The study area is located in the Humid Temperate Ecodomain, Humid Continental Highlands Ecodivision, Sub-boreal Interior Ecoprovince, Omineca Mountains Ecoregion and Parsnip Trench Ecosection. The BEC system delineates the province into BGC zones based on topographic and climatic conditions that are reflected by the presence of specific plant and animal communities. Based on mapping provided on the iMap BC (Government of BC 2009), the study area occurs within the Williston Sub-Boreal Spruce moist cool biogeoclimatic unit (SBSmk2).

2.0 METHODS

Field work in 2012 was conducted during three site visits. The first site visit occurred from May 27 to 29, 2012. Satellite enabled stream gauging stations providing real-time water level and temperature information were installed on Six Mile and Ole creeks. The second site visit occurred during July to conduct Rainbow Trout spawning surveys and amphibian searches. The third site visit was conducted during August to conduct the juvenile and small-bodied fish surveys (mark-resight). Field activities in 2012 are summarized in Table 2 and detailed methodologies are provided in the following sub-sections.

Table 2: Summary of 2012 Field Program.

Dates	Field Work Conducted
May 27 to 29, 2012	■ Installation of stream gauging stations and discharge measurements at Six Mile and Ole creeks
July 3 to 6, 2012	■ Spawning surveys ■ Discharge measurements at stream gauging stations ■ Amphibian surveys
August 19 to 29, 2012	■ Juvenile and small-bodied fish population estimates ■ Discharge measurements at stream gauging stations

2.1 Climate Data and Reservoir Level

Snow pillow survey data from the nearest available stations to the project locations were compared with the 2011 season as well as the mean generated from the previous 10 years. Data from the winter of 2012 had not been verified by the BC River Forecasting Center and was therefore not available from the publicly accessible website; the BC River Forecast Center was contacted and supplied these data with the qualification that they has not been verified.

Daily mean values of Williston Reservoir level were obtained from BC Hydro. Reservoir levels from 2012 were compared to the mean, 25th percentile, and 75th percentile of historical data from 1973-2011.

2.2 Remote Stream Gauging Station Installation

Between May 27 and 29, 2012, satellite enabled water level stations were installed on Six Mile Creek and Ole Creek. The location of these stations is shown in Maps A2 and A5 in Appendix A. Each station consists of the following:

- one KPSI SDI-12 pressure and temperature transducer (Measurement Specialties, Hampton, Virginia, USA) accurate to 0.05% with a range of 0 to 4 metres water depth;
- one ambient temperature probe (model 6057D, Unidata Ltd., Perth, Australia; accuracy ± 0.1°C) housed in a gilled radiation shield;
- 12 V sealed lead acid battery charged by a 20 watt solar panel;
- Remote satellite terminal (2015D Neon Remote Terminal –Satellite, Unidata Ltd., Perth, Australia) with 15,000 data point storage memory; and,
- a backup Hobo Water Temperature Pro water temperature logger (Onset Computer Corporation, Massachusetts, USA; accuracy of ± 0.1°C and range of 0°C to 50°C).

The station measures water level, water temperature and air temperature at 5 minute intervals. Data are hosted by the Neon system (Unidata Ltd., Perth, Australia) and can be accessed on the internet by permission from BC Hydro.

The current regime is set to upload data to the website at one hour intervals, if a satellite connection is not established, the unit attempts to connect two more times at seven minute intervals. If a connection is still not successfully established, the data are uploaded the next time a connection is established (generally occurring every two hours based on performance thus far). The recording and communication schemes can be adjusted remotely via the Neon webpage.

The stations were set up in locations that provided some protection from floating debris and ice, where banks and substrate appeared stable, and where the units were generally inconspicuous. The probes were placed within stainless steel conduit (to act as a stilling well) that was anchored within a reasonably deep pool that is assumed to contain water year round (Appendix B, Photos 1 and 2). Holes were drilled along the length of the conduit to ensure that the water level inside the conduit is representative of the stream. A staff gauge was connected directly to the side of the conduit via hose clamps. The top of the pipe, anchoring rebar, and the top of the staff gauge were surveyed with a laser level so that any change in their position can be detected; a bench mark was established by placing a large nail in a mature nearby tree. The air temperature sensors were placed on the shady side of a tree approximately 1 m above the ground. The Neon terminal box, battery box, and solar panels were fastened to trees in order to provide protection from animals. The location details and surveyed elevations of both stations are provided in Tables 3 and 4, respectively.

Table 3: Location and Installation Details for Neon Satellite-Enabled Stream Gauging Stations.

Location	Station #	Neon Serial #	UTMs			Date and Time of Installation
			Zone	X	Y	
Ole Creek	1	4870	10V	6257596	404853	May 28, 2012 13:05
Six Mile Creek	2	5012	10U	6163771	474511	May 27, 2012 15:38

Table 4: Surveyed Elevations for Neon Stations.

Location	Measured Elevation (m)	Corrected Elevation (m)
Six Mile Station (Neon ID 5012)		
Bench Mark	-0.065	0.000
Upstream Nail	2.408	2.473
Downstream Nail	2.414	2.479
Top of T-Post	2.357	2.422
Top of Pipe	1.867	1.932
Top of Staff Gauge	2.828	2.893
Ole Station (Neon ID 4870)		
Bench Mark	1.370	0.000
Top of Pipe	2.466	1.096
Top of Rebar	2.687	1.317
Top of Staff Gauge	3.419	2.049

Stream discharge was calculated based on velocity and depth measurements taken at the gauging stations during each of the three site visits in 2012. Discharge was calculated using the velocity-area method (McMahon *et al.* 1996). A staff gauge reading was also taken and water temperature was measured using an alcohol thermometer. Stream discharge calculated from the three site visits was plotted against the water level measured at that time by the gauging station and staff gauge measurements. Linear regression was used to describe the relationship between discharge and water level.

Following station installation in Six Mile Creek during late May, stream flows were very high which made wading difficult in most locations. Therefore, measurements for discharge calculation were taken at the nearest safe downstream location, which was approximately 60 m downstream of the sensor. During that time, the thalweg could not be crossed safely. Therefore, the final 6 m of the discharge profile was visually estimated. In subsequent visits when flows in Six Mile Creek were lower, measurements were taken directly at the gauging station. Measurements for discharge calculation at Ole Creek were taken at a location approximately 10 m downstream of the bridge and 130 m upstream of the gauging station because the channel was braided at the gauging station.

After installation of the gauging station on Six Mile Creek, water level and temperature data sometimes logged and transmitted values that appeared reasonable, but occasionally logged values that were clearly errors. The manufacturer of the equipment concluded that the errors were because of a malfunctioning probe. The probe was replaced on August 20, 2012, and the new equipment has been logging data without errors since that time. When the new probe was installed, it was positioned slightly higher (0.051 m) in the housing pipe than the original probe. Therefore, all water level values prior to August 20, 2012 at 15:00 were corrected by subtracting 0.051 m to be comparable to all subsequent values. Water level and temperature data from before August 20, 2012 were cleaned by removing impossible values and obvious outliers.

During the August site visit in 2012, a temperature logger (HOBO Water Temperature Pro v2 Data Logger – U22-001, Onset, Bourne, Massachusetts, USA) was installed at each gauging station as a source of backup temperature data and to verify temperature measurements from the satellite-transmitted station. Those units remain in the streams and will continue logging through the program.

2.3 Amphibian Searches

The amphibian field surveys were completed according to the Resource Inventory Standards Committee (RISC) standards (1998) from July 3 to 6, 2012. Area-based surveys of small ponds and wetlands were completed within suitable habitat in the vicinity of each tributary and the time effort for each search was documented. Data collected included encounters with amphibian egg masses, larvae (tadpoles) and metamorphs (sub-adults and adults). Data recorded included species identification, sex (where feasible), developmental stage, weight (adults only), snout-vent length (SVL; adults only), and general notes regarding the habitat in which the specimen was found including air and water temperatures. Identification keys in Corkran and Thoms (1996) were used to verify identification of egg masses and larvae encountered in the field. Encounters were geo-referenced and photo-documented.

Where amphibians were observed during other field activities, they were recorded as ‘incidental observations’; they were georeferenced and general notes regarding the habitat, behaviour, and other notable features were taken.

2.4 Visual Assessment of Tributary Access Blockage

During the early July and August field visits, the mouth of the each study stream was visited and assessed visually for flow or debris blockage that could impede fish passage. A photo reference location was established near the mouth of each study stream and digital photos were taken at these locations during both site visits. The Global Positioning System (GPS) location was recorded as Universal Transverse Mercator (UTM) coordinates in the NAD83 projection. The height of the camera above the ground was measured with a ruler and the azimuth was measured using a compass (Table 5). Photos from the same position will be taken in future years of the monitoring program. The photo-plot locations, as recorded during July, are provided in Appendix B.

Table 5: Location and Details of Photo Reference Locations at Stream Mouths.

Stream	UTM coordinates			Height above ground (m)	Azimuth (°)	Compass Declination (°)
	Zone	X	Y			
Six Mile	10	474658	6162760	1.6	165, 60	18
Lamonti	10	475396	6161782	1.7	270, 200	18
Ole	10	405814	6257625	2.0	10, 80	18
Factor Ross	10	395397	6275823	1.4	340, 280, 220	18

2.5 Spawner Surveys

A stream walk was conducted by a crew of two workers at each study stream to enumerate Rainbow Trout spawners and redds (timing provided below). One person walked up each stream bank starting at the outlet. All habitat types were assessed for fish presence and for evidence of spawning (i.e., cleared gravel patches). The location of any spawners and redds was recorded with a GPS. In addition, the location and approximate area of suitable spawning gravels was recorded in order to assess the approximate amount of spawning habitat in the surveyed reaches.

In 2011, spawner surveys were conducted from May 9 to 19 to target Arctic Grayling and from June 8 to 10 to target Rainbow Trout. Because no Arctic Grayling were observed during any of the site visits or survey efforts in 2011, spawner survey efforts focused on Rainbow Trout in 2012. Stream flow and water temperature data from the satellite-transmitted gauging station was used to plan the timing of the spawner surveys in 2012, given that Rainbow Trout typically begin spawning when water temperatures reach 5°C (McPhail 2007). The dates and distance of stream length surveyed for each stream are shown in Table 6. Water temperatures in the streams during the first week of July 2012, averaged 5°C (see results in Section 3.2).

Table 6: Spawning Surveys Details.

Stream	Date	Stream Length Surveyed (m)	Starting Point	End Point
Lamonti	July 3, 2012	1850	Stream Mouth	~200 m upstream of forestry road bridge
Six Mile	July 4, 2012	1622	Stream Mouth	Confluence of Patsuk Creek
Ole	July 5, 2012	1871	Stream Mouth	Forestry road bridge
Factor Ross	July 6, 2012	1140	Stream Mouth	~150 m upstream of forestry road bridge

2.6 Juvenile and Small-Bodied Fish Survey

As recommended in the TOR (BC Hydro 2008), the first year of the study in 2011 used multiple-pass removal-depletion electrofishing to estimate the abundance of juvenile and small-bodied fishes in the control and treatment streams. Because of very low catch rates, potential for relatively high sub-sampling error, and the logistical challenges of this method in remote and difficult to access streams, it was recommended that an alternative method be used to estimate fish abundance in subsequent years.

The juvenile and small-bodied fish survey in 2012 used a mark-resight method, which is a variation of commonly used mark-recapture methods but involves visually observing marked and unmarked fish for the recapture session instead of actually capturing them. Fish were captured, marked with a brightly coloured external tag, and released, followed by snorkel surveys after a minimum 24 hours period to allow captured fish to redistribute into the system. Minnow trapping was originally proposed as the method of fish capture for the initial marking session. However, catch rates during the first two days of overnight, baited, minnow trapping on Six Mile Creek were very low (see results in Section 3.7). Backpack electrofishing was attempted as an alternative and proved to be a much more effective capture technique, so it was adopted for the remainder of the program. Additional methodological details and sampling protocols are provided in Appendix C.

Sampling Sites

Sampling reaches in the four study streams were from the mouth to 1.4 km to 1.9 km upstream (Maps A2-A5). Sampling sites within these reaches had to be suitable and safe for snorkel surveys. Therefore, all pools and low velocity habitats within these reaches were sampled by electrofishing (Appendix D, Table D1). Snorkel surveys were conducted at all sites where fish were marked and released during electrofishing. In addition, sites adjacent to where marked fish were released were sampled in order to assess movement of fish between sites. If time permitted, additional sites that had been electrofished but where marked fish were not released were selected randomly for snorkel surveys. For five sites on Six Mile Creek (SM2, SM3, SM4, SM11, and SM12) that were electrofished but not snorkelled, UTM coordinates were not recorded. The approximate location of these five sites is shown in Map A2 (Appendix A).

Because our sampling was limited to pools and low-velocity habitats, the estimates of abundance generated extend only to these habitats; habitats such as riffles and rapids are excluded. The focus of this component of the monitoring program is to estimate the juvenile abundance of targeted salmonid species, all of which have a strong habitat preference for low velocity habitats (McPhail 2007; Korman et al. 2011). Therefore, the sampling sites and methods are appropriate for addressing the management objectives and likely provide a reasonable index to monitor juvenile abundance in the study streams.

Electrofishing and Fish Marking

All pool and low-velocity habitats were sampled using a backpack electrofisher (LR-24, Smith-Root Inc., Vancouver, Washington, USA). A three person field crew conducted this work: one crew member operated the electrofisher, another captured fish with a dip-net, and the third took notes and carried a bucket for holding captured fish. Captured fish were identified to species (except some smaller sculpins that were identified to genus) and weighed with an electronic scale (± 1g). Fork length (total length in the case of sculpins) was measured to the nearest 1 mm. Fish were marked with an external tag that consisted of size 18 barbed fishing hook that had fluorescent yarn tied around the shank. The hook was inserted through the flesh directly behind the dorsal fin using needle-nose pliers. Photographs of different sizes and species of fish that were tagged during the surveys are provided in Appendix B (Photos 3 to 9). All species of fish that were caught were tagged using this method except for sculpin. Sculpin were not tagged in this study because they are likely too small for the tagging method and are not a target species for habitat enhancement. After processing, tagged fish were released at the capture site. Water temperature and conductivity were measured each day and electrofisher settings (voltage, frequency, and duty cycle) were recorded. At each electrofishing site, the UTM coordinates were recorded from a handheld GPS, the time electrofished in seconds was recorded (sample effort), the area (m^2) of habitat sampled was measured using a fibreglass measuring tape, and the habitat complexity was ranked qualitatively based on the type and abundance (%) of available cover. Habitat complexity was based on the total of all cover types (e.g., large and small woody debris, cobble and boulders, turbulence, undercuts) and was ranked as low (<10% cover), medium (10-40% cover) or high (>40% cover).

A fish collection permit was obtained from the Ministry of Forests, Lands and Natural Resource Operations (MFLNRO; Permit No. PG12-80063) prior to fish sampling. Fish sampling data will be submitted online to the MFLNRO as required by the permit.

Minnow Trapping

Minnow trapping was conducted for two days on Six Mile Creek. Because minnow trapping catches were very low and electrofishing proved to be a more effective technique, minnow trapping was discontinued and not used as a capture method on the other three creeks. In Six Mile Creek, minnow traps were deployed at all pool and low-velocity habitats encountered starting at the stream mouth up to 1.8 km upstream. Traps were baited with either salmon roe or seafood-flavoured wet cat food and tied to shore with thin rope for security. The UTM coordinates were recorded using a handheld GPS and the habitat complexity was ranked as low, medium or high as described above. Minnow traps were left to fish overnight and checked the following day. All fish captured were processed the same way as those caught by electrofishing (described above).

Snorkel Surveys

Snorkel surveys were conducted by a three person crew. Two people equipped with drysuits, waterproof flashlights, masks and snorkels conducted the survey while the third crew member recorded the data. The surveys began with a visual survey of the site to observe fish in shallow, near-shore, and other areas where the bottom was clearly visible. The site would then be surveyed by one person from under water using a mask and snorkel. The second snorkeler would then survey the site as a double-check. At larger sites, two people would snorkel and survey the site simultaneously and communicate to avoid counting the same fish twice. During the surveys, all marked and unmarked fish were counted and identified to species, and their fork lengths were estimated. On some occasions, if a fish could not be reliably identified to species, fish were captured by the snorkeler using a small dip-net to confirm taxonomic identification. Sites surveyed by snorkelling included all sites where marked fish were released, sites adjacent to sites with marked fish, and if time permitted, additional sites with no marked fish that were selected randomly from the remaining electrofishing sites. At each site, the same spatial area that was measured and sampled during electrofishing was surveyed by snorkelling. Water clarity and visibility were very high in all the study streams and it was almost always possible to see the bottom and entire length of the site from underwater. Therefore, water clarity was not measured but any changes to water clarity that affected visibility (e.g., sediment stirred-up by observers) were noted. All snorkel surveys were conducted beginning 30 minutes after sunset one day following the release of marked fish. A photo of a tagged fish observed underwater during snorkelling is provided in Appendix B, Photo 9.

Data Analysis

Catch-per-unit-effort (CPUE) for electrofishing was calculated for each species and stream as the number of fish per second and the number of fish per unit area (#/100 m^2). CPUE for snorkel surveys was calculated for each species and stream as the number of fish observed per unit area (#/100 m^2), combining all sites that were surveyed.

A Bayesian probability implementation of the Petersen method for closed population mark-recapture data was used to estimate the abundance of fish in the study streams using the mark-resight data. The classic Petersen model for two capture sessions assumes a closed population and equal recapture probability and estimates the total number of individuals in the population (N) with the formula:

$$N = Mn/m$$

Where: M = number of individuals marked from the first sample (electrofishing), n = total number of fish (marked and unmarked) in the second sample (total observed during snorkel survey), and m = number of marked fish recaptured in the second sample (number of marked fish observed during snorkel survey)

In the Bayesian implementation of the Petersen model, the number of unmarked fish (u) is binomially distributed given the size of the total unmarked population (N) and the catchability (q), and the number of recaptured fish (m) is binomially distributed given the size of the total number of marked fish released (M) and the catchability (q) (Mantyniemi and Romakkaniemi 2003). All combinations of fish species and stream that had sufficient mark-resight data were included in the same model but were included as separate strata. Therefore, catchability was allowed to vary for each species-stream stratum. The prior distribution for catchability was a uniform distribution between 0 and 1, which is considered a vague or uninformative prior (Mantyniemi and Romakkaniemi 2003). The prior distribution for the total number of unmarked fish in the population was a normal distribution with a mean of 40 and a precision of 0.0001, which was chosen based on the total numbers of fish observed during snorkelling, because the model would not converge with an uninformative prior for the unmarked fish parameter. The analysis was conducted using the software package R2.15.1 (R Development Core Team 2012) and the R2WinBUGS package that interfaced with the program WinBUGS (Lunn et al. 2000). The complete model specification used is shown in the model code in Appendix E. Species and stream stratum that were included in the model were Six Mile Rainbow Trout, Lamonti Rainbow Trout, Lamonti Bull Trout, Ole Bull Trout, and Factor Ross Bull Trout. For each species and stream stratum, the analysis pooled data from marked and unmarked fish at all sites that were snorkelled to generate population estimates. Mean values of the abundance estimate and 95% credibility intervals were calculated in WinBUGS. Abundance estimates represent the total number of fish estimated in all the pools that were snorkelled. Therefore, abundance was divided by the spatial area (m^2) of all the pools snorkelled to calculate density in fish/100 m^2 so that results are comparable through time.

We also calculated abundance using a traditional (non-Bayesian) Petersen model, for species where there were sufficient recaptures, to compare to the stratified Bayesian model. Petersen estimates were conducted using the software package R2.15.1 (R Development Core Team 2012) and the package FSA. Confidence intervals were calculated in FSA, which uses the binomial, normal or Poisson approximation depending on sample size and recapture rate following Seber (1982).

3.0 RESULTS AND DISCUSSION

3.1 Climate Data

Snow packs for the 2011 and 2012 study years are compared with historical means from two automated snow pillow gauging stations which are assumed to most closely resemble conditions at the study sites: Aiken Lake (Station ID: 4A309) for the northern locations and Pine Pass (Station ID: 4OA2P) for the southern. Table 7 provides the details of these survey stations.

Table 7: Snow Pillow Survey Locations and Relative Distances from Trial Tributary Locations.

Station ID	UTMs (Zone 10)		Elevation (m)	Proximity to Trial Tributary
	Northing	Easting		
Aiken Lake (4A30P)	6276204	332204	1040	~95 km Northwest of Factor Ross
Pine Pass (4A02P)	6133801	523251	1400	~45 km Southwest of Six Mile Bay

The mean Snow Water Equivalent (SWE) of the previous 10 years is compared to the 2011 and 2012 seasons in Figures 1 and 2. It should be noted that the data for the spring of 2012 has not been verified and should be considered preliminary. Data were provided by BC River Forecast Center.

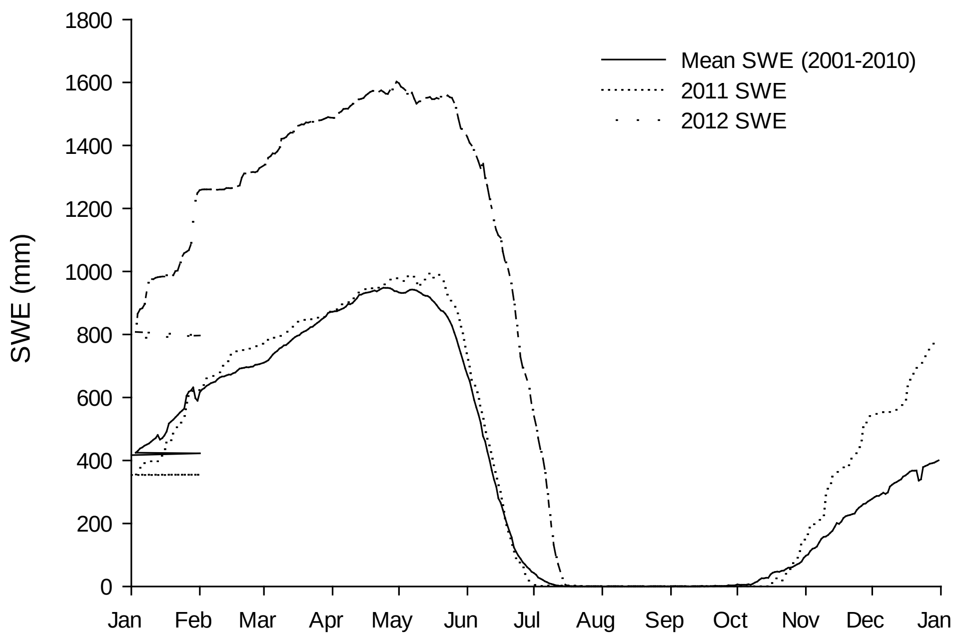

Figure 1: Ten Year Mean versus 2011 and 2012 Snow Water Equivalent (SWE) at the Pine Pass Station.

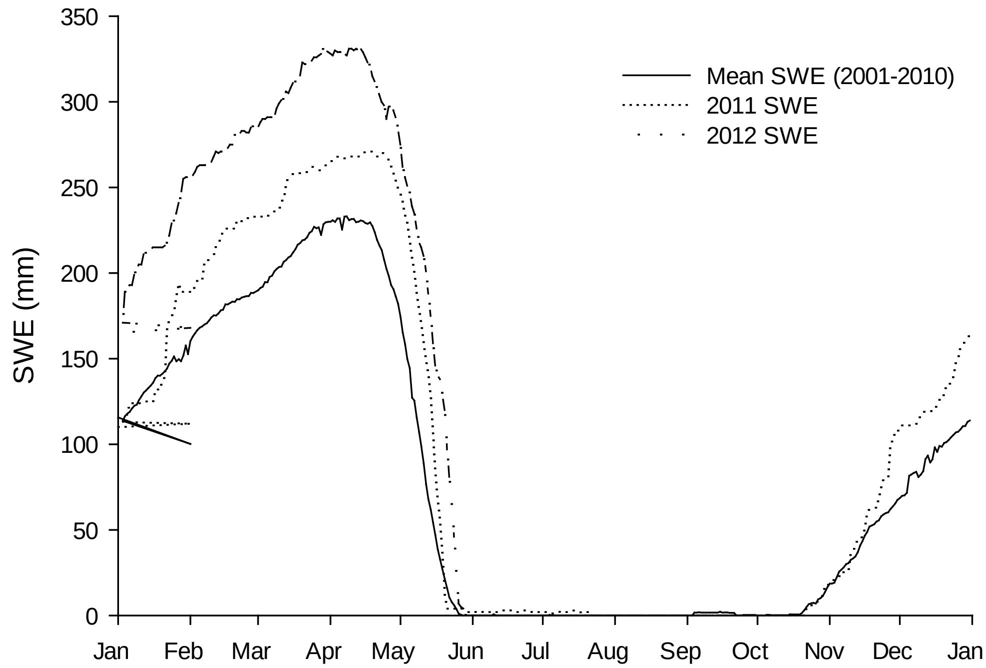

Figure 2: Ten Year Mean versus 2011 and 2012 Snow Water Equivalent (SWE) at the Aiken Lake Station.

This analysis suggests that snowpacks were above average within the trial tributary catchment areas in both the 2011 and, in particularly, in the 2012 season. These snowpacks are likely to have contributed to above average spring discharges and cooler water temperatures during both years of monitoring.

Further analysis of regional stream discharge was attempted in 2011 by comparing the 2011 hydrometric curve of the Nation River with the mean from the previous 10 years. The Nation River is a large tributary of the Williston Reservoir located on the southwest side, approximately half way between the northern and southern trial tributary locations. Environment Canada maintains a water survey station (ID 07ED003) near the mouth of this river. It was assumed that discharge curves at this location would be somewhat representative of regional conditions. However, analysis of these data showed that the 2011 discharge was below average, which conflicts with what was observed in the field, particularly at the southern sites. It may be that the characteristics of the catchment area (i.e., size, slope, location) are not representative. This analysis was therefore discontinued.

3.2 Remote Stream Gauging Station Data

3.2.1 Six Mile Creek

Daily mean, minimum and maximum were calculated from the Six Mile Creek Neon ambient air temperature data in order to smooth the data curve and improve the readability of the graph (Figure 3).There were no outliers or anomalous data points requiring removal from the data set and the air temperature data are consistent with what would be expected in the region. Note that a 20°C difference between daily minimum and daily maximum ambient air temperature is not uncommon.

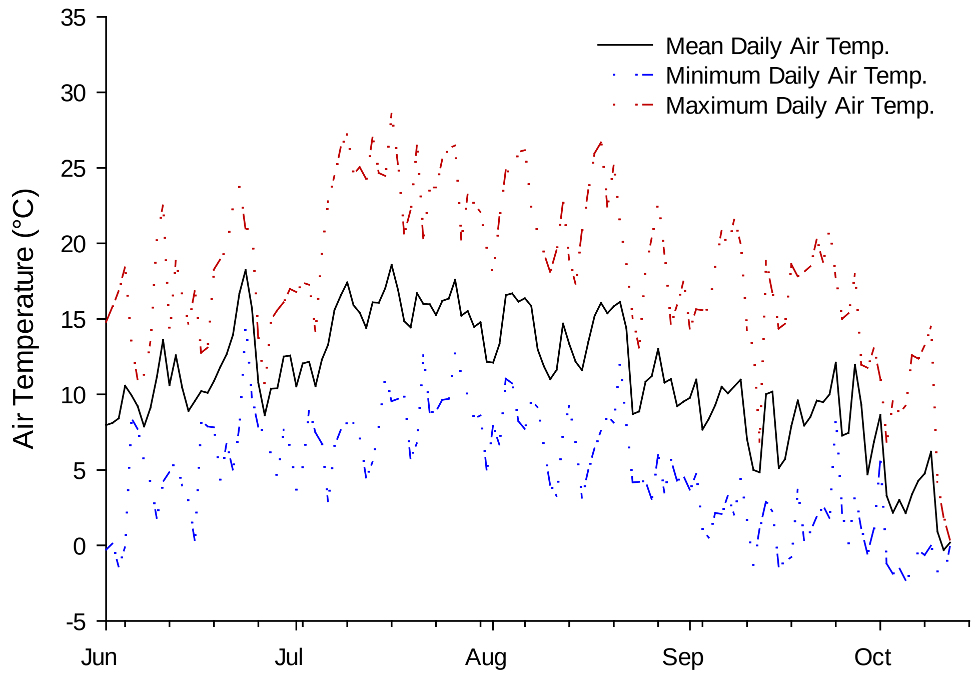

Figure 3: Mean, minimum, and maximum daily air temperature measured at the Six Mile Neon station, 2012.

The maximum recorded air temperature at Six Mile between June 1 and the last data point captured in this report (October 12) is 28.6°C and the coldest is -2.3°C.

The same approach applied to the air temperature was applied to the water temperature data. However, as the KPSI probe was periodically malfunctioning (until it was replaced in August), nonsensical or suspicious data points were removed from the data set (denoted by gaps in Figure 4). Water temperate at Six Mile Creek ranged from 0.0°C to 14.9°C. Caution must be applied to these values as the KPSI probe was clearly malfunctioning and data were cleaned subjectively; data after August 20 can be considered more reliable as a new probe was installed at that time and no outliers have been recorded in the data since this time.

The water level in Six Mile Creek, as recorded by the Neon station, is provided in Figure 5. Again, data before August 20 should be considered with caution. As above, gaps in the line denote data removed due to nonsensical recorded values.

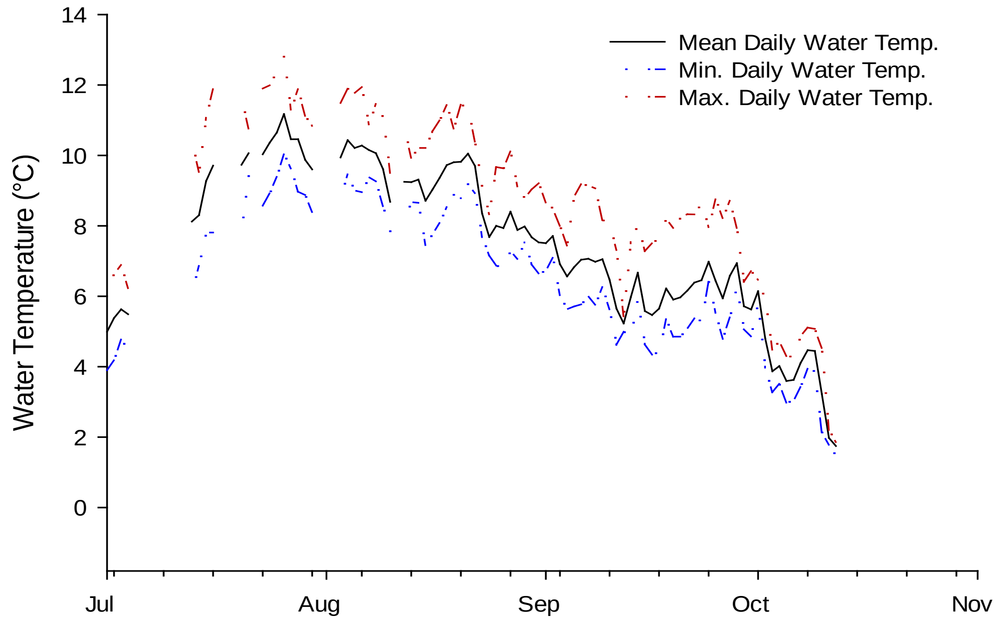

Figure 4: Daily Mean, minimum, and maximum water temperature measured at the Six Mile Neon Station, 2012.

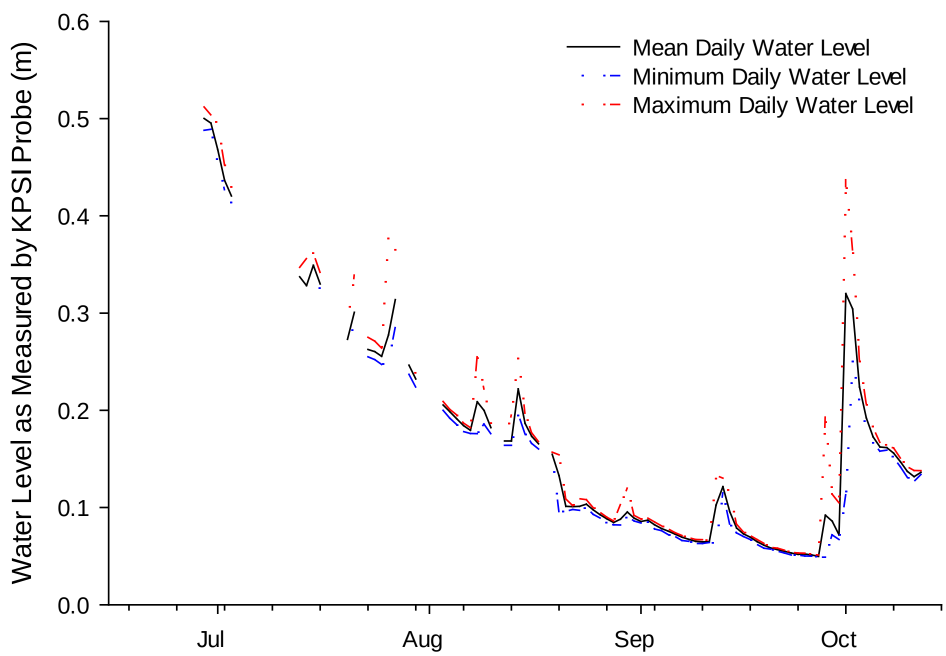

Figure 5: Mean, maximum, and minimum daily water level measured at the Six Mile Neon Station, 2012.

Water level generally decreased between late June and September; however, there was a very sharp spike on October 1. The data shows an incremental increase through this period consistent with a strong rain event. We attempted to cross-reference this with available weather information; however, no historical precipitation data are available in reasonable proximity to the station. Recorded weather in Fort St. John and Prince George did indicate rain showers during this period.

Air temperature, water temperature, and water level as recorded by the Neon station on Ole Creek are provided in Figures 6 through 8.

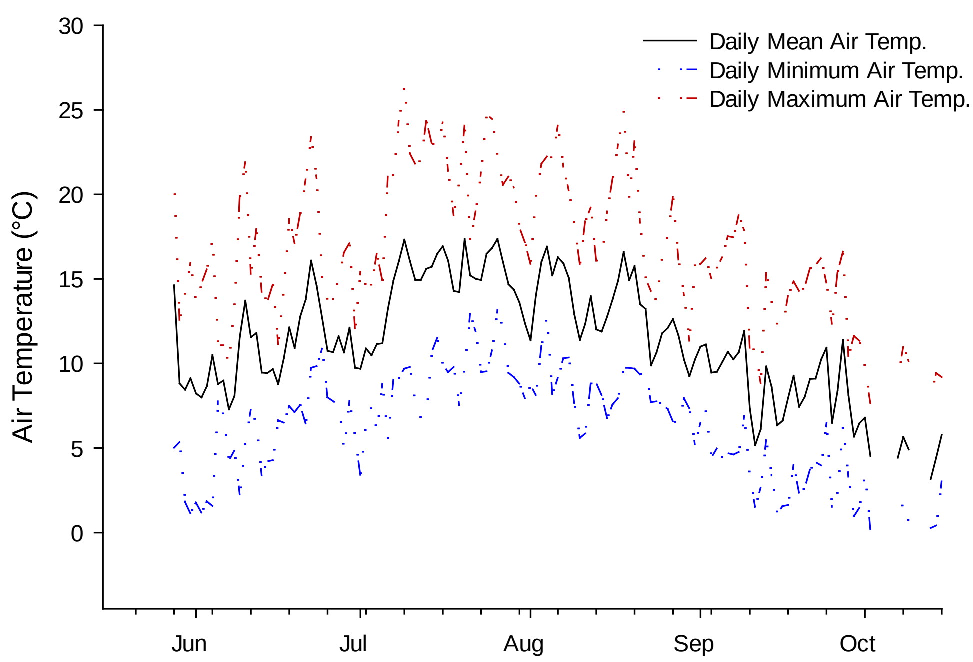

Figure 6: Air temperature measured at the satellite-transmitting gauge station on Ole Creek in 2012.

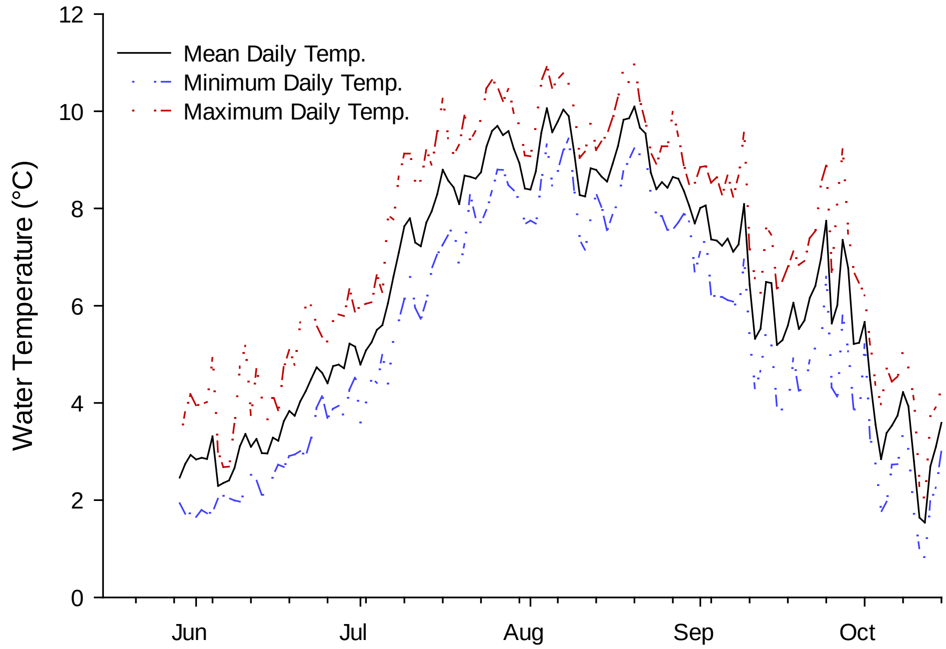

Figure 7: Mean, minimum, and maximum water temperature measured at the Ole Creek Neon station, 2012.

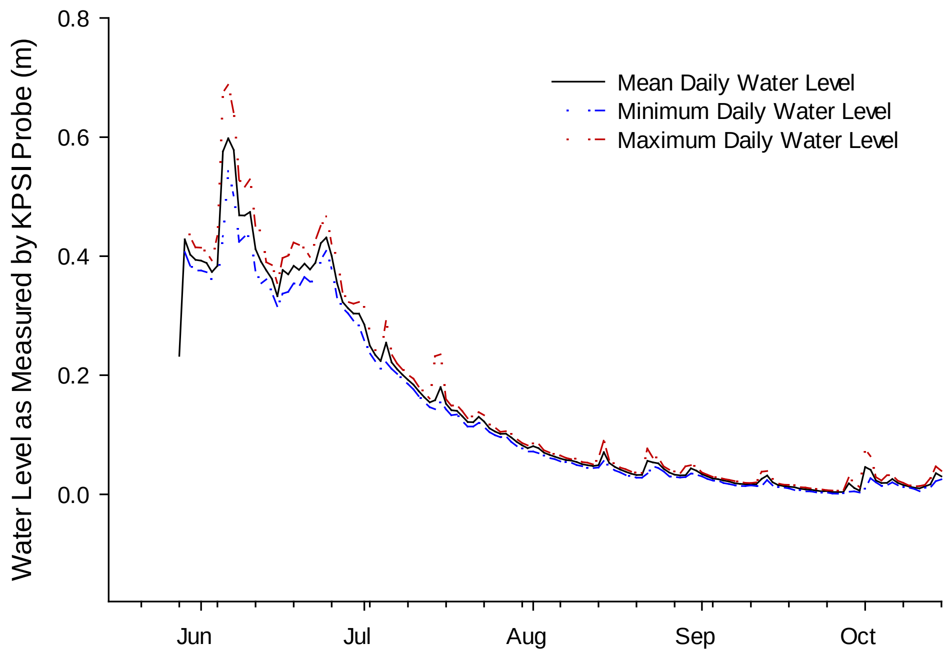

Figure 8: Mean, maximum, and minimum daily water level measured at the Ole Neon Station, 2012.

Air temperature on Ole Creek ranged from 0.2°C to 26.5°C with the warmest temperatures occurring between July and August. Water temperature in Ole Creek ranged from 0.8°C to 11.0°C.

The water level in Ole Creek showed a peak in early July and a gradual decrease through the season. Note that on October 1 a small spike aligns with the very large spike recorded at Six Mile Creek, again suggesting a regional rain event.

3.3 Stream Discharge and Reservoir Level

Discharge calculated from depth-velocity data were regressed against staff gauge readings and satellite-transmitted level logger data (Figure 9; Figure 10; Appendix D, Table D2). There were three discharge and staff gauge measurements from each stream in 2012, but only two satellite level logger measurements for the Six Mile station because of the KPSI probe malfunction. One of the discharge measurements at Ole Creek appears suspect (similar discharge to different staff gauge water level) and could be an inaccurate measurement. It was thought that the channel, being prone to evulsion, may have braided between the discharge measurement location (at the bridge) and the gauging station since the first measurement, which would account for this discrepancy, however, no channel evulsion was observed. Additional discharge-water level data points in future years are needed to refine the stage discharge curve and provide an accurate model of these streams. After additional discharge measurements at different water levels are taken, a hydrograph of discharges in the two creeks will be produced for the two creeks based on the relationship between discharge and satellite-transmitted level data.

The Williston Reservoir level was much greater than average in 2012 (Figure 11). Compared to historical data from 1973 to 2011, the level in 2012 exceeded the 75th percentile for most of the spring and summer.

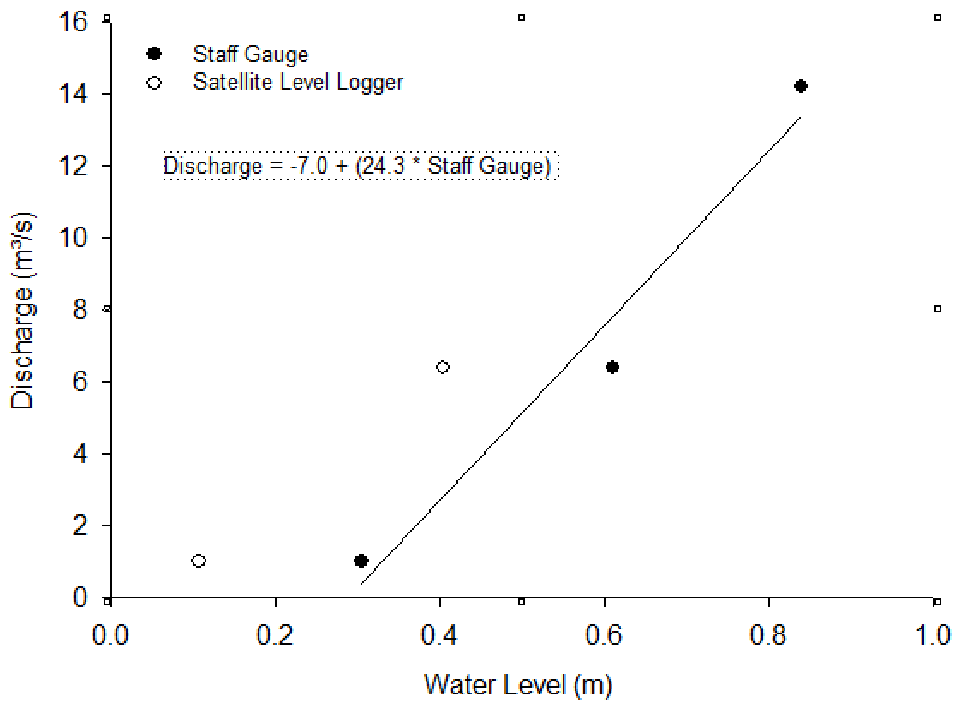

Figure 9: Discharge versus water level relationship for gauging station at Six Mile Creek in 2012.

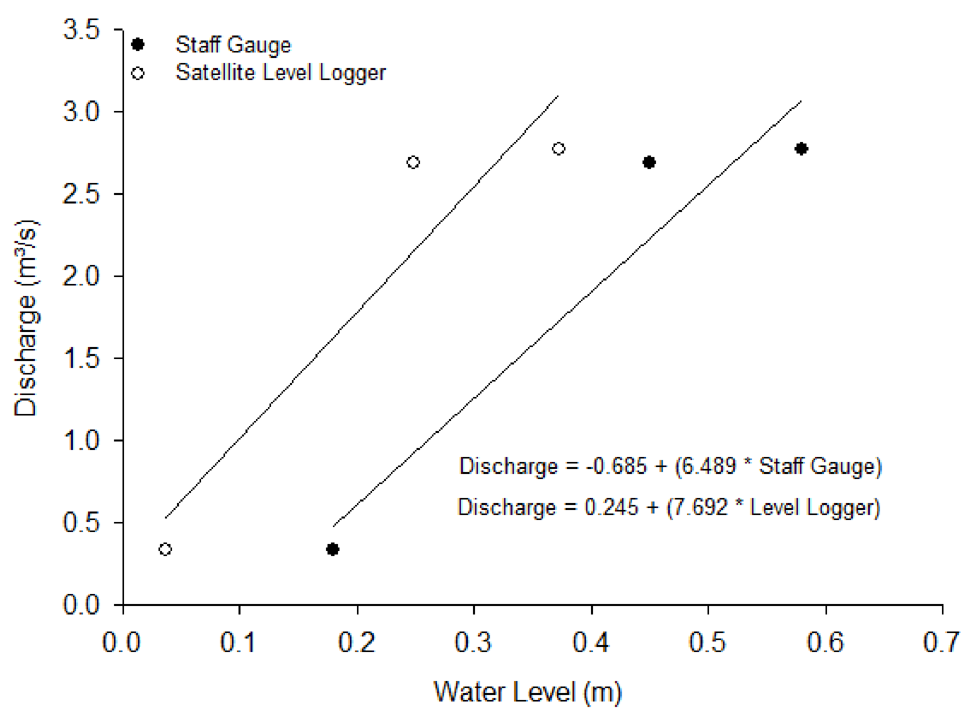

Figure 10: Discharge versus water level relationship for gauging station at Ole Creek in 2012.

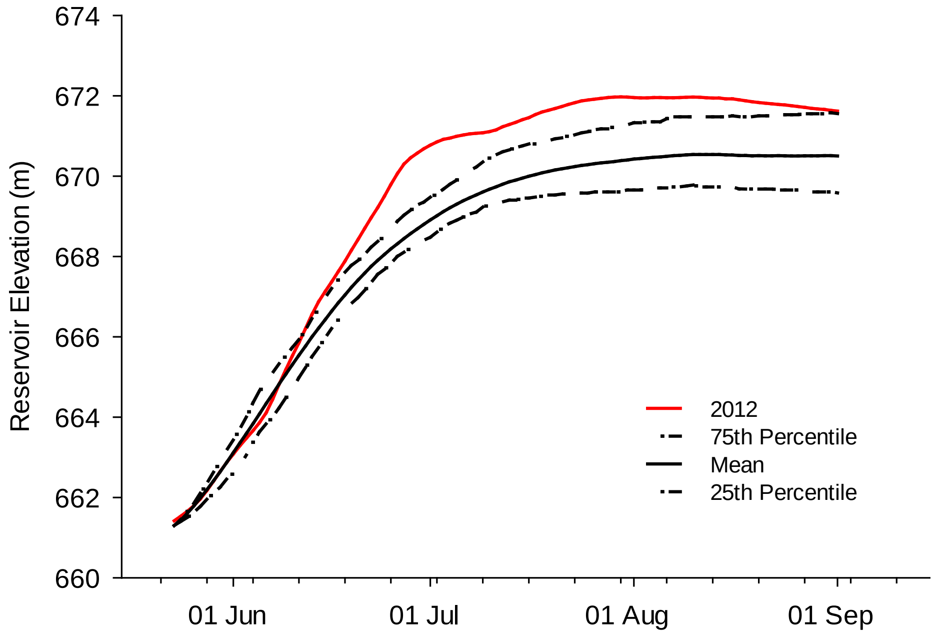

Figure 11: Williston Reservoir level in 2012 compared to the mean, 25th percentile, and 75th percentile from historical records (1973-2011).

The addition of the satellite-transmitting stream level and temperature logging station provides important data and context to help interpret changes in amphibian and fish ecology over time. Temperature and discharge will continue to be used in future years to help plan the timing of spawning surveys and fish population estimates. Because these are the first continuous temperature and discharge data for the study streams, it is not possible to compare these data to other years. However, climate data (i.e., large snowpack) and higher than normal reservoir levels in 2012 suggest that temperatures were likely cooler than average and discharges likely higher than average. The high reservoir levels in 2012 influenced the water depths at and near the mouths of the tributaries, resulting in greater depths in these areas than is typical during the summer months (typically low water conditions in the streams) which have important implications for fish access and usage in the study streams.

3.4 Amphibian Searches

Amphibian searches were conducted at several sites on each creek during July 2012. Locations and effort were similar, though not identical to amphibian searches in 2011. The results of these surveys are provided in Appendix D, Table D3. Table 8 and Table 9 (below) compare catch per unit effort (CPUE) calculations from the amphibian searches in 2012 and 2011, respectively.

An error was noted in the reporting of the 2011 amphibian data, the data table provided in Appendix D (Golder 2011), however, was correct. It has been corrected herein (Table 9) and a corrected database will be provided with the 2012 data.

CPUE is a crude means of comparing amphibian populations; however, the total catch in 2011 and 2012 is not adequate for more vigorous relative abundance estimates. It should be noted that tadpoles were excluded from the CPUE calculations as they tend to occur in high densities that may skew results towards an overestimation where they are observed, particularly where adult amphibian numbers are low. Tadpoles were only found at Six Mile Creek in 2012, no egg masses were found at any of the study streams during the 2012 surveys.

Table 8: Summary of amphibian search effort at the four study streams in 2012.

Site	Search Effort		# Amphibians Caught/Observed*	Catch per Unit Effort	
	Area (m^2)	Time (min)		(#/Area x100 m)	(#/min)
Six Mile Creek	2800	150	5	0.178	0.033
Lamonti Creek	2800	120	1	0.036	0.008
Factor Ross Creek	2000	100	2	0.100	0.020
Ole Creek	2800	120	2	0.071	0.017

***Not including tadpoles**

Table 9: Summary of amphibian search effort at the four study streams in 2011.

Site	Search Effort		# Amphibians Caught/Observed*	Catch per Unit Effort	
	Area (m^2)	Time (min)		(#/Area x100 m)	(#/min)
Six Mile Creek	7700	395	4	0.052	0.010
Lamonti Creek	3200	210	1	0.031	0.005
Factor Ross Creek	3800	200	0	0.000	0.000
Ole Creek	1300	150	7	0.538	0.047

***Not including tadpoles**

Amphibians were observed in low numbers within the project area, as reflected by the CPUE estimates in the above tables. Catch remains too low for valid comparable statistical analysis between years. It should be noted that in 2011, searches were conducted during the spring and summer months; in 2012, searches were restricted to spring.

In 2012 Columbia spotted frogs were the only amphibian species observed in Six Mile Creek; both tadpoles and adults were observed. Western toads were observed during searches at Lamonti and Ole creeks. Additionally, a wood frog egg mass was incidentally observed (i.e., not observed during time constrained searches) at Ole Creek. Western toad and wood frog were observed during searches at Factor Ross Creek. The greatest number of amphibians was observed near Six Mile Creek but overall CPUE of amphibians was similar among the streams (Table 10).

Table 10: Difference in CPUE for Amphibians between 2011 and 2012 Sampling Sessions.

Site	Catch per Unit Effort 2011		Catch per Unit Effort 2012		Total Difference in CPUE 2011 vs. 2012	
	(#/Area x100 m)	(#/min)	(#/Area x100 m)	(#/min)	(#/Area x100 m)	(#/min)
Six Mile	0.052	0.010	0.178	0.033	0.126	0.023
Lamonti	0.031	0.005	0.036	0.008	0.005	0.003
Factor Ross	0.00	0.00	0.100	0.020	0.100	0.020
Ole	0.538	0.047	0.071	0.017	0.467	0.030

Amphibian surveys along the tributary streams have indicated that impacts resulting from the proposed enhancement works at the stream mouths are unlikely to impact amphibian habitat outside the immediate area of the works (i.e., the drawdowns zone at the stream mouths). No suitable amphibian breeding areas (confirmed or otherwise) within the surveyed areas have been found to be connected to the stream channel in a way that would allow fish to access amphibian breeding areas. Therefore, it is not reasonable to think that an increase in the number of fish within the lower sections of the tributary systems is going to impact amphibians within the adjacent upland areas.

It is recommended that future amphibian surveys target areas where there is a plausible impact from the enhancement works (i.e., at the stream mouths). Evidence of breeding has been observed within the drawdown zone at Six Mile Creek only; however, juvenile western toadlets have also been observed at the mouth of Ole Creek. It is conceivable that a reduction of LWD at Ole Creek may result in a reduction of habitat quality (i.e., cover) at the mouth of this stream. At Six Mile Creek, it is conceivable that channelization of the mainstem may reduce the availability of small wetted features within the drawdown zone (such as that where the long-toed salamander eggs were observed) and thereby reduce amphibian breeding habitat.

3.5 Visual Assessment of Tributary Access Blockage

Impediments to fish access were not observed at the mouths of any of the tributaries during the site visits in early July and late August 2012. The stream mouths were not assessed during the late May site visit, when the gauging stations were installed. Stream discharges were characterized as high during the May and July visits and low-medium during the August site visit. Reservoir levels were higher than normal in 2012 (Figure 11).

There was very little woody debris accumulation near the mouths of Six Mile and Lamonti creeks during the early July and late August visits in 2012. The bay at the mouth of Ole Creek had a large amount of LWD floating on the surface but the debris likely did not impair fish passage due to the high reservoir and stream levels. There was a moderate amount of LWD at the mouth of Factor Ross Creek during the early July visit. The photos from permanent photo plots are provided in Appendix B, Photos 10 to 26.

3.6 Spawner Surveys

Stream lengths assessed during the spawner surveys were 1.6 km for Six Mile Creek, 1.9 km for Lamonti Creek, 1.9 km for Ole Creek, and 1.1 km for Factor Ross Creek. Redds or spawners were not observed in Lamonti, Ole or Factor Ross creeks. One Rainbow Trout with spawning colouration (estimated ~250 mm fork length) was observed migrating up Six Mile Creek approximately 340 m upstream of the mouth on July 4, 2012. Redds or other spawners were not observed on Six Mile Creek. However, spawner surveys were only conducted on one day and redds from spawning that may have occurred earlier in the season could have been obscured by high spring stream flows, making them difficult to observe. Young-of-the-year fish were observed during August in Six Mile Creek (Rainbow Trout and Bull Trout), Factor Ross Creek (Bull Trout), and Ole Creek (Bull Trout), suggesting that spawning had occurred in these tributaries.

The locations and spatial areas of suitable spawning gravels within the surveyed sections of each stream are provided in Appendix D, Table D4. In general, there was very little suitable spawning gravel in the lower reaches of the tributaries: Lamonti Creek (12.5 m^2 total), Ole Creek (19.0 m^2 total), Six Mile Creek (111.5 m^2 total), and Factor Ross Creek (71.0 m^2 total).

Water temperatures measured at the gauging station at the time of the July stream surveys ranged from 5°C to 7°C in Six Mile Creek and 5°C to 6°C in Ole Creek. Stream temperature measured with an alcohol thermometer during the spawner surveys supports that temperatures recorded by the KPSI probes are accurate and that the survey was conducted in appropriate thermal conditions for Rainbow Trout spawning (~5°C).

During night snorkelling on August 21, 2012, several Rainbow Trout young-of-the-year were observed in shallow (<5 cm depth) water near shore. Two of these fish were captured by dip-net in order to confirm species identification and estimate the approximate age. The approximate spawning date was then estimated based on developmental rates from published literature and stream water temperatures. Growth rates after fry emergence are highly variable depending on food availability but based on previous observations of recently emerged fry, the two Rainbow Trout in Six Mile Creek were likely approximately one week post-emergence. Murray (1980) reported a mean time of 65 days from fertilization to emergence at a water temperature of 8.0°C, and 42 days at 10°C. Water temperatures in Six Mile Creek averaged between 5°C and 7°C between early and mid-July, and were ~9-10°C by late July. Using the development times from Murray (1980) and assuming the fry caught on August 21 emerged on August 14, the estimated spawning date would be June 10 (based on developmental rate at 8°C) or July 3 (based developmental rate at 11°C). An earlier study found that it took 85 days at a constant temperature of 10°C until hatch, then 12°C after hatch to reach stage 37 (defined as fish with yolk sac absorbed and adipose fin in final form). The fry collected from Six Mile were older than stage 37, and temperatures were cooler, suggesting that development would be slightly slower. Based on developmental times from Vernier (1960), the estimated spawning date was May 28 at the latest. The estimated spawning dates of June 10 and July 3 based on Murray (1980) are likely more realistic for Williston Tributaries, and are more consistent with the preferred hydrological and temperature conditions for the species, as well as the observation of a Rainbow Trout in spawning colouration observed on July 4.

A Rainbow Trout in spawning colouration, as well as the presence of young-of-the-year Rainbow Trout, provide evidence that this species spawned in Six Mile Creek in 2012. The presence of young-of-the-year Bull Trout in Factor Ross and Ole Creeks suggests that Bull Trout spawned successfully in these streams as well. In addition, we observed one large Kokanee in spawning colours upstream of the canyon in Ole Creek, and two smaller Kokanee that were starting to have spawning colours holding approximately 50 m upstream of the mouth of Factor Ross Creek. These observations raise the possibility that Kokanee could also be spawning in the two northern study streams. The Arctic Grayling observed in Factor Ross Creek were likely sub-adults because they were all >230 mm in fork length, which suggests an age of two years according to Ballard and Shrimpton

(2009). We have no information to suggest whether or not adult Arctic Grayling successfully spawned in Factor Ross as these individuals were observed in August, and none were seen during the spring surveys. Arctic Grayling would be expected to spawn at water temperatures near 4°C, which we estimate would occur in May or June in the study streams, based on temperature data from satellite-enable stream gauging stations in Ole and Six Mile creeks (Figures 4 and 7).

Any impediments to tributary access for fish, such as perched mouths and debris blockages, would likely be a problem in the early spring (April and possibly May) when the reservoir level and stream levels are both very low. Tributary access for fall adfluvial spawners (i.e., Bull Trout, Kokanee) is not likely an issue. During our visits in early July and August, there were no visible impediments to tributary access because both the reservoir and stream levels were high, flooding the stream mouths and not impeding fish access. Reservoir levels were higher than normal in the first two years of study in 2011 and 2012 (Golder 2012 and Figure 11) and tributary access was likely less of a problem compared to years with lower reservoir levels.

The failure to observe spawners and redds in most of the study streams should not be interpreted as evidence that spawning did not occur because of the limited spatial and temporal scope of the surveys. In 2011 and 2012, spawner surveys were conducted on one day for each stream. Sampling during a single point in time is not ideal to compare the relative amount of spawning among years, because changes in the timing of either the surveys or spawning could appear in the data as changes in the number of spawners. For instance, a year with a large number of spawners but an early survey and late spawning would be biased low compared to a year with fewer spawners but a survey that occurred at or slightly after peak spawning. A large increase in the effort and resources available for monitoring the abundance of spawning, such as weekly surveys over the whole potential spawning period or a fish fence, is not possible given the available resources. With the available resources, stream walk spawner surveys are still likely the best method but efforts should be made to conduct surveys near the end of the spawning period. Because Rainbow Trout redds are typically visible up to weeks after spawning, a survey near the end of the spawning period is likely the best option for assessing of the total spawning in a given year based on a one day survey (Gallagher et al. 2007). It is possible that atypically high stream flows could have made redds less visible in 2012 but timing the surveys near the end of the expected spawning period during the descending limb of the hydrograph remains the recommended option for future years. The estimated spawning period based on the fry and spawner observations discussed above and temperature and discharge conditions in 2011 and 2012 is approximately early June to early July. The recommended timing for surveys is near the end of this range, and will be adjusted using the satellite-transmitted water level and temperature data and known preferred conditions for Rainbow Trout. More effort may be required during the spawner survey to cover more stream area and allow for repeated observations.

Based on the effectiveness of snorkelling during the fish abundance survey in August 2012, it is recommended that snorkelling also be used, where possible, during spawner surveys in future years. Extra care will be required for snorkelling during higher stream flows and it will not be possible in some sites due to safety considerations. Snorkelling observations could be conducted in a random sample of the pools encountered during surveys, and the total effort (number of pools and spatial area) would be recorded for comparison to subsequent years. Snorkelling would only be used during spawner surveys if needed and if conditions make it safe to use this technique. The addition of snorkelling to attempt to improve fish detection, combined with surveying a longer reach of stream is recommended to improve monitoring of fish spawning in the study streams, based on a one day survey.

3.7 Juvenile and Small-Bodied Fish Survey

Catches of fish by electrofishing were low for most species in all four streams. Less than five individuals large enough to tag of each species were caught in all streams, except for Ole Creek, where 11 Bull Trout were tagged. Abundance estimates from the Bayesian model were larger than Petersen estimates, and had narrower confidence intervals in all cases (Table 11) For three of the species-stream groups, there was a 100% recapture rate (all marked fish were observed during snorkelling). In these cases, the Petersen estimate is equal to the sum of all fish observed. In Factor Ross Creek, there were no recaptures so the Petersen method could not generate an estimate, whereas the Bayesian model did produce an abundance estimate. Petersen estimates are only provided for comparison to the Bayesian estimates to demonstrate the advantages of the method. The Bayesian estimates, as well as CPUE from snorkelling and electrofishing, will be discussed and interpreted below and used for comparison to future years of the study. The mark-resight data used for the abundance estimates are provided in Table 12. Mark-resight abundance estimates were intended primarily for Rainbow Trout because they are the targeted species for enhancement and monitoring. However, the mark-resight method was also used to estimate abundance of other species, when possible, to validate the method and provide the context of other fish populations when interpreting changes before and after enhancement.

The different sampling methods for fish population abundance in 2011 make it difficult to compare the results to 2012. In 2011, two to three 100 m long sample sites in each stream were sampled by multiple-pass electrofishing. Stream widths were measured in order to calculate the sample area in each case. However, in 2011 the sampling sites included the entire stream width and all habitat types, whereas sampling in 2012 included only pools and low-velocity habitats. Thus, catch per unit effort in fish per unit area (#/m^2) is available for both years, but the difference in habitats makes these measures unsuitable to compare overall abundance in the streams between years. Therefore, our comparison of 2012 and 2011 results will be limited to the species caught or observed and total catch in each stream.

The original method for this program prescribed the use of minnow traps for collection of fish for marking; however, when this method was employed at the first site (Six Mile Creek) at the beginning of the program, catch was very low (Appendix D, Table D5). Minnow traps were deployed over two days at 29 different sites for a total of 869 trap-hours; total catch over this period was three fish (one Rainbow Trout, one Bull Trout and one Burbot). This equates to a CPUE of 0.083 fish per trap-day. Minnow trapping was therefore discontinued in favour of electrofishing for the remainder of the program.

During snorkelling, areas adjacent to the mark and release sites were also surveyed to assess movement among sites. At Six Mile, Ole and Factor Ross creeks, all marked fish that were observed were located in the same site where they were tagged and released. In Lamonti Creek, two fish (one Rainbow Trout and One Bull Trout) were observed at a site adjacent to that of capture and release. One fish had moved upstream and the other had moved downstream and in both cases the site was within 50 m of the capture and release location.

Table 11: Bayesian Population Estimates from Mark-resight Data Compared to Traditional Petersen Mark-recapture Estimates and Snorkelling Observations.

Stream	Species	Bayesian Estimate					Snorkelling Obs.		Traditional Petersen			
		Mean	SD	LCI	UCI	Mean/100 m²	#	#/100 m²	Mean	LCI	UCI	Mean/m²
Six Mile	Rainbow Trout	28.3	10.7	20.2	55.6	10.1	20	7.1	20	8	57	7.1
Lamonti	Rainbow Trout	10.0	8.2	5.1	33.9	4.9	5	2.5	5	3	17	2.5
Lamonti	Bull Trout	22.3	21.2	7.2	81.8	11.0	7	3.4	7	2	136	3.4
Ole	Bull Trout	123.9	41.1	65.7	221.2	32.5	31	8.1	114	39	551	0.3
Factor Ross	Bull Trout	59.1	46.3	14.5	179.2	14.6	11	2.7	n/a	n/a	n/a	n/a

Key: SD= standard deviation, LCI= lower credibility (Bayesian) or confidence (Petersen) interval, UCI= upper credibility (Bayesian) or confidence (Petersen) interval

Table 12: Mark-resight Data Used for Fish Abundance Estimates for four Williston Reservoir Tributaries in 2012.

Stream	Species	1st Sample (Electrofishing)	2nd Sample (Snorkelling)		
		N	u	m	n
Six Mile	Rainbow Trout	3	17	3	20
Lamonti	Rainbow Trout	2	3	2	5
Lamonti	Bull Trout	1	6	1	7
Ole	Bull Trout	11	28	3	31
Factor Ross	Bull Trout	3	11	0	11

Key: N = number of fish marked in first sample; u =number of unmarked fish in second sample; m =number of marked fish in second sample; n =total number of fish in second sample

Six Mile Creek

Fish caught or observed in Six Mile Creek by backpack electrofishing or snorkelling included Burbot, Bull Trout, sculpin sp., Mountain Whitefish, and Rainbow Trout (Table 13). Sculpin sp. comprised the greatest proportion of the electrofishing catch, followed by Bull Trout and Rainbow Trout. Rainbow Trout, however, comprised the vast majority of the fish observed during the snorkel survey.

The abundance estimate (mean ± standard deviation) for Rainbow Trout in Six Mile Creek was 28 ± 10. The total area sampled (pools and low-velocity habitat) was divided by the estimate to calculate density, which was 10 fish/100 m^2. Rainbow Trout was the only species that had mark-resight data that allowed an estimate of abundance. All three taxa that were caught in 2011 (Rainbow Trout, Mountain Whitefish, and sculpin) were also caught in 2012, with greater numbers of fish caught/observed in 2012 for all three taxa.

Table 13: Catch-per-unit-effort (CPUE) during Electrofishing and Snorkel Surveys in Six Mile Creek.

Species	Electrofishing					Snorkelling	
	# Caught	# Observed	# Caught + Obs.	CPUE (fish/sec)	CPUE (fish/100 m^2)	# Observed	CPUE (fish obs/100 m^2)
Rainbow Trout	2	0	2	0.0009	n/a	20	7.14
Arctic Grayling	0	0	0	0.0000	n/a	0	0.00
Kokanee	0	0	0	0.0000	n/a	0	0.00
Bull Trout	4	0	4	0.0019	n/a	0	0.00
Mountain Whitefish	0	0	0	0.0000	n/a	0*	0.00
Burbot	2	0	2	0.0009	n/a	0	0.00
Sculpin sp.	6	6	12	0.0056	n/a	1*	0.36

*** Does not include two sculpin sp., one Mountain Whitefish, and two unknown salmonid species that were incidentally observed at sites where spatial area was not measured.**

Lamonti Creek

Fish species caught or observed in Lamonti Creek by backpack electrofishing or snorkelling were Bull Trout, sculpin sp., and Rainbow Trout (Table 14). Catches of Rainbow Trout (2 caught and 1 observed) and Bull Trout (1 caught) were quite low, but six unknown salmonid fish were also observed (but not caught for a positive identification) while electrofishing. A greater number of Rainbow Trout were caught (4 caught and 1 observed) in 2011 compared to 2012, and Mountain Whitefish were caught in 2011 but not 2012.

The abundance estimate (mean ± standard deviation) for Rainbow Trout in Lamonti Creek was 10 ± 8 and the density was 5 fish/100 m^2. The abundance estimate for Bull Trout in Lamonti Creek was 22 ± 21 and the density was 11 fish/100 m^2. Because there was a 100% resight rate for marked fish for Bull Trout and Rainbow Trout in Lamonti Creek, the Petersen estimate for these groups was simply the total number of fish observed and the Bayesian estimate was much higher.

Table 14: Catch-per-unit-effort (CPUE) during Electrofishing and Snorkel Surveys in Lamonti Creek.

Species	Electrofishing					Snorkelling	
	# Caught	# Observed	# Caught + Obs.	CPUE (fish/s)	CPUE (fish/100 m^2)	# Observed	CPUE (fish obs/100 m^2)
Rainbow Trout	2	1	3	0.0027	0.85	5	2.46
Arctic Grayling	0	0	0	0.0000	0.00	0	0.00
Kokanee	0	0	0	0.0000	0.00	0	0.00
Bull Trout	1	0	1	0.0009	0.28	7	3.44
Mountain Whitefish	0	0	0	0.0000	0.00	0	0.00
Burbot	0	0	0	0	0	0	0.00
Sculpin sp.	1	2	3	0.0027	0.85	0	0.00

Ole Creek

Fish species observed in Ole Creek by backpack electrofishing or snorkelling were Bull Trout, sculpin sp., Mountain Whitefish, and Rainbow Trout (Table 15). A large number of Bull Trout were observed during electrofishing (13 caught and 3 observed) and snorkelling (31 observed) whereas the number of other fish species caught was much lower (Table 15). In 2011, Mountain Whitefish (5 caught and 3 observed) and Bull Trout (3 caught and 3 observed) comprised the majority of the catch. One very large fish (estimated fork length of 550 mm) with a red tail and fins was observed but not captured during electrofishing upstream of the bridge in Ole Creek. It is very likely this fish was a large kokanee with spawning colouration.

The abundance estimate (mean ± standard deviation) for Bull Trout in Ole Creek was 124 ± 41 and the density was 32 fish/100 m^2. Abundance was not estimated for any other species because sample sizes were too small, despite Rainbow Trout being the target species.

Table 15: Catch-per-unit-effort (CPUE) during Electrofishing and Snorkel Surveys in Ole Creek.

Species	Electrofishing					Snorkelling	
	# Caught	# Observed	# Caught + Obs.	CPUE (fish/s)	CPUE (fish/100 m^2)	# Observed	CPUE (fish obs/100 m^2)
Rainbow Trout	1	1	2	0.0011	0.52	2	0.52
Arctic Grayling	0	0	0	0.0000	0.00	0	0.00
Kokanee	0	1	1	0.0006	0.26	0	0.00
Bull Trout	13	3	16	0.0091	4.20	31	8.14
Mountain Whitefish	0	0	0	0	0	4	1.05
Burbot	0	0	0	0	0	0	0.00
Sculpin sp.	2	2	4	0.0023	1.05	0	0.00

Factor Ross Creek

Bull Trout, sculpin sp., Arctic Grayling, Kokanee, Mountain Whitefish, and Rainbow Trout were caught or observed in Factor Ross Creek during electrofishing and snorkelling (Table 16). Additionally, a group of three grayling was observed (1 was caught and 2 were missed) at a site upstream of the forestry road bridge, another was observed during the snorkel survey at a site near the mouth. Catches and species diversity in 2012 were much higher than in 2011, when only sculpin sp. and Mountain Whitefish were caught.

A large proportion of the Bull Trout (8 of 11) and Mountain Whitefish (17 of 42) observed during the snorkel survey were at the most downstream site (near the mouth; site FR1 on Appendix A, Map A4). Stream conditions at this site had considerable influence from the high reservoir levels resulting in a deeper and wider morphology; it was considered part of the stream as there were still observable flows and was upstream of the area thought to cause potential seasonal access blockage.

The large size of many of the Bull Trout and Mountain Whitefish observed at this site suggests that they could be adfluvial fish. Two Kokanee with the beginnings of spawning colouration were also caught at site FR1 near the mouth whereas none were observed further upstream.

The abundance estimate (mean ± standard deviation) for Bull Trout in Factor Ross Creek was 59 ± 46, and the density was 14 fish/100 m^2. Abundance was not estimated for any other species because sample sizes were too small, despite Rainbow Trout being the target species.

Table 16: Catch-per-unit-effort (CPUE) during Electrofishing and Snorkel Surveys in Factor Ross Creek.

Species	Electrofishing					Snorkelling	
	# Caught	# Observed	# Caught + Obs.	CPUE (fish/s)	CPUE (fish/100 m^2)	# Observed	CPUE (fish obs/100 m^2)
Rainbow Trout	0	0	0	0.0000	0.00	1	0.25
Arctic Grayling	1	2	3	0.0024	0.56	1	0.25
Kokanee	2	0	2	0.0016	0.37	0	0.00
Bull Trout	3	1	4	0.0033	0.74	11	2.72
Mountain Whitefish	0	0	0	0.0000	0.00	42	10.38
Burbot	0	0	0	0.0000	0.00	0	0.00
Sculpin sp.	3	0	3	0.0024	0.56	1	0.25

Juvenile Fish Discussion

The mark-resight method using electrofishing and snorkelling was an improvement over the multiple-pass removal-depletion electrofishing method used in 2011. A greater number of species and more fish were caught or observed in 2012 than in 2011. The larger catch could, at least partially, be attributed to the larger spatial area sampled in 2012. However, the numbers of fish caught or observed in 2012 were still fairly low and recapture rates varied widely, such that most abundance estimates had large confidence intervals or abundance could not be estimated using mark-resight data. Abundance estimates could be improved by increasing effort to two electrofishing sessions and two snorkel surveys per stream. When sampling streams with low fish densities like the Williston tributaries, it is likely important to sample large spatial area to catch a sufficient number of fish to estimate abundance using mark-resight data. The stratified Bayesian mark-resight model used in 2012 was a good method to estimate abundance of fish species with relatively low catches and varying catchability. The fact that fish were rarely or never resighted outside of the site of capture and release suggests that the assumption of a closed-population is valid for these study sites.

The main objective of the monitoring program is to assess fish abundance, diversity and habitat before and after the tributary access enhancements. The key management questions relating to fisheries within the Tributary Habitat Review monitoring program are:

- Does fish abundance and diversity in tributaries increase as a result of enhancement?
- Is the area and quality of fish habitat created by the tributary enhancement maintained over time?

The monitoring program in 2012 provides a good assessment of abundance and diversity of fish in the study streams to compare to future years before and after enhancement. In cases where sample sizes are too low to generate a reliable abundance estimate, CPUE from electrofishing and snorkelling each provide a reasonable index of abundance to assess trends over time. The second management question, which involves the area and quality of habitat, depends primarily on if tributary access enhancements continue to prevent access blockages in the future. Enhancements are focused on preventing tributary access blockages caused by perched mouths or debris jams and will not create a substantial amount of new habitat or upstream habitat affects. Therefore, the second management question will be addressed by monitoring blockages at the mouth by visual inspections and photos, and monitoring habitat usage through the spawner surveys and juvenile fish abundance assessments.

Six Mile Creek (enhancement treatment stream) and Lamonti Creek (control), which are the streams thought to have access impeded by perched mouths, had similar fish communities, as fish observed or caught were mostly Rainbow Trout or Bull Trout. In 2012, a greater number of Rainbow Trout were observed in Six Mile Creek, and a greater number of Bull Trout were caught or observed in Lamonti Creek. Ole (enhancement treatment stream) and Factor Ross (control) are the tributaries thought to be susceptible to debris jam blockages. Fish caught or observed in Ole Creek were mostly Bull Trout, although Rainbow Trout were also observed. The presence of several fish species of various size classes (90-550 mm) suggests that the steep-gradient canyon in Ole Creek, which is mid-way between the mouth and the forestry road bridge, is not a complete barrier to fish movement, at least at the stream discharges that occurred in 2011 and 2012. In comparison, Factor Ross Creek also had large numbers of Bull Trout and some Rainbow Trout, but large numbers of Mountain Whitefish were also observed.

Factor Ross Creek was the only stream where Arctic Grayling were observed. Arctic Grayling are one of the species targeted by the tributary access improvement plan. According to fish distribution records, Arctic Grayling have also been recorded in Six Mile Creek (year of capture not reported; BC Ministry of Environment 2011 (FISS)) but none have been observed in Six Mile Creek during the course of this study (2011 and 2012). Arctic Grayling are found in greater numbers in larger tributaries of Williston Reservoir, such as the Table and Anzac Rivers in the Parsnip Reach where they were observed to initiate migrations in late April and likely spawned during high flows in late May to mid-June (Blackman 2002b). According to a literature review about Arctic Grayling in Williston Reservoir, little is known about the use of smaller tributaries by the species but it is possible that some may use small streams for either spawning or summer feeding (Blackman 2002a). It is not clear based on our data whether Arctic Grayling were present in Factor Ross Creek but no other streams because of access-blockages during the spawning period or other reasons.

The before-after control-impact study design for this monitoring program is scheduled to have three years of monitoring before enhancements and seven years of monitoring after enhancements (BC Hydro 2008). As noted in the spawner survey discussion (Section 3.6), the higher than normal reservoir and stream flows in the first two study years resulted in conditions at the stream mouths that were not prone to access blockages. Although we did not observe the stream mouths in April when reservoir levels were at their lowest, access to all four stream mouths was probably not compromised during most of the spring and summer of 2011 and 2012, including in June-July when Rainbow Trout were likely migrating upstream to spawn. Therefore, it is important to note that if all three years of monitoring before enhancement (treatment) occur during high reservoir level years when tributary access for fish is less problematic, then it will be difficult to compare the effectiveness of access enhancements works to years when fish access is impeded and infer changes in usage of habitat in these streams by adfluvial fish.

4.0 RECOMMENDATIONS

Based on the results of the 2011 and 2012 monitoring programs, recommendations for future years of study are:

- Spawner surveys should continue to focus on Rainbow Trout spawning but cover a greater distance of stream length in future years. Satellite-transmitted water temperature and stream level data should be used to plan the timing of the surveys, which should be conducted when stream temperatures reach 5-7°C, and shortly after the peak spawning date. Spawning timing in 2012 was estimated to be between early June and early July. It is recommended that the spawner surveys be conducted by stream walks as in past years but that snorkelling is also used during surveys to improve detection of adult fish.
- Assessment of stream access and blockages in the early spring (likely in early May depending on weather and stream conditions) could be conducted in conjunction with a spring stream gauge maintenance program and would include photo point monitoring at each stream mouth.
- As recommended in the report from the first year of study in 2011 (Golder 2012) and in consultation with BC Hydro, songbird and vegetation monitoring were not conducted in 2012. Proposed enhancement may create a small amount of additional riparian habitat through vegetation re-growth but the majority of bird habitat along the study streams would be unaffected. Therefore, it would be difficult or impossible to link changes in abundance and diversity to tributary access enhancements. Riparian vegetation could be affected by the enhancements, but without clearly defined enhancement plans and locations, it is not possible to design and implement an effective monitoring program to assess changes in vegetation attributed to the habitat enhancements. Baseline data on vegetation and songbird abundance and diversity is available from first year of the study in 2011. However, for these reasons stated above, it is recommended that songbird monitoring not be conducted in 2013, and that the vegetation portion of the monitoring program continue to be suspended until enhancement works are more clearly defined.
- Continue to use the mark-resight method involving electrofishing and snorkelling to estimate abundance of the fish in the study streams. By increasing sampling effort to two electrofishing capture sessions and two snorkel survey resighting sessions for each stream, samples sizes may be large enough to generate more precise abundance estimates for more fish species.
- Consider changes to the study design to five years of monitoring before tributary enhancement and five years after enhancement. If the third year of pre-enhancement monitoring is characterized by high reservoir and stream levels, then the first three years would all represent years when tributary access blockages were very unlikely, which would make before-after comparisons of fish access to tributaries unlikely to show a change even if one existed. Five years of pre-enhancement monitoring would be reasonable regardless of environmental conditions, but would be highly recommended if reservoir and stream flows are higher than normal again in 2013.
- In the meantime, refine the enhancement designs to incorporate more woody debris in mounds that would elevate the structures close to the stream mouths to above the full pool level. That could provide an opportunity to incorporate other components of the management questions such as vegetation and bird habitat enhancement.

- As the enhancement works are not anticipated to impact amphibian habitat in upstream areas, it is recommended that amphibian surveys be focussed within the drawdown zone where potential impacts from the enhancement works are plausible, specifically:
    - At Six Mile Creek, the large mudflat areas of the drawdown zone contain small wet depressions. It is not clear what the source of the water within these depressions is, it may be rainfall, fed by side channels from the stream, or a combination of the two. If the stream is the source of water, it is plausible that re-contouring the stream channel may result in a loss of these features and thereby, a loss of amphibian breeding habitat. In 2011 long-toed salamander eggs were noted within one of these features, however, it is not known if adequate incubation occurred prior to inundation as the reservoir level rose. As cover may well be a limiting feature of amphibian habitat in these areas, the use of cover boards should be considered.
    - At Ole Creek, woody debris at the mouth may provide cover for amphibians (western toadlets have been observed at this location). Enhancement works designed to limit or remove woody accumulation in the bay may therefore reduce the quality of amphibian habitat. More search effort should be applied to this area. Additionally, it would be useful to identify natal areas. Based on the development of the individuals encountered, it is estimated that a natal pool is likely within 1 km of the stream mouth.
- A Level 1 Habitat Assessment has not been completed due to the limited inferred value with the changes to the monitoring program. A modified Level 1 Habitat Assessment should be completed within the drawdown zone at least once prior to enhancement implementation. The sampling design and location for the habitat assessment will be determined in consultation with BC Hydro. One option would be to conduct the Level 1 Habitat Assessment within the drawdown zone in the early spring when reservoir levels are the lowest, in order to provide a direct assessment of the effects of the enhancements on fish habitat in the affected areas. Habitat further upstream in the study tributaries is not expected to be affected by enhancements and is unlikely to change drastically because of natural processes during the monitoring period. Therefore, a Level 1 Habitat Assessment in areas upstream of the drawdown zone is not recommended, although other habitat variables (e.g., spatial areas of spawning gravels or sample sites) will continue to be monitored during the sampling program.

5.0 PRELIMINARY WORK PLAN FOR 2013

Table 17 provides a preliminary summary of the proposed 2013 field schedule.

Table 17: Preliminary 2013 Field Schedule.

Timing	Activities
Early Spring (as required)	Neon station maintenance, stream discharge measurements, stream mouth photo points and Arctic Grayling stream access assessment, amphibian surveys (if time allows).
June (targeting approx. 5°C water temp.)	Rainbow Trout spawning surveys, discharge measurements, stream mouth photo points and Rainbow Trout stream access assessment, amphibian surveys.
August	Juvenile and small bodied fish surveys (mark-resight), discharge measurements, stream mouth photo points, modified Level 1 Fish Habitat Assessments, amphibian surveys (if time allows).

6.0 CLOSURE

We trust that the above meets your current requirements, should you have further questions please contact the undersigned.

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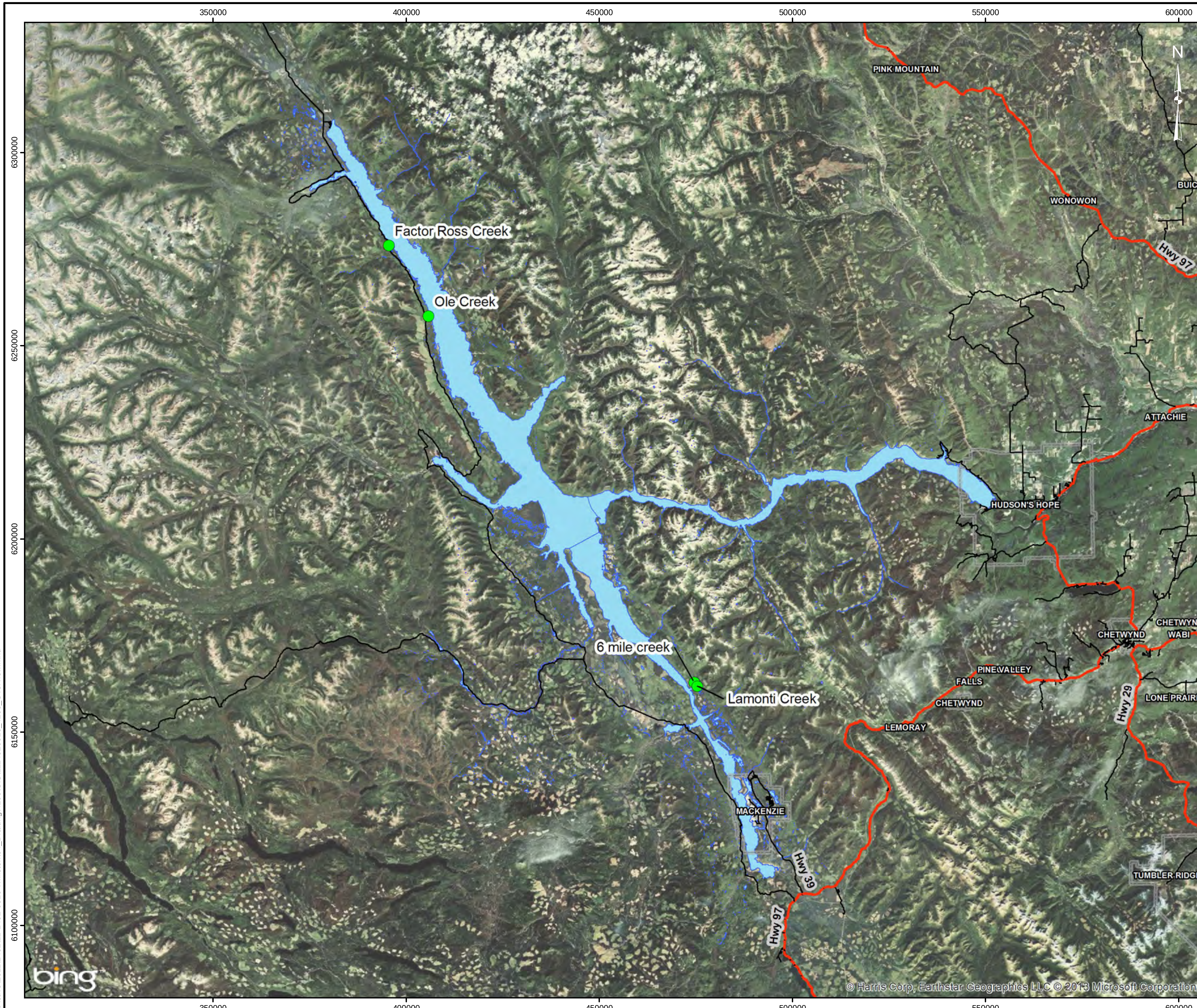
APPENDIX A

Maps



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LEGEND

- SITE LOCATION
- HIGHWAY
- ROAD
- MUNICIPALITY

REFERENCE

1. Base imagery: Bing Maps;
   (c) 2010 Microsoft Corporation and its data suppliers
2. Town and Cities obtained from IHS.
3. Waterbody, Watercourse, Roads: Geobase.ca

Projection: UTM Zone 10 Datum: NAD 83

30 0 30

SCALE 1:1,000,000 KILOMETRES

PROJECT

BC HYDRO GMSMON #17
WILLISTON RESERVOIR TRIBUTARY MONITORING
WILLISTON RESERVOIR, BC

TITLE

OVERVIEW MAP

Golder Associates

PROJECT NO. 11-1492-0016			PHASE No. 4200	
DESIGN	DJA	17 Oct. 2012	SCALE AS SHOWN	REV. 0
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CHECK	DJA	19 Feb. 2013		
REVIEW	DJA	19 Feb. 2013		

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LEGEND

- AMPHIBIAN SURVEY LOCATION
- ELECTROFISHING SITES
- GAUGING STATION

100 0 100

SCALE METRES

REFERENCES

1. SURVEY DATA OBTAINED FROM FIELD OBSERVATIONS.
2. Imagery obtained from BING Maps for ArcGIS published by Microsoft Corporation, Redmond, WA, March 2001 To July 2004

PROJECT

BC HYDRO GMSMON #17
WILLISTON RESERVOIR TRIBUTARY MONITORING
WILLISTON RESERVOIR, BC

TITLE

SIX MILE CREEK

Golder Associates
Kelowna, BC

PROJECT No.	11-1492-0016.4200	
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CADD	BEJ	18OCT12
CHECK	DR	31OCT12
REVIEW	DJA	31OCT12

FILE No.	1114920016_4200_2		
SCALE	AS SHOWN	REV.	0

MAP: 2

LEGEND

- AMPHIBIAN SURVEY LOCATION (orange)
- ELECTROFISHING SITES (blue)

REFERENCES

1. SURVEY DATA OBTAINED FROM FIELD OBSERVATIONS.
2. WILLISTON_1mPix_2009_south.tif: BC Hydro.

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SCALE METRES

PROJECT
BC HYDRO GMSMON #17
WILLISTON RESERVOIR TRIBUTARY MONITORING
WILLISTON RESERVOIR, BC

TITLE
LAMONTI CREEK

Golder Associates
Kelowna, BC

PROJECT No.	11-1492-0016.4200		FILE No.	1114920016_4200_3
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CHECK	DR	31OCT12	**MAP: 3**	
REVIEW	DJA	31OCT12		

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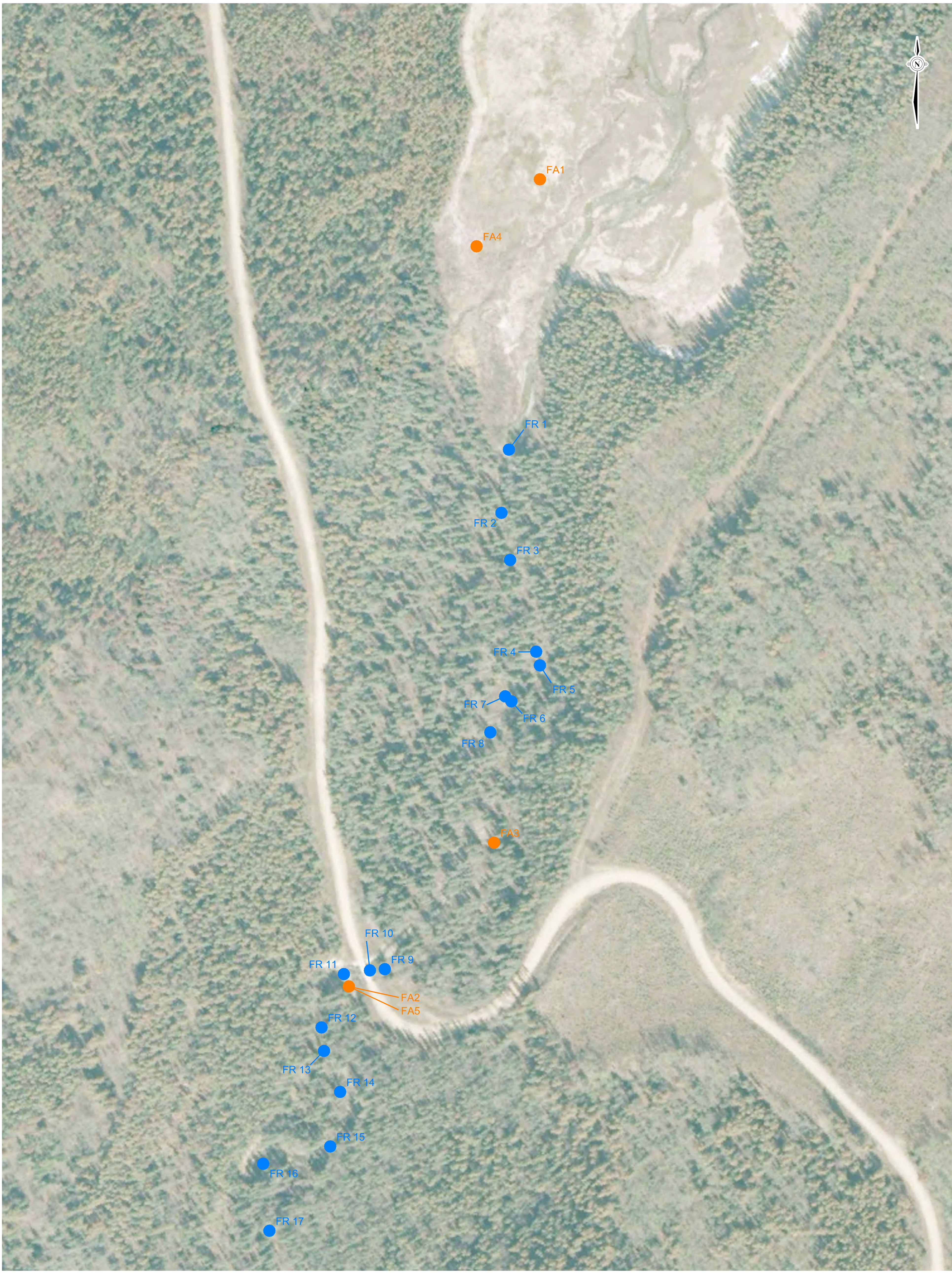

LEGEND

- AMPHIBIAN SURVEY LOCATION
- ELECTROFISHING SITES

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SCALE METRES

REFERENCES

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2. WILLISTON_1mPix_2009_south.tif: BC Hydro.

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BC HYDRO GMSMON #17
WILLISTON RESERVOIR TRIBUTARY MONITORING
WILLISTON RESERVOIR, BC

TITLE
FACTOR ROSS CREEK

Golder Associates
Kelowna, BC

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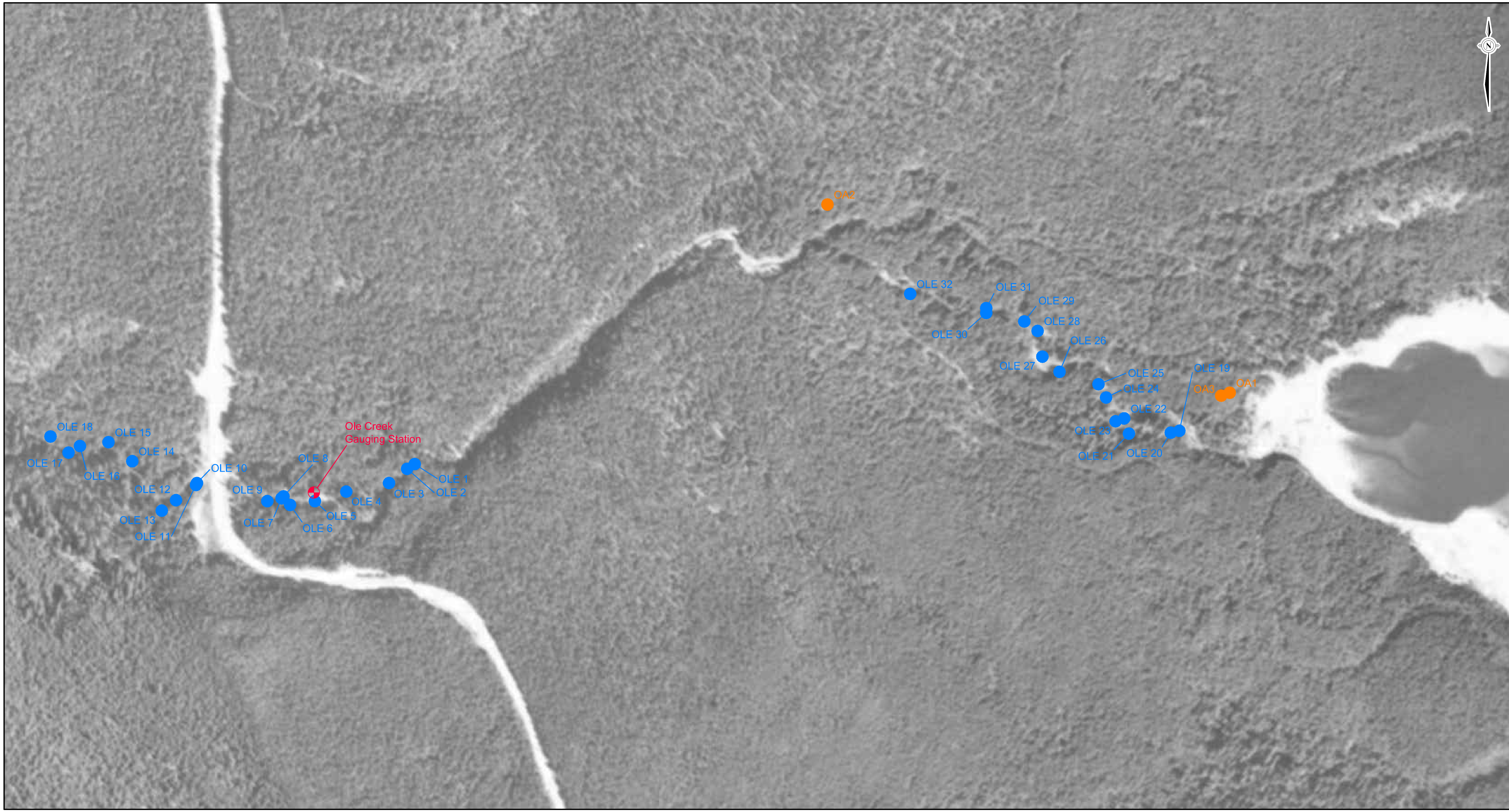
REVIEW	DJA	31OCT12		



LEGEND

- AMPHIBIAN SURVEY LOCATION
- ELECTROFISHING SITES
- GAUGING STATION

REFERENCES

1. SURVEY DATA OBTAINED FROM FIELD OBSERVATIONS.
2. Imagery obtained from BING Maps for ArcGIS published by Microsoft Corporation, Redmond, WA, March 2001 To July 2004.

50 0 50
SCALE METRES

PROJECT
BC HYDRO GMSMON #17
WILLISTON RESERVOIR TRIBUTARY MONITORING
WILLISTON RESERVOIR, BC

TITLE
OLE CREEK

Golder Associates
Kelowna, BC

PROJECT No.	11-1492-0016.2000		FILE No.	1114920016_2000_5
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CHECK	DR	31OCT12		
REVIEW	DJA	31OCT12		

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APPENDIX B

Photo Plates

Photo 1. Housing for water level and temperature probe at Six Mile Creek gauging station.

Photo 2. Housing for water level and temperature probe at Ole Creek gauging station.

Photo 3. Rainbow Trout tagged with fishing hook and yarn during Williston Reservoir Tributary Enhancement Monitoring.

Photo 4. Rainbow Trout tagged with fishing hook and yarn during Williston Reservoir Tributary Enhancement Monitoring.

Photo 5. Arctic Grayling tagged with fishing hook and yarn during Williston Reservoir Tributary Enhancement Monitoring.

Photo 6. Bull Trout tagged with fishing hook and yarn during Williston Reservoir Tributary Enhancement Monitoring.

Photo 7. Kokanee tagged with fishing hook and yarn during Williston Reservoir Tributary Enhancement Monitoring.

Photo 8. Burbot tagged with fishing hook and yarn during Williston Reservoir Tributary Enhancement Monitoring.

Photo 9. Example of a tagged Rainbow Trout observed underwater during night snorkelling survey.

Photo 10. Six Mile Creek mouth on July 4, 2012 taken from reference photo point (azimuth = 165°).

Photo 11. Six Mile Creek mouth on July 4, 2012 taken from reference photo point (azimuth = 60°).

Photo 12. Lamonti Creek mouth on July 3, 2012 taken from reference photo point (azimuth = 270°).

Photo 13. Lamonti Creek mouth on July 3, 2012 taken from reference photo point (azimuth = 200°).

Photo 14. Ole Creek mouth on July 5, 2012, looking downstream (not taken at exact photo plot).

Photo 15. Factor Ross Creek mouth on July 6, 2012 taken from reference photo point (azimuth = 340°).

Photo 16. Factor Ross Creek mouth on July 6, 2012 taken from reference photo point (azimuth = 280°).

Photo 17. Factor Ross Creek mouth on July 6, 2012 taken from reference photo point (azimuth = 220°).

Photo 18. Six Mile Creek mouth on August 19, 2012 taken from reference photo point (azimuth = 165°).

Photo 19. Six Mile Creek mouth on August 19, 2012 taken from reference photo point (azimuth = 60°).

Photo 20. Lamonti Creek mouth on August 22, 2012 taken from reference photo point (azimuth = 270°).

Photo 21. Lamonti Creek mouth on August 22, 2012 taken from reference photo point (azimuth = 200°).

Photo 22. Ole Creek mouth on August 27, 2012 taken from reference photo point (azimuth = 80°).

Photo 23. Ole Creek mouth on August 27, 2012 taken from reference photo point (azimuth = 10°).

Photo 24. Factor Ross Creek mouth on August 25, 2012 taken from reference photo point (azimuth = 340°).

Photo 25. Factor Ross Creek mouth on August 25, 2012 taken from reference photo point (azimuth = 280°).

Photo 26. Factor Ross Creek mouth on August 25, 2012 taken from reference photo point (azimuth = 220°).

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APPENDIX C

Methodological Details and Sampling Protocols

The following section provides additional details of methodology and sampling protocols to follow in future years of the study to ensure consistency in data collection among study years.

Sampling Sites

Sampling reaches in the four study streams were from the mouth to 1.4 km to 1.9 km upstream (Maps A2-A5). Sampling sites within these reaches had to be suitable and safe for snorkel surveys. Therefore, all pools and low velocity habitats within these reaches were sampled by electrofishing (Table D1, Appendix D). Snorkel surveys were conducted at all sites where fish were marked and released during electrofishing. In addition, sites adjacent to where marked fish were released were sampled in order to assess movement of fish between sites. If time permitted, additional sites that had been electrofished but where marked fish were not released were selected randomly for snorkel surveys. UTM coordinates should be recorded for all electrofishing and snorkelling sites. Sites were also marked with high-visibility flagging tape to help locate the site in the night-time during snorkel surveys. For sites that are longer or have a less obvious start and end, flagging tape should be placed at the top and bottom end of the site.

Because our sampling was limited to pools and low-velocity habitats, the estimates of abundance generated extend only to these habitats; habitats such as riffles and rapids are excluded. The focus of this component of the monitoring program is to estimate the juvenile abundance of targeted salmonid species, all of which have a strong habitat preference for low velocity habitats (McPhail 2007; Korman et al. 2011). Therefore, the sampling sites and methods are appropriate for addressing the management objectives and likely provide a reasonable index to monitor juvenile abundance in the study streams.

Electrofishing and Fish Marking

All pool and low-velocity habitats were sampled using a backpack electrofisher (LR-24, Smith-Root Inc., Vancouver, Washington, USA). A three person field crew conducted this work: one crew member operated the electrofisher, another captured fish with a dip-net, and the third took notes and carried a bucket for holding captured fish. Electrofishing output frequency in Hz was selected based on the size of fish, and was typically 30-50 Hz because juvenile fish were being targeted, and was adjusted while sampling if needed to avoid injuring larger fish. The “Quick-Setup” function of the LR-24 was used to automatically select an appropriate pulse width for the manufacturer recommended duty cycle, and voltage based on the conductivity measured by the electrofisher.

Captured fish were identified to species (except some smaller sculpins that were identified to genus) and weighed with an electronic scale (± 1g). Fork length (total length in the case of sculpins) was measured to the nearest 1 mm. Fish were marked with an external tag that consisted of size 18 barbed fishing hook that had fluorescent yarn tied around the shank. The yarn and hook tags were tied using a fly-tying bobbin and fastened using either half-hitches or a whip-finish. Yarn should cover the shank but not trail off the hook more than a few millimetres. Assumptions of the mark-resight technique are that catchability (in this case: resight-ability) is not different between marked and unmarked fish, and that are marks are not lost or un-observed when a fish is sighted. Therefore, the goal of the marking is to make the hook and yarn mark clearly visible if the fish is seen, but not make the fish drastically more visible than unmarked fish. The hook was inserted through the flesh directly behind the dorsal fin using needle-nose pliers while holding the fish in one hand. Photographs of different sizes and species of fish that were tagged during the surveys are provided in Appendix C (Photos 2 to 8). All species of fish that were caught were tagged using this method except for sculpin. Sculpin were not tagged in this study because they are likely too small for the tagging method. After processing, tagged fish were released at the capture site. Water temperature and conductivity were measured each day and electrofisher settings (voltage, frequency, and duty cycle) were recorded. At each electrofishing site, the UTM coordinates were recorded from a handheld GPS, the time electrofished in seconds was recorded (sample effort), the area (m^2) of habitat sampled was measured using a fibreglass measuring tape, and the habitat complexity was ranked qualitatively based on the type and abundance (%) of available cover. Habitat complexity was based on the total of all cover types (e.g., large and small woody debris, cobble and boulders, turbulence, undercuts) and was ranked as low (<10% cover), medium (10-40% cover) or high (>40% cover).

A fish collection permit was obtained from the Ministry of Forests, Lands and Natural Resource Operations (MFLNRO; Permit No. PG12-80063) prior to fish sampling. Fish sampling data were submitted online to the MFLNRO as required by the permit.

Snorkel Surveys

Snorkel surveys were conducted by a three person crew. Two people equipped with drysuits, waterproof flashlights, masks and snorkels conducted the survey while the third crew member recorded the data. The surveys began with a visual survey of the site to observe fish in shallow, near-shore, and other areas where the bottom was clearly visible. The site was then surveyed by one person from under water using a mask and snorkel. The second snorkeler would then survey the site as a double-check. At larger sites, two people would snorkel and survey the site simultaneously and communicate to avoid counting the same fish twice. Observers approached the site from downstream and surveyed the site while moving upstream. Observers prepared their equipment away from the site and approached the site slowly and quietly to avoid disturbing the fish. Using a quiet and stealthy approach, most of the fish were typically observed during the initial above-water survey or during the first 10 seconds of snorkelling. Snorkelers continued to observe until they were confident there were no un-counted visible fish, as some fish that were initially startled came out from cover after a short time. Total underwater observation time depended on the size of the site and complexity of cover but was typically from 20 seconds up to several minutes per observer. At debris jams and other high cover areas, observers can position themselves at various angles around the debris to view as much of the area as possible. Caution must be used when surveying near debris jams, which should always be surveyed from downstream if possible. In areas with high flows or debris, the second observer can act as a safety spotter to help the snorkeler maintain position or be positioned downstream with a throwbag if appropriate. Portions of the site that could be reliably surveyed because of woody debris or other cover were not included in the total spatial area surveyed. Portions of the site that could not be effectively observed by snorkelling often could also not be effectively electrofished, so the area sampled by electrofishing and snorkelling was nearly always the same at each site.

During the surveys, all marked and unmarked fish were counted and identified to species, and their fork lengths were estimated. On some occasions, if a fish could not be reliably identified to species, fish were captured by the snorkeler using a small dip-net to confirm taxonomic identification. Sites surveyed by snorkelling included all sites where marked fish were released, sites adjacent to sites with marked fish, and if time permitted, additional sites with no marked fish that were selected randomly from the remaining electrofishing sites. At each site, the same spatial area that was measured and sampled during electrofishing was surveyed by snorkelling. If some of the electrofishing site was not observable by snorkelling then the spatial area that was surveyed was estimated.

Water clarity and visibility were very high in all the study streams in 2012 and it was always possible to see the bottom and entire length of the site from underwater. Therefore, water clarity was not measured but any changes to water clarity that affected visibility (e.g., sediment stirred-up by observers) were noted. In future years of the study, an object of known size (e.g. a fake wood or plastic fish) should be used to confirm that water clarity is not limiting visibility and if it is, to quantify the distance that can be observed underwater. Objects of known size should also be observed underwater at the start of snorkelling in each stream to help train observers in estimating fish sizes, and confirm that their fork length estimates are accurate.

All snorkel surveys were conducted beginning 30 minutes after sunset one day following the release of marked fish. A photo of a tagged fish observed underwater during snorkelling is provided in Photo 9 (Appendix C).

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APPENDIX D

Data Tables

Table D1: Locations of sample sites for electrofishing and snorkel surveys in four Williston Reservoir tributaries in 2012.

Name	Zone	Easting	Northing	Area (m^2)	Complexity	Comments
FR1	10V	395364	6275741	143	Medium	Close to river mouth but still moving water
FR2	10V	395358	6275690	9	Low	Behind mid-channel boulder and boulder further upstream
FR3	10V	395365	6275652	6	Low	
FR4	10V	395386	6275578	9	Low	RDB eddy
FR5	10V	395389	6275567	37	Low	RDB and LDB near log
FR6	10V	395366	6275538	6	Low	Behind mid-channel boulder
FR7	10V	395361	6275542	48	Medium	
FR8	10V	395349	6275513	39	Low	Whole stream width
FR9	10V	395264	6275322	20	Low	Two RDB eddies
FR10	10V	395252	6275321	10	Medium	RDB and LDB
FR11	10V	395231	6275318	44	Low	
FR12	10V	395213	6275275	25	Medium	Whole stream width
FR13	10V	395215	6275256	8.75	Medium	RDB
FR14	10V	395228	6275223	9	Low	Cottonwood, two log jams, RDB
FR15	10V	395220	6275179	50	Medium	Whole stream width
FR16	10V	395166	6275165	64	Medium	Whole stream width
FR17	10V	395171	6275111	12	Low	RDB
LAM1	10U	475341	6161951	15	Medium	
LAM2	10U	475364	6161959	16	Medium	
LAM3	10U	475389	6161982	25	Medium	
LAM4	10U	475420	6161993	16.5	Low	
LAM5	10U	475433	6161997	42	High	
LAM6	10U	475450	6161970	71	Low	
LAM7	10U	475480	6161933	18	Low	
LAM8	10U	475518	6161914	7	High	
LAM9	10U	475546	6161933	22.5	High	
LAM10	10U	475638	6161945	8	Medium	
LAM11	10U	475651	6161941	5	Medium	
LAM12	10U	475717	6161929	18	Low	
LAM13	10U	475746	6161914	13.5	Low	
LAM14	10U	475768	6161926	24	High	
LAM15	10U	475872	6161851	15	Low	
LAM16	10U	475893	6161825	7	Medium	
LAM17	10U	475955	6161788	14	Medium	
LAM18	10U	476052	6161811	16	Medium	
OLE1	10V	404959	6257626	44	Low	Whole stream width

OLE2	10V	404951	6257621	6	Medium	Two LDB pools
OLE3	10V	404932	6257606	36	Medium	Pool below 0.88 m waterfall (main pool and two LDB pools)
OLE4	10V	404887	6257597	4.5	Medium	LDB side channel
OLE5	10V	404854	6257587	3	Low	LDB
OLE6	10V	404828	6257583	9.5	Medium	RDB of left channel and whole width of right channel
OLE7	10V	404819	6257590	8	Medium	
OLE8	10V	404821	6257592	7.5	Medium	Right side channel
OLE9	10V	404804	6257587	19	High	Whole width and two pools within log jam
OLE10	10V	404730	6257606	8	Medium	Left side channel
OLE11	10V	404729	6257604	10	Medium	RDB
OLE12	10V	404708	6257588	3	Medium	End of side channel on LDB
OLE13	10V	404693	6257577	36	Low	Back-water where old stream channel used to be on RDB of right channel
OLE14	10V	404662	6257629	3	Low	Mid-channel boulder and LDB
OLE15	10V	404637	6257649	2	Medium	RDB
OLE16	10V	404607	6257645	6.5	Low	Mid-channel and LDB
OLE17	10V	404595	6257638	5	Medium	RDB
OLE18	10V	404576	6257655	6	Medium	LDB
OLE19	10V	405763	6257661	21	Low	Whole stream width
OLE20	10V	405754	6257659	7.5	High	Whole stream width under log
OLE21	10V	405710	6257658	8.5	Medium	Left channel
OLE22	10V	405705	6257674	8	Medium	Under root wad
OLE23	10V	405696	6257671	10	High	Log jam, mostly LDB
OLE24	10V	405686	6257696	10	Medium	Confluence of old stream bed and stream through forest
OLE25	10V	405678	6257710	16	Medium	LDB pool and whole width pool
OLE26	10V	405637	6257723	19	Low	Start of right channel
OLE27	10V	405619	6257739	3	Low	Mid-channel log
OLE28	10V	405614	6257766	8	Medium	LDB pool
OLE29	10V	405600	6257776	14	Medium	LDB pool
OLE30	10V	405560	6257785	21	Medium	Whole stream width below log
OLE31	10V	405560	6257790	11	Medium	LDB upstream of log
OLE32	10V	405480	6257805	7	Medium	Two pools, whole width right channel
SM1	10U	474520	6163620	85	Medium	RDB eddy, sand and cobble
SM2						
SM3						
SM4						
SM5	10U	474510	6163761	51	Medium	RDB with large woody debris; across from staff gauge and 10 m downstream

SM6	10U	474491	6163801			
SM7	10U	474477	6163846			RDB with some large woody debris
SM8	10U	474461	6163878			
SM9	10U	474462	6163931	22	Medium	Small pool below log and pool at bottom of log jam 10m upstream of Patsuk Creek
SM10	10U	474446	6163956	24	Medium	RDB with small woody debris and LDB between boulders
SM11						
SM12						
SM13	10U	474411	6164076	16	Low	
SM14	10U	474420	6164125	72	Low	Large pool downstream of constriction

Table D2: Staff gauge measurements and discharges from velocity and depth measurements at Six Mile and Ole creeks in 2012.

Date	Time	Staff Gauge	Water Temp.	Total Discharge
Six Mile Creek				
May 27, 2012	16:00	0.84	3	14.18
July 04, 2012	15:30	0.61	6	6.40
August 21, 2012	11:15	0.305	12.5	0.99
Ole Creek				
May 28, 2012	13:30	0.58	3	2.77
July 05, 2012	16:45	0.45	6	2.69
August 25, 2012	15:12	0.18	7.5	0.33

Table D3: Amphibians caught or observed at the four study creeks in 2012.

Creek	Species	# Observed	SVL[a] (mm)	Weight (g)	Caught/Observed/Incidental[b]
Six Mile	Spotted Frog	1	64	24	Caught
		1	50	n/a	Observed
		1	37	10	Caught
		1	n/a	n/a	Observed
		1	53	12	Caught
		6	Tadpoles	n/a	Observed
Lamonti	Western Toad	1	n/a	n/a	Observed
Factor Ross	Western Toad	1	n/a	n/a	Observed
	Wood Frog	1	25	1	Caught
Ole	Western Toad	1	25	1	Caught
		1	24	1	Caught

a. SVL: = Snout to Vent Length

b. Caught or Observed during timed-searches or incidentally observed at other times

Table D4: Universal Transverse Mercator (UTM) coordinates and dimensions of gravel substrates suitable for Rainbow Trout spawning that were observed during spawner surveys in July 2012.

Creek	UTM Coordinates			Average Dimensions (m)		Area (m^2)
	Zone	Northing	Easting	X	Y	
Lamonti	10U	6161958	475335	1.5	3	4.5
Lamonti	10U	6161983	475459	2	4	8
TOTAL						**12.5**
Six Mile	10U	6163114	474587	1.5	5	7.5
Six Mile	10U	6163302	474549	8	1.5	12
Six Mile	10U	6163489	474638	2	4	8
Six Mile	10U	6163501	474628	5	4	20
Six Mile	10U	6163510	474607	8	4	32
Six Mile	10U	6163667	474562	2	3	6
Six Mile	10U	6163747	474503	4	4	16
Six Mile	10U	6163888	474462	5	2	10
TOTAL						**111.5**
Ole	10V	6257671	405775	1	1	1
Ole	10V	6257676	405691	1	4	4
Ole	10V	6257813	405205	4	2	8
Ole	10V	6257773	405174	2	2	4
Ole	10V	6257597	404944	2	1	2
TOTAL						**19**
Factor Ross	10V	6275732	395362	1	5	5
Factor Ross	10V	6275493	395357	2	2	4
Factor Ross	10V	6275352	395283	2	6	12
Factor Ross	10V	6275333	395264	3	10	30
Factor Ross	10V	6275313	395226	1	1	1
Factor Ross	10V	6275303	395212	3	1	3
Factor Ross	10V	6275257	395213	4	4	16
TOTAL						**71**

Table D5: Catch and effort data from minnow trapping on Six Mile Creek on August 19-21, 2012.

Site	Effort (trap*hours)	# Fish	Species*	Length (mm)	Weight (g)	Marked (Yes/No)
SM1	21.4	0				
SM2	20.8	0				
SM3	20.3	0				
SM4	20.0	0				
SM5	19.7	0				
SM6	19.1	1	BT	94	10	Yes
SM7	18.8	0				
SM8	18.5	0				
SM9	18.3	0				
SM10	18.1	0				
SM11	17.8	0				
SM11	23.75	0				
SM10	23.7	0				
SM9	23.7	0				
SM8	23.6	0				
SM7	23.5	0				
SM5	23.1	0				
SM4	22.9	0				
SM3	22.9	0				
SM2	22.8	1	BB	161	26	Yes
SM1	23.0	0				
SM12	23.7	0				
SM13	23.8	0				
SM14	24.0	0				
SM15	24.2	0				
SM16	23.8	0				
SM17	23.8	0				
SM18	23.9	0				
SM19	23.8	0				
SM20	23.9	0				
SM21	23.8	0				
SM22	23.9	0				
SM23	23.9	1	RB	73	4	Yes
SM24	23.8	0				
SM25	23.9	0				
SM26	24.1	0				
SM27	24.2	0				
SM28	18.3	0				
SM29	22.7	0				

*Species codes: BB = Burbot, BT = Bull Trout, RB = Rainbow Trout

APPENDIX E

Model Code

Program R/WinBUGS code for closed-population Bayesian mark-resight abundance estimates for fish in four Williston Reservoir tributaries. The estimates are stratified by creek / species, as specified below.
##Date: 18 October 2012
##Programmer: Sima Usvyatsov

```
library(R2WinBUGS)

sink("pop.abundance.txt")
cat("
## Model definition
model cr1{
## Likelihood function; s = number of creeks/species combinations.
     for(i in 1:s){
          ## Marked fish
          n[i] ~ dbin(p[i],N[i])
          ## Unmarked fish
           u[i] ~ dbin(p[i],U[i])
           }
## Prior distribution
     for(i in 1:s){
         ## Capture probabilities
         p[i] ~ dunif(0, 1)
         ## Number of unmarked fish
         U[i] ~ dnorm(40, 0.0001)
                    }
}
", fill = TRUE)
sink()

## Data list
win.data <- list(s=5, N = c(11, 3, 2, 1, 3), n = c(3, 3, 2, 1, NA), u = c(31, 17, 3, 6, 11)) ### order of creeks/species: Ole BT, Six Mile RB, Lamonti RB, Lamonti BT, Factor Ross BT.
## Initial values
inits <- function() list(U = c(110, 80, 50, 50, 50), p = c(0.5, 0.5, 0.5, 0.5, 0.5))
params <- c("U", "p")
ni <- 10000
nt <- 5
nb <- 1000
nc <- 3

out <- bugs(win.data, inits, params, "pop.abundance.txt", n.chains = nc, n.thin = nt, n.iter = ni, n.burnin = nb, debug = TRUE, working.directory = getwd())
```

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