Peace Project Water Use Plan

Williston Reservoir Tributary Habitat Review

Study Year 3

Reference: GMSMON-17

Williston Reservoir Tributary Habitat Review - 2013 Summary Report - Revision 1

Study Period: 2013

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GMSMON#17 WILLISTON RESERVOIR TRIBUTARY HABITAT REVIEW

Williston Reservoir Tributary Habitat Review - 2013 Data Summary Report

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REPORT

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Executive Summary

This report presents the results of Year 3 (2013) of monitoring at the Williston Reservoir tributaries selected for trial enhancement works to improve fish passage (GMSMON#17). During 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 mouths, where the mouth of the stream is perched above the low water level of the reservoir with fast and/or shallow water flow in between. Proposed habitat enhancements 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.

This monitoring program consists of a Before-After, Control-Impact (BACI) study design to assess the effectiveness of habitat enhancements. Six Mile Creek (enhancement) and Lamonti Creek (control) were selected as sites with potential perched mouth blockages. Ole Creek (enhancement) and Factor Ross Creek (control) were selected as sites with potential woody debris blockages. Rainbow Trout (*Oncorhynchus mykiss*) and Arctic Grayling (*Thymallus arcticus*) were the target species because they spawn in the spring when reservoir levels are at their lowest and tributary access blockages are most likely to occur. However, other fish species were monitored to help interpret the results and assess the effects of enhancements on the fish community. Components of the study included water temperature and discharge monitoring, visual assessments of tributary access blockages, amphibian searches, spring fish spawner surveys, and summer juvenile and small-bodied fish population estimates for each stream. Vegetation sampling and bird surveys were conducted in the first year of monitoring in 2011, but not in 2012 and 2013 because the proposed habitat enhancements were not expected to have a large effect on vegetation or bird populations.

Satellite-transmitting stream gauging stations equipped with water level loggers, and air and water temperature probes were installed on the enhancement streams (Ole and Six Mile creeks) in late May 2012. These provided real-time temperature and water level information accessible via the internet. Stream discharge (based on water level and snowpack data) and reservoir elevations were greater than average during 2011 and 2012 and lower during 2013.

Visual assessments of stream mouths were conducted in early spring (April or May), spring (late June to July), and summer (late August) of 2011 to 2013 to document evidence of any potential barriers to fish passage. Debris blockages or flows that were too shallow or fast for fish passage within the drawdown zone have not been observed during any site visits. Although barriers to fish passage were not observed, habitat in the drawdown zone was generally poor quality, consisting primarily of fast-flowing riffles with little cover, and few pools or resting areas.

Time-constrained searches for amphibians were conducted at each tributary during spring of 2013. Species observed were wood frogs (*Lithobates sylvatica*), Columbia spotted frogs (*Rana luteiventris)*, and western toads (*Anaxyrus boreas*). Catch-per-unit-effort (CPUE) was similar to previous surveys in 2011 and 2012. Amphibian habitat near the mouths of Six Mile and Ole creeks was identified in this report and should be considered when implementing habitat enhancements.

During spring spawner surveys from 2011 to 2013, redds have not been observed on any of the four tributaries and only one spawner was observed (a Rainbow Trout with spawning colouration in Six Mile Creek in 2012). Locations and spatial area of suitable spawning gravels were recorded. In general, there was a limited amount of suitable spawning habitat in the lower reaches (up to 2 km) of the tributaries that were surveyed. However, the occurrence of young-of-the-year fry and juveniles suggested that Rainbow Trout, Bull Trout (*Salvelinus*

confuentus), and Mountain Whitefish (*Prosopium williamsoni*) spawned in the study stream catchments during the three years of monitoring. Adult Kokanee (*Oncorhynchus nerka*) were also observed in Ole Creek, suggesting that this species may be spawning in the northern tributaries.

The juvenile and small-bodied fish population survey in 2012 and 2013 used a mark-resight method involving backpack electrofishing to capture and tag fish, and snorkel surveying to resight fish. Abundance estimates from the mark-resight model, as well as CPUE while electrofishing and snorkel surveying will be used to compare fish populations before and after habitat enhancements. Habitat enhancements are planned for spring 2014. Subsequent monitoring years will be considered post enhancement.

Six Mile Creek (enhancement) and Lamonti Creek (control) had similar fish communities, as fish observed or caught were mostly Rainbow Trout or Bull Trout. Fish caught or observed in Ole Creek (enhancement) were mostly Bull Trout, with smaller numbers (<5) of Rainbow Trout and Mountain Whitefish. In Factor Ross Creek (control) Bull Trout and Mountain Whitefish were the most common species, but Rainbow Trout were also present. A small number of Arctic Grayling was observed in Factor Ross Creek in 2012 (four fish) and 2013 (one fish) but this target species has not been observed in the other three study tributaries. Abundance estimates and CPUE for electrofishing and snorkel surveying varied between 2012 and 2013 for all species but in general do not suggest large differences in densities between the two study years.

In 2013, fry surveys were conducted in conjunction with the night-time snorkel surveys to better quantify densities of young-of-the-year salmonids in the study streams. Suitable fry habitat was searched and the number of fry and the linear distance of shoreline sampled were recorded. The data will be used to quantify how well suitable young-of-the-year habitats were seeded with fry, and compared to years following habitat enhancement. Rainbow Trout fry density was greatest in Six Mile Creek (0.42 fry/m), followed by Lamonti Creek (0.07 fry/m). The density of Rainbow Trout fry was low in Ole Creek (0.01 fry/m). Fry were not observed in Factor Ross Creek, although rain and high stream flows likely reduced habitat suitability and observer efficiency.

The following recommendations are made based on the first three 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 following freshet flows. 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. Fry surveys also should be continued in future years of the study.
- Further refine the enhancement designs of GMS WORKS #19 to incorporate more woody debris and willow stakes in mounds that would elevate the structures close to the stream mouths to above the full pool level.
- Increase habitat diversity in the enhancement streams within the drawdown zone to provide cover for fish migration.
- Amphibian sampling should continue using time-constrained searches as a method but effort should be focused on target areas where impacts from the enhancement works are most likely (i.e., within the drawdown zone at the stream mouths).

Table 1 ES: GMSMON#17 Status of Objectives, Management Questions and Hypotheses after Year 3.

Objective	Management Questions	Management Null Hypotheses	Year 1 (2011) Status	Year 2 (2012) Status	Year 3 (2013) 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.	One year of pre-enhancement fish data have been collected. Based on the limited baseline data available, hypothesis cannot be rejected at this time.	Two years of pre-enhancement fish data have been collected. A new monitoring method was used in 2012 and was recommended for future years of study.	Three years of pre-enhancement fish abundance data have been collected. Years 2 and 3 used a mark-resight method that is recommended for post-enhancement monitoring.
	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.	Fish access to tributary habitat was monitored by spawner surveys and visual assessment of access blockages. Based on the limited baseline data available, hypothesis cannot be rejected at this time.	Usage of upstream habitats by adfluvial fish has been monitored by visual assessments of stream mouth blockage and spawner surveys. Baseline data only at this time.	Enhancements will not directly affect habitats upstream of the stream mouths at typical stream flows. Usage of upstream fish habitat depends on accessibility of tributaries. No access blockages have been observed during field sessions of the first three years of monitoring. Photo reference monitoring to continue to monitor for changes in habitat quality near the tributary mouths.
	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. BC Hydro has agreed that the vegetation program will be suspended until the year of the enhancement works.	Monitoring was suspended until the implementation of the enhancement works. Data from Year 1 provide baseline pre-enhancement data in the study area.	Monitoring was suspended until the implementation of the enhancement works. Data from Year 1 provide baseline pre-enhancement vegetation data in the study area.
	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 are required.	Continuing baseline data collection. We suggest increasing sampling effort in future years due to generally low populations.	Three years of pre-enhancement amphibian data have been collected. Efforts focused near the stream mouths where enhancements could potentially affect amphibian habitats.
	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 are required.	Need more emphasis on measuring habitat quality for amphibian species in future years. Baseline only at this time.	Enhancements are focused in the drawdown zone, where little breeding habitat was observed. Amphibian habitats near the stream mouths that could be affected by enhancements were identified in this report.
	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. Planned enhancements are not likely to affect songbird habitat 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.	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.

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1.0 INTRODUCTION

The 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 starts during spring freshet and extends into summer. 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 mouths, where the mouth of the stream is perched above the low water level of the reservoir with fast 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 Creek and Six Mile Creek enhancement were later developed (KWL 2011, 2013) and are expected to be implemented during early 2014. 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 include woody revetments, vegetated geogrid banks and enhanced log jams, all of which are designed to reduce erosion, reinforce channel banks, and prevent channel bifurcation (KWL 2011). At Ole Creek, the proposed enhancements include removal of a debris-caused barrier and stabilization of the cleared channel via installation of woody revetments, gravel berms, and woody debris catchers 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 to 60 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 and are both within Six Mile Bay, approximately 1 km apart (Appendix A, Map 1).

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 sucker species (Blackman 1992) in the study area 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 some of 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 and 2013 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, 2012, or 2013. Bull Trout (*Salvelinus confluentus*), Mountain Whitefish (*Prosopium williamsoni*), and Kokanee (*Oncorhynchus nerka*) occur in the study tributaries (Golder 2012, 2013a) and can have adfluvial life-histories but spawn in the fall when tributary access is less likely to be obstructed.

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 Reservoir 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 2008).

The 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 2013 for fish, amphibian and environmental conditions and compare with 2011 and 2012, 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 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. The habitat enhancements are planned for implementation during late winter to early spring 2014, prior to the 2014 monitoring program.

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 are 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 for spawning shortly after ice-out. 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 gravel 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 sampling objective of the fish component of the program is to address the management questions 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). Amphibian species known within the study area 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 (e.g., western toad [*Anaxyrus boreas*]). 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, 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 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 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 Williston 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. Based on observations during the Year 1 of study in 2011 and review of the proposed habitat enhancement construction (KWL 2011, 2013), 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 Year 1 (Golder 2012), songbird surveys were not conducted in 2013 and monitoring efforts were focused on fish and fish habitat where the proposed designed enhancements are most likely to yield a change.

The 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 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 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 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

The sampling program focused on the lower reaches of each tributary, from where each stream flows into Williston Reservoir (mouth) upstream approximately 1-2 km. An overview of the project area is provided in Appendix A, Map 1 and a map of each stream is provided in Maps 2 to 5 (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 BC. 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 2013 was conducted during three site visits. The first site visit occurred from April 29 to May 1. Satellite-enabled stream gauging stations on Six Mile and Ole creeks were serviced, stream discharge was measured, and the tributary mouths were assessed for fish passability. The second site visit occurred during June to conduct 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 2013 are summarized in Table 2 and detailed methodologies are provided in the following sub-sections.

Table 2: Summary of 2013 Field Program.

Dates	Field Work Conducted
April 29 to May 1, 2013	■ Maintenance of stream gauging stations and discharge measurements at Six Mile and Ole creeks ■ Visual assessment of fish passability at tributary mouths
June 16 to 22, 2013	■ Spawning surveys ■ Discharge measurements at stream gauging stations ■ Amphibian surveys ■ Visual assessment of fish passability at tributary mouths
August 16 to 28, 2013	■ Juvenile and small-bodied fish population estimates ■ Discharge measurements at stream gauging stations

2.1 Snowpack and Reservoir Level

Snow pillow survey data from the nearest available stations to the study tributaries were compared with the 2011, 2012, and 2013 seasons as well as the mean of the previous 10 years. Data from the winter of 2013 had not been verified by the BC River Forecasting Center and were therefore not available from the publicly accessible website; the BC River Forecast Center supplied these data with the qualification that they had not been verified. Daily averages of snow water equivalency (SWE) data were calculated and presented in this report. The three study years (2011, 2012, and 2013) were then plotted with the daily average SWE from the previous 10 year of available data (2001-2010).

Daily mean values of the Williston Reservoir level were obtained from BC Hydro. Reservoir levels from all three study years were plotted, along with a 38 year average (1973-2011).

2.2 Remote Stream Gauging Station

In May of 2012, satellite-enabled water level stations were installed on Six Mile Creek and Ole Creek. The location of these stations is shown in Maps 2 and 5 of 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 v2 water temperature logger (Onset® Computer Corporation, Massachusetts, USA; accuracy of ± 0.1°C and range of 0°C to 50°C).

The stations measure water level, water temperature, and air temperature at 15 minute intervals. Note that logging schemes have been changed several times in order to correct glitches. 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 and 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 in a reasonably deep portion of river 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 was the same as the stream. A staff gauge was connected directly to the side of the conduit with 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 could 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 2 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 of the stations are provided in Table 3.

Table 3: Location and Installation Details for 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

Maintenance of the two station was conducted in the spring of 2013 (April 29 –May 1). Generally, the stations were found to be in good condition and appeared to be operating normally. A technical memorandum was prepared that further describes the activities and results of this trip (Golder 2013b). A re-survey of the two stations was conducted at this time to confirm that they had not moved. The results of the baseline and secondary surveys are provided in Table 4. The 0.218 m difference in the surveyed elevations of the Six Mile T-post is expected to be due to a combination of surveyor error and the limitations of conducting the second survey on snow. The rest of the survey results suggested little or no movement at this station.

Table 4: Surveyed Elevations for Stream-Gauging Stations.

Component	2013 Re-Survey		Original Survey (m)	Difference Between Surveys (m)
	Elevation (m)	Difference from Benchmark (m)		
Six Mile Creek Station (5018)				
Benchmark	-0.110	-	-	-
Upstream Nail	2.330	2.44	2.47	0.033
Top of T-post	2.530	2.64	2.42	0.218
Top of Stilling Pipe	1.750	1.86	1.93	0.072
Top of Staff Gauge	2.715	2.83	2.89	0.068
Ole Creek Station (4078)				
Benchmark	0.780	-	-	-
Top of Rebar	2.100	1.320	1.317	0.003
Top of Stilling Pipe	1.880	1.100	1.096	0.004
Top of Staff Gauge	2.850	2.07	2.049	0.021

After installation of the gauging station on Six Mile Creek in 2012, 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. Since the replacement of the probe, the new equipment has been running well with only a few data outliers that are likely attributable to wrap around error. We have been working with Steve Biduk of GeoScientific in Burnaby, BC, to adjust the data schemes to prevent these errors.

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.

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. These operated for approximately one year; these units were collected and replaced in August of 2013. The data were offloaded and were compared to the temperature data from the KPSI probes.

Stream discharge was calculated based on the velocity and depth measurements taken at the gauging stations during each of the three site visits in 2012 and three visits in 2013. 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 was plotted against the water level measured at that time by the gauging station and staff gauge measurements. Polynomial regression was used to describe the relationship between discharge and water level.

In order to get an estimate of measurement error when collecting stream discharge data, two replicate sets of depth-velocity data were collected during each site visit in 2013. When replicates were conducted, the mean of the two discharges was used in plotting against the water level measured on the staff gauge or recorded by the Neon.

Following station installation in Six Mile Creek during late May, 2012, 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 discharge in Six Mile Creek was 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 forestry road bridge and 130 m upstream of the gauging station as the channel is much more uniform at this location.

All water level and temperature data were cleaned by removing impossible values and obvious outliers. A complete database is stored on the Golder server in Kelowna. Average daily water temperatures were calculated and presented in this report in order to smooth the data and ease comparison with other years.

2.3 Amphibian Searches

The amphibian field surveys were completed in 2011 to 2013 according to the Resource Inventory Standards Committee standards for time-constrained searches (RIC 1998). Time-constrained searches of small ponds and wetlands were completed within suitable habitat in the vicinity of each tributary and the search time for each search was documented. In 2011 and 2012, wetlands along the lower reaches of the tributaries were included in the searches. In 2013, surveys were mostly conducted in areas near the stream mouths to target areas that are most likely to be affected by habitat enhancements. This adjustment was made once a preliminary enhancement design was provided and it was determined that no foreseeable impacts to amphibian habitat in areas outside of the footprint area (i.e., drawdown zone) would occur. Data collected included encounters with amphibian egg masses, larvae (tadpoles) and metamorphs (sub-adults and adults). Although search time was the unit of effort for amphibians surveys, the approximate area of habitat searched also was recorded for comparison to previous study years. Data recorded included species identification, sex (where feasible), developmental stage, weight (adults only), snout-vent length (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. Catch-per-unit-effort (CPUE) was calculated in the number of amphibians per minute and number per 100 m². 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.

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 and Fish Habitat

During the May, June, 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 all site visits in 2012 and 2013. Global Positioning System (GPS) locations were recorded as Universal Transverse Mercator (UTM) coordinates in the NAD83 projection and are indicated on Maps 2 to 5 in Appendix A. 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 can be compared to photos from future years of the monitoring program. These same photo reference locations can be used to assess changes in fish habitat near the stream mouths.

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	475293	6162003	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. 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. Only areas of suitable sized spawning gravel and flows appropriate for spawning (>10 cm depth and suitable water velocity) were included.

To improve detection of spawners, snorkelling was also used during the 2013 survey. One worker equipped with a drysuit, mask, and snorkel made observations at selected locations where the velocity and depth were suitable for snorkelling, while the other worker was stationed downstream and equipped with a throwbag for safety.

The surface area of the habitat observed during snorkelling was estimated to quantify sampling effort, so that these observations can be compared to future studies if needed. As visibility likely varies across time and among tributaries, snorkelling observation efficiency was quantified by measuring the horizontal distance at which a 30 cm yellow ruler was visible underwater.

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 spawner surveys in 2011 or 2012, spawner survey efforts focused on Rainbow Trout in 2013. Stream flow and water temperature data from the satellite-transmitted gauging station were used to plan the timing of the spawner surveys in 2013, 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.

Table 6: Spawning Surveys Details.

Stream	Date	Stream Length Surveyed (km)	Starting Point	End Point
Lamonti	June 17, 2013	1.4	Stream Mouth	~500 m upstream of Parsnip forestry road
Six Mile	June 18, 2013	1.9	Stream Mouth	~300 m upstream of Patsuk Creek confluence
Ole	June 19, 2013	1.9	Stream Mouth	~400 m upstream of Factor Ross forestry road
Factor Ross	June 20, 2013	1.2	Stream Mouth	~450 m upstream of Factor Ross forestry road

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 (Golder 2012).

The juvenile and small-bodied fish survey in 2012 and 2013 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 by backpack electrofishing, 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. Sampling protocols are described in the sections below and additional methodological details are provided in Appendix C.

Sampling Sites

Sampling reaches in the four study streams were from the mouth to 1.4 km to 2.0 km upstream (Appendix A, Maps 2 to 5). 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 electrofishing was conducted, with the exception of a few sites (sites SM30-32 on Six Mile Creek and sites OLE21-22 on Ole Creek) that were not snorkelled because of logistical constraints. This was a slight change from methods in 2012. In 2012, snorkelling was conducted at sites where fish had been marked and released, sites adjacent to where marked fish were released, and if time permitted, additional randomly selected electrofishing sites. In future years of the study, it is recommended that all electrofishing sites be sampled by snorkelling, as was done in 2013. Because the monitoring program will compare density estimates and numbers of fish per unit area, this difference in the number of sites snorkelled in 2012 and 2013 is not expected to affect comparability of the data between years.

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 and weighed with an electronic scale (± 1 g). Fork length (total length in the case of sculpins [*Cottus* spp.]) was measured to the nearest 1 mm.

Fish were marked with fluorescent yarn that was attached through the flesh directly behind the dorsal fin using a surgical suture (size 2-0 non-absorbable monofilament with 24 mm 3/8 circle cutting needle), tied using a surgeon's knot consisting of a double throw followed by one or two single throws depending on fish size. In 2012, fish were marked behind the dorsal using a size 18 barbed fishing hook that had fluorescent yarn tied around the shank. Sutures were used in 2013 and are recommended in future years of the study because they are likely less invasive than fishing hooks and less likely to have effects on behaviour or swimming. Photographs of different sizes and species of fish that were tagged during the surveys are provided in Appendix B (Photos 3 to 10). 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 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. PG13-85702) prior to fish sampling. Fish sampling data will be 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 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.

Snorkel surveys were conducted at all sites that were electrofished, except for a few sites (sites SM30-32 on Six Mile Creek and sites OLE21-22 on Ole Creek) that were not snorkelled because of insufficient time. At each site, the same spatial area that was measured and sampled during electrofishing was surveyed by snorkelling. Visibility was quantified by recording the horizontal distance at which a 30 cm yellow ruler was visible underwater by the snorkelers. All snorkel surveys were conducted beginning 30 minutes after sunset one day following the release of marked fish.

Fry Surveys

Although salmonid fry (i.e., young-of-the-year fish) were often observed incidentally in the margins of the study streams at night during 2012, relatively small numbers of salmonid fry (<5 per tributary) were captured or observed in sampling sites in 2012 (mainly because there were no formal searches conducted). For this reason, visual surveys were conducted in 2013 in conjunction with the night-time snorkel surveys, to improve detection of salmonid fry and provide an index of the number of young-of-the-year fish (especially Rainbow Trout) to compare with years following habitat enhancement. Fry surveys were conducted at the same time as the night-time snorkel surveys by the crew member who was recording notes, while the other two crew members snorkelled the site. Fry surveys were conducted adjacent to the snorkelling sites in areas that provided good habitat for salmonid fry, based on professional judgement. Although habitat variables were not measured, habitats considered suitable for fry were characterized by water depths less than 20 cm and water velocities less than 0.1 m/s, and were typically near the stream margin (Raleigh et al. 1984; McPhail 2007). Photographs of representative habitat searched during fry surveys are in photos 11 and 12 of Appendix D. If there was no suitable fry habitat in the vicinity of the snorkelling site, then a fry survey was not conducted at that sample site. For each site, the number of fry observed, estimated fork lengths, and the linear distance of shoreline surveyed was recorded. Whenever possible, a sub-sample of observed fry was captured with a small dip-net to confirm species identification. Although fry survey sites were not randomly selected, they likely provide a reasonable representation of suitable fry habitat in the study tributaries. The data will be used to quantify how well suitable young-of-the-year habitats were seeded with fry, and compared to years following habitat enhancement.

Data Analysis

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.

CPUE for fry surveys was calculated as the number of fry per linear metre of shoreline (#/m). For fry survey data analysis, only Rainbow Trout <40 mm and Bull Trout <70mm were considered to be fry and were included in the CPUE, whereas larger fish were assumed to be older (age-1 or greater). Although we do not have length-age data to support these criteria, those cut-offs were selected based on other populations in British Columbia (McPhail 2007), and are unlikely to have significantly affected the results, as very few (two Bull Trout and one Rainbow Trout) larger fish were observed during the surveys. Although sculpin were not target species in the study, they were often observed during fry surveys and were included in the data summary to provide supporting information about potential changes in the fish community over time.

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 strata that were included in the model were Six Mile Bull Trout, Lamonti Bull Trout, Lamonti Rainbow Trout, Ole Bull Trout, Factor Ross Mountain Whitefish, 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. 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.

Abundance was also calculated 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

3.1 Physical and Environmental Variables

3.1.1 Snowpack

Snow packs for the 2011, 2012 and 2013 study years were compared with historical means from two automated snow pillow gauging stations which were assumed to most closely resemble conditions at the study sites (Table 7). These stations are Aiken Lake (Station ID: 4A309) for the northern tributaries (Ole and Factor Ross) and Pine Pass (Station ID: 4OA2P) for the southern tributaries (Six Mile and Lamonti).

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 SWE of the previous 10 years is compared to the 2011, 2012 and 2013 seasons in Figures 1 and 2. It should be noted that the data for 2012 and 2013 have not been verified and should be considered preliminary.

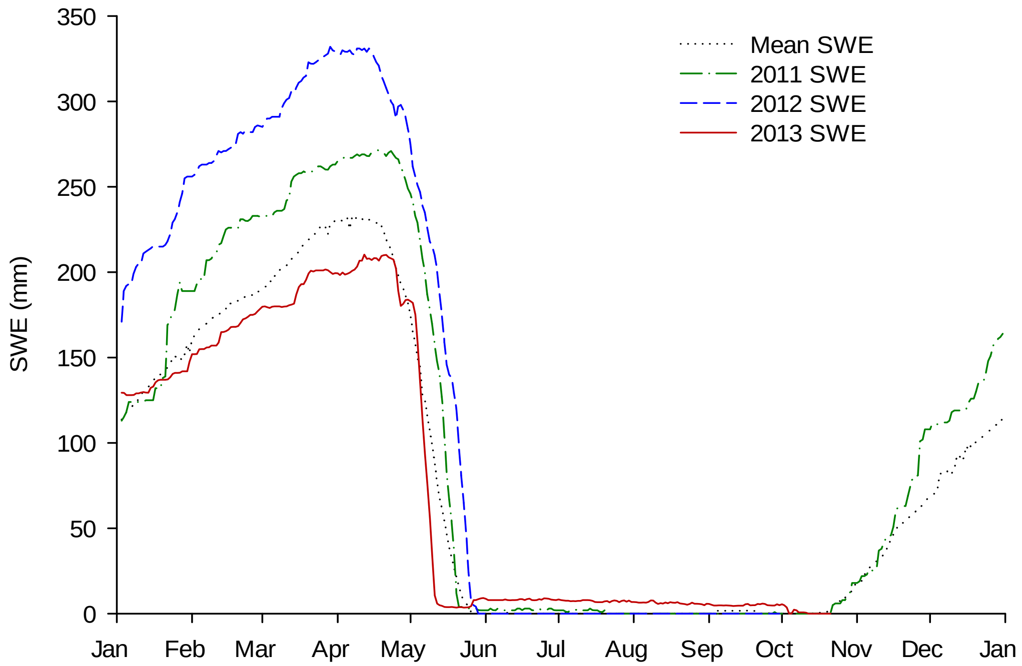

Figure 1: Ten year mean (2001-2010) versus 2011, 2012 and 2013 Snow Water Equivalent (SWE) at the Aiken Lake Station.

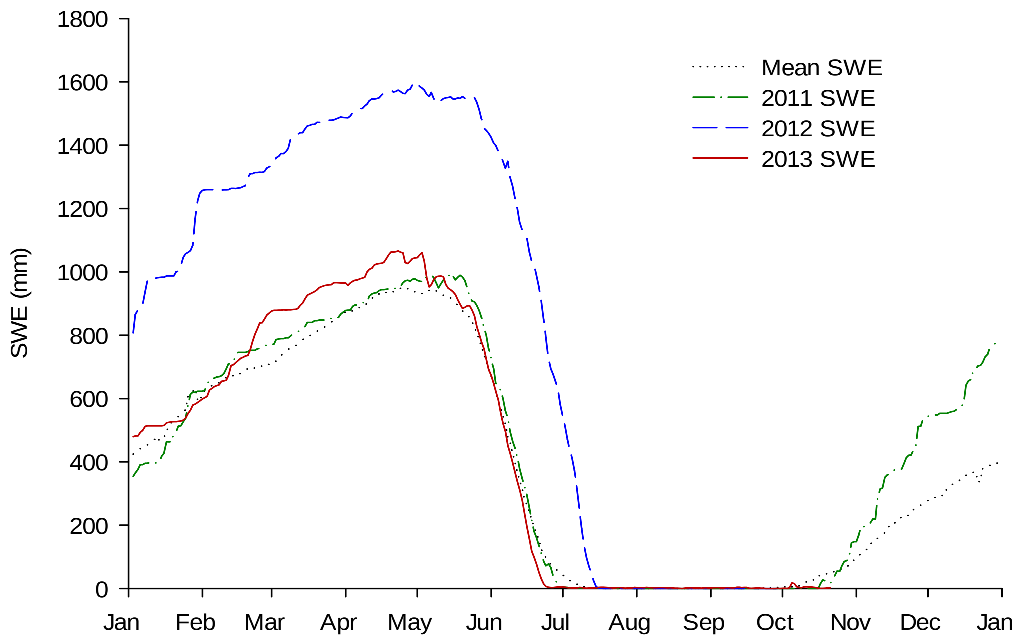

Figure 2: Ten year mean (2001-2010) versus 2011, 2012 and 2013 Snow Water Equivalent (SWE) at the Pine Pass Station.

Snowpacks were above average within the trial tributary catchment areas in both the 2011 and, in particularly, in the 2012 season. In 2013, the snowpack at Aiken Lake (Figure 1) was slightly below the 10-year mean and slightly above the 10-year mean at the Pine Pass Station (Figure 2). The 2012 snowpack in particular likely contributed to above average spring discharges and cooler water temperatures during the 2012 season. For Six Mile Creek (Pine Pass Station), the snowpack in 2011 season was the closest to the 10-year mean, compared to the other two years of this monitoring study. For Ole Creek (Aiken Lake Station), the snowpack in 2013 was closest to the 10-year mean snowpack.

3.1.2 Reservoir Elevation

Reservoir levels from the three study years are compared to a 38-year mean in Figure 3. Reservoir elevation was greater than the historical mean in 2012 and slightly lower than the mean in 2013. In 2011, reservoir elevation was less than the mean from June to mid-July, but greater than the mean from mid-July through September.

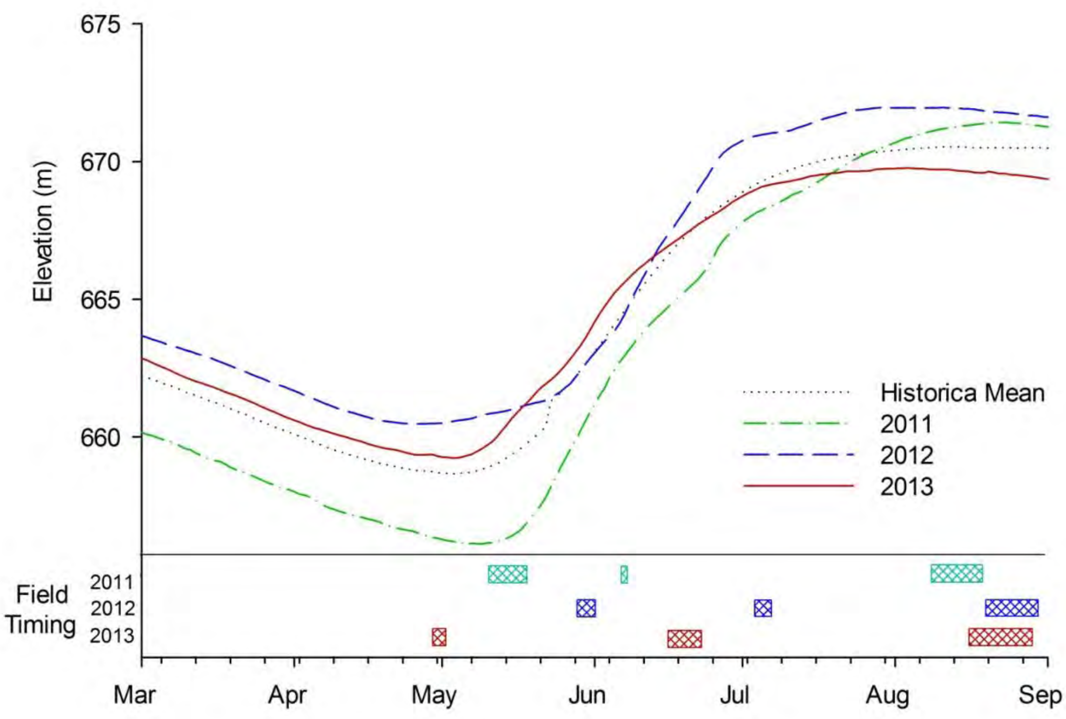

Figure 3: Average daily summer reservoir elevations in 2011, 2012, and 2013 compared to calculated historical means (1973- 2011) for Williston Reservoir.

3.1.3 Stream Gauging Station

Six Mile Creek

Daily means were calculated from the Six Mile Creek Neon ambient air temperature data (Figure 4).There were no outliers or anomalous data points requiring removal from the data set and the air temperature data were consistent with what would be expected in the region. Note that in 2012 analysis of daily minimum and maximum temperatures showed that a 20°C difference was not uncommon.

Daily mean air temperature in 2012 and 2013 generally peaked near the beginning of August. The warmest temperatures recorded in 2012 and 2013 were 28.6°C and 29.8°C, respectively. Both occurred in July. The coldest temperature was -29.2°C recorded on December 29, 2012. Note the dramatic changes in the average daily temperatures during the winter months (November to February).

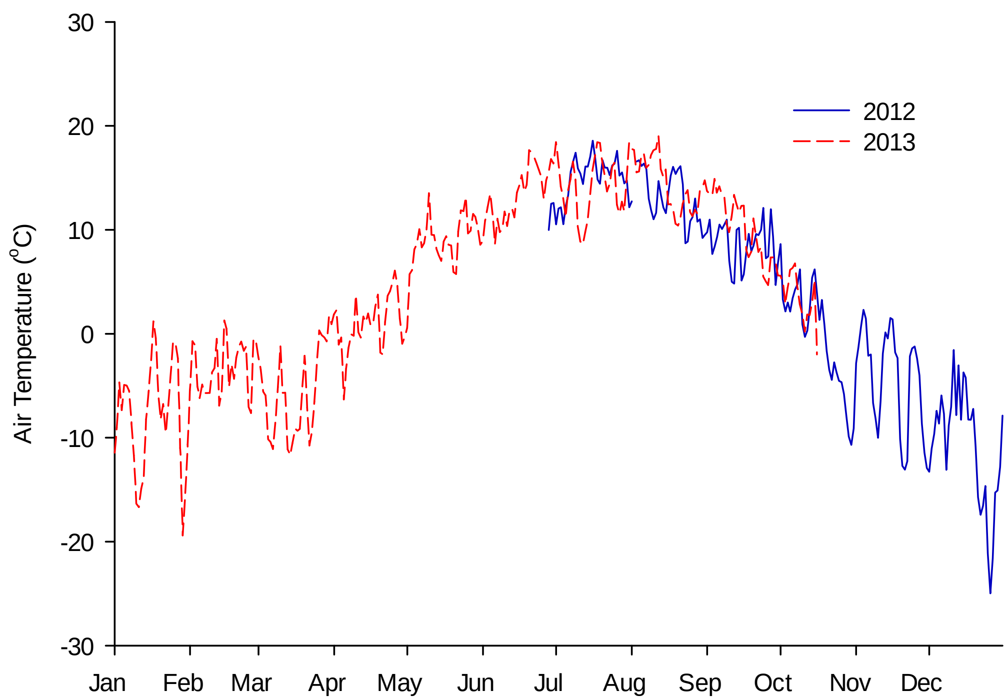

Figure 4: Average daily air temperature recorded at Six Mile Creek (Station 5012).

Average daily water temperature in Six Mile Creek, as recorded by the satellite-transmitting KPSI probe, is provided in Figure 5. Water temperature data before August 20, 2012 appear reasonable but should be considered with caution because of the malfunctioning probe (see Section 2.2). Gaps in the water temperature line in Figure 4 denote data removed due to nonsensical recorded values.

A large increase in water temperature in July of 2012 was removed as a suspected outlier; however, when the data are compared with the water level data below (Figure 6), two very large increases are also shown. This suggests that either the error affected both components of the probe, or a very large, warm, rainfall event occurred. A similar spike shown in the data from Ole Creek suggests the latter. A similar increase was observed in data from the backup water temperature logger, although the increase was not as large (Figure D1, Appendix D).

The warmest recorded water temperatures were 12.91°C and 13.55°C in 2012 and 2013, respectively. Both occurred in the middle of August. The coldest water temperatures were -2.72°C in 2012 and 2.18°C in 2013; they occurred in December and March, respectively.

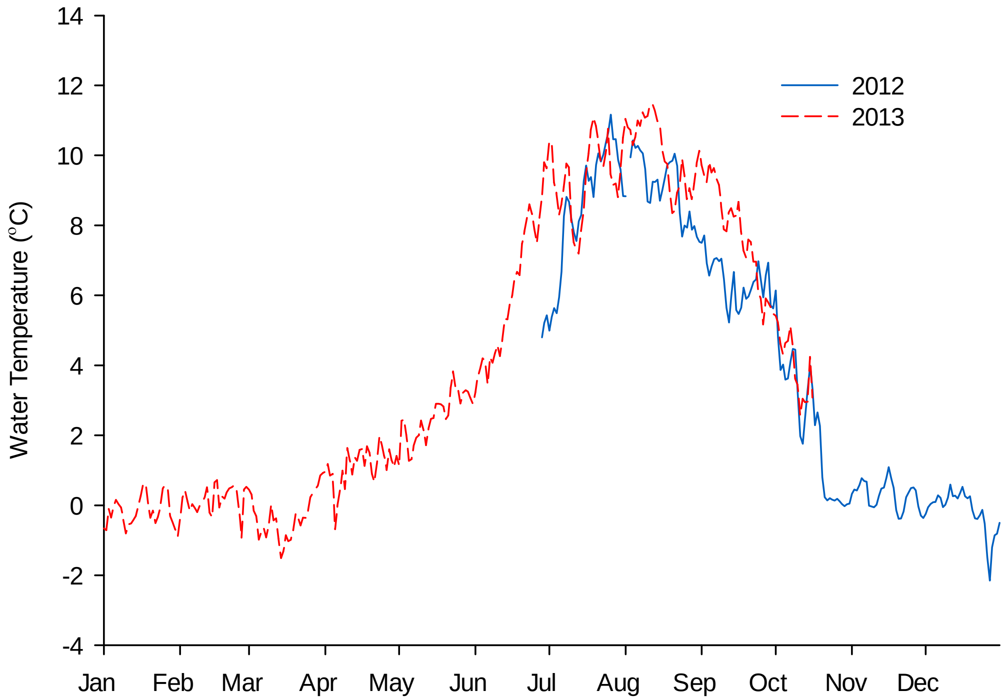

Figure 5: Average daily water temperatures recorded at Six Mile Creek (Station 5012).

Water temperature data from the backup temperature logger is provided in Appendix D, Figure D1. Raw water temperature data logged at 15-minute intervals are presented instead of averages to show daily temperature variation. Water temperature recorded by the backup temperature logger and satellite-transmitting probe are compared in Appendix D, Figure D2. Generally, water temperatures recorded by the two devices were in very close agreement. The only deviations occur during very cold periods during the winter months. This is likely attributable to a difference in the positioning of the sensors: the satellite-transmitting probe sits in the water column and may at times be at, or just above the surface, whereas the backup water temperature logger is at or near the bottom of the stream.

Average daily water levels, as recorded by the satellite-transmitting gauging station during the 2012 and 2013 seasons, are shown in Figure 6. Water level in 2013 in Six Mile Creek peaked in early June. A second peak in mid-October corresponds with the onset of the wetter fall season. Note the 2012 data are incomplete due to a malfunctioning KPSI probe. We did attempt to cross-reference spikes in this data with available weather information; however, no available historical precipitation data are available in reasonable proximity to this station. We were able to verify regional rain events on October 1, 2012 at Fort St. John and Prince George which would correspond to one of the spikes. The sharp spike in January, 2012 is difficult to explain as the temperature was exceedingly cold during this period. Water temperature increased gradually and there were no obvious outliers. One possible explanation is that a debris or ice jam formed downstream and temporarily elevated the water level at the probe. The peak water level climbed nearly 30 cm over four hours then decreased over one hour. The intermediate values in both cases show steady trends.

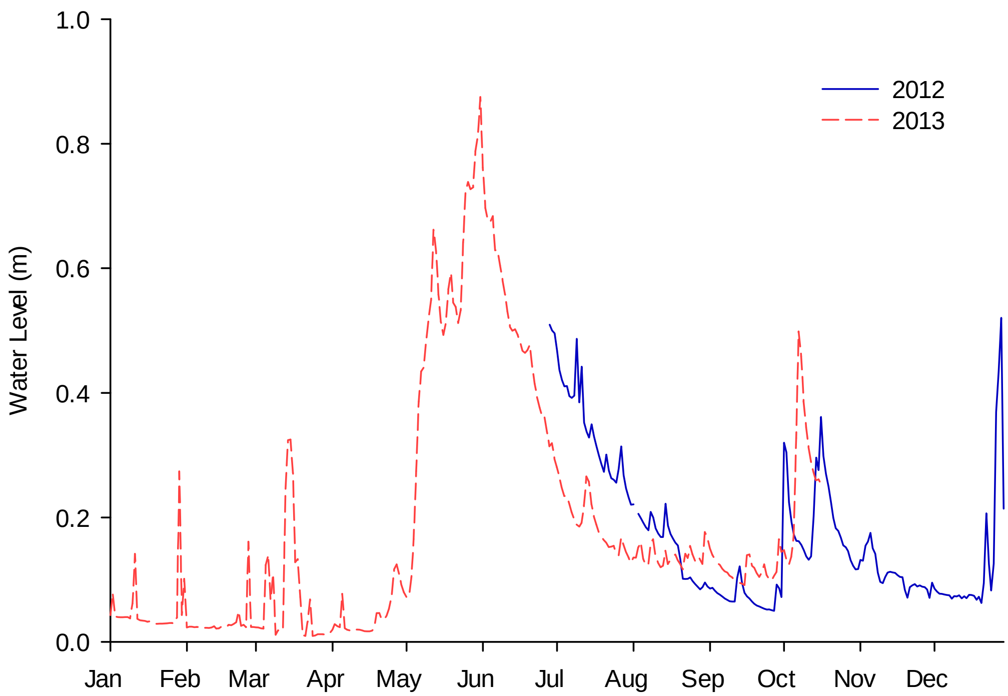

Figure 6: Average daily water level recorded at Six Mile Creek (Station 5012).

Ole Creek

Air temperatures in summer were similar in 2012 and 2013 (Figure 7). The maximum air temperature recorded at the Ole Creek station was 26.48°C in 2012 and 25.86°C in 2013 which occurred in July and June, respectively. The coldest recorded temperature was -22.13°C on January 29, 2013. Note that there were a number of erroneous results assumed to be due to wrap around errors which occurred during cold weather in November and December of 2012. These data were removed and may have obscured the coldest temperatures. Air temperature in January and February was extremely variable.

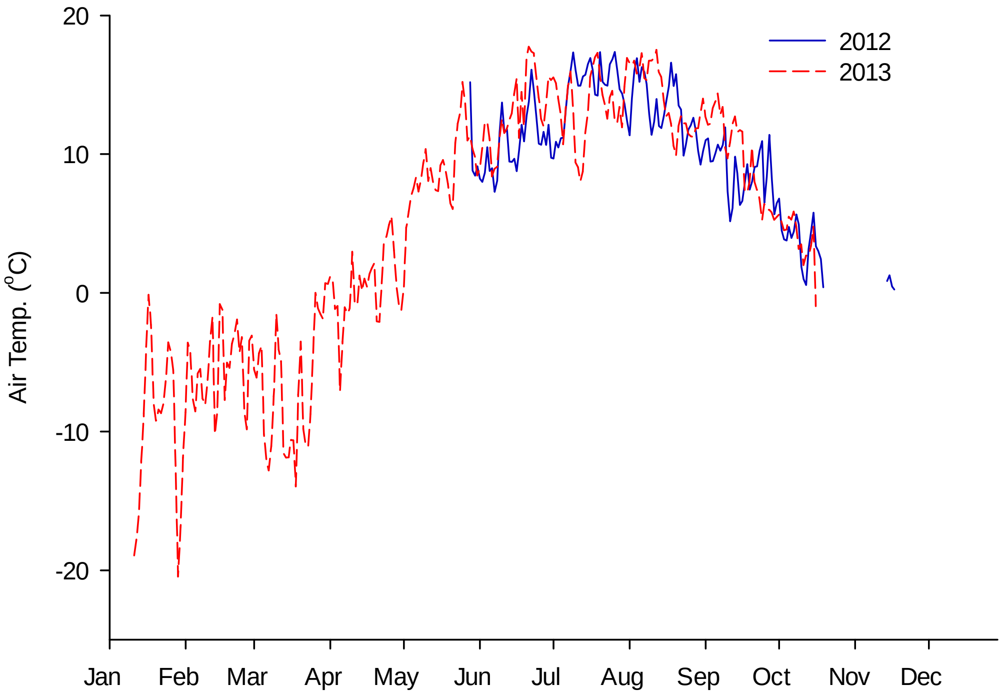

Figure 7: Average daily air temperature recorded at Ole Creek (Station 4780).

Peak water temperatures in Ole Creek occurred in August in 2012 and 2013 (Figure 7). The maximum recorded water temperature was 11.71°C on August 11, 2013. In 2012, the warmest recorded water temperature was 11.00°C on August 20. Some of the coldest recorded temperatures are suspect as they are considerably below freezing. It appears that this probe occasionally perched above the water and therefore the recorded temperature was actually the air temperature just above the water surface. This appears to be the case with the values recorded at the end of November as the water level data for this period was in the negative values. Data from January and February appear to have correctly recorded water temperature; the lowest value recorded was -2.06°C on January 29th.

Water temperature data from the entire deployment (July 2012 to August 2013) of the backup water temperature logger is shown in Appendix D, Figure D3. Appendix D, Figure D4 compares the average daily water temperature recorded by the backup water temperature logger with that recorded by the satellite-transmitting KPSI probe over the same period. Note that during warm water periods the data are in close agreement. Areas where there is some dissimilarity include periods during cold weather where likely the same explanation provided for the Six Mile Creek station applies. Some slight dissimilarity during August of 2012 may also be explained by the depth of the probe. The trends were very similar; however, the temperature recoded by the backup temperature logger, which was deeper than the KPSI probe, was approximately 1°C cooler. Two large increases in water temperature recorded by the KPSI probe near the beginning of May 2013 are difficult to explain (Figure 8).

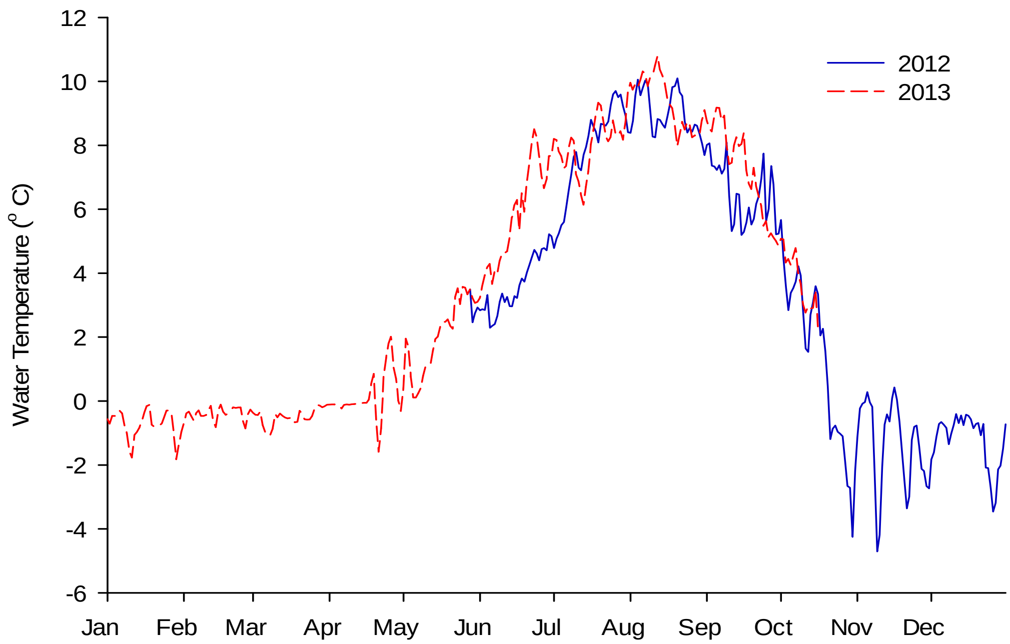

Figure 8: Average daily water temperatures recorded at Ole Creek (Station 4780).

Freshet at the Ole Creek station also appears to occur in early June according to the first two years of water level data (Figure 9). The probe was likely out of the water during periods of very low water; the 'x'-axis in the figure above starts at 0.0 m but the data show a number of values below this indicating an exposed probe. Water temperature should be compared to the water level to ensure that the value is within a period where a depth is recorded by the probe.

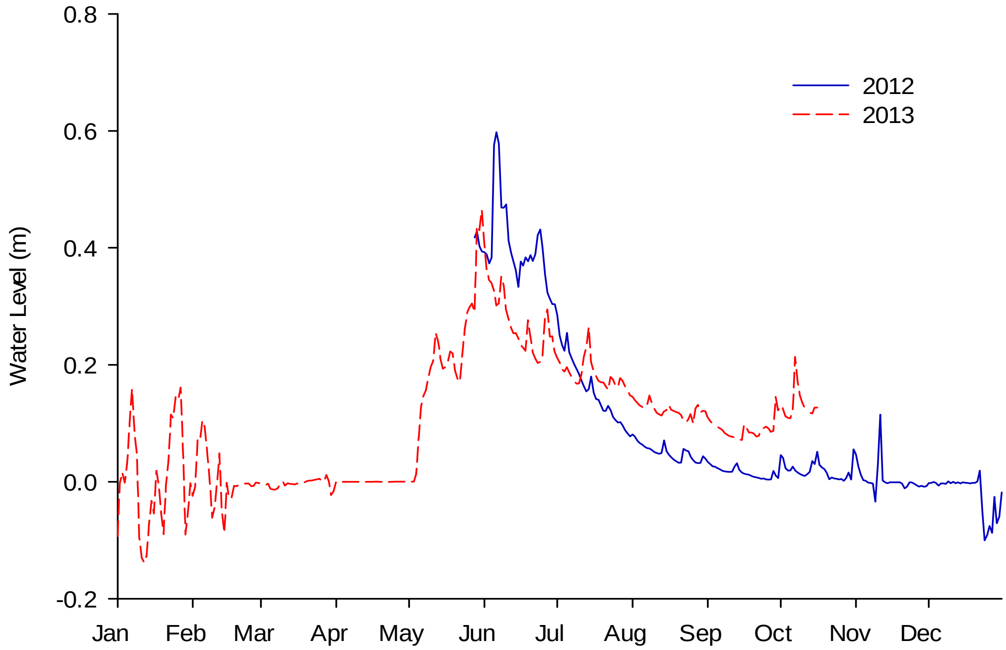

Figure 9: Average daily water level recorded at Ole Creek (Station 4780).

3.1.4 Discharge

Six Mile

Discharge calculated from depth-velocity data at Six Mile Creek was regressed against staff gauge readings and satellite-transmitted water level data (Figure 10). There were three discharge and staff gauge measurements from this stream in 2012, but only two overlapped with the Neon level logger data because of the KPSI probe malfunction. The discharge measurement from May 27, 2012 (during freshet) was not used for the discharge-staff gauge regression because it was an outlier, which may have been due to measurement error. This was not surprising as the final measurement across the thalweg had to be estimated due to very high water not allowing the surveyors to cross the stream safely. In 2013, three discharges were measured: one in each May, June and August.

Additional discharge-water level data points in future years are needed to refine the stage-discharge curve, especially for intermediate discharge levels. A minimum of ten discharge measurement are recommended by the RISC (1999) in order to validate a stage-discharge model. Water level and discharge values used in regressions are provided in Appendix D, Table D2.

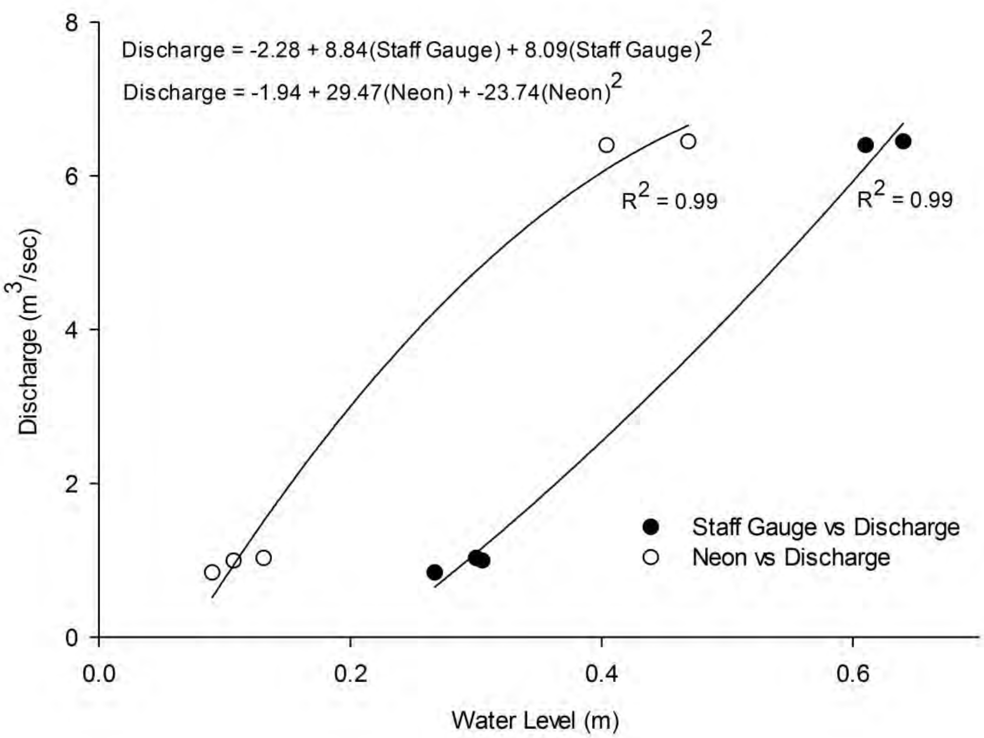

Figure 10: Discharge water level relationship at Six Mile Creek.

Potential error of stream discharge measurements was assessed by conducting replicate measurements. The results of these replicates are provided in Table 8.

Table 8: Analysis of Replicate Discharge Sampling at Six Mile Creek.

Date of Measurements	Total Discharge (m³/s) Replicate		Difference (m³/s)
	1	2	
April 29, 2013	0.866	0.820	0.046
June18, 2013	6.527	6.378	0.149
August 17, 2013	0.982	1.079	0.097
		Mean Difference:	0.098

Ole Creek

Discharge calculated from depth-velocity data at Ole Creek was regressed against staff gauge readings and satellite-transmitted level logger data (Figure 11). There were three discharge and staff gauge measurements from this stream in 2012 and three in 2013. Additional discharge measurements, particularly at intermediate levels, are required to refine the model; this is further discussed in Section 5.0

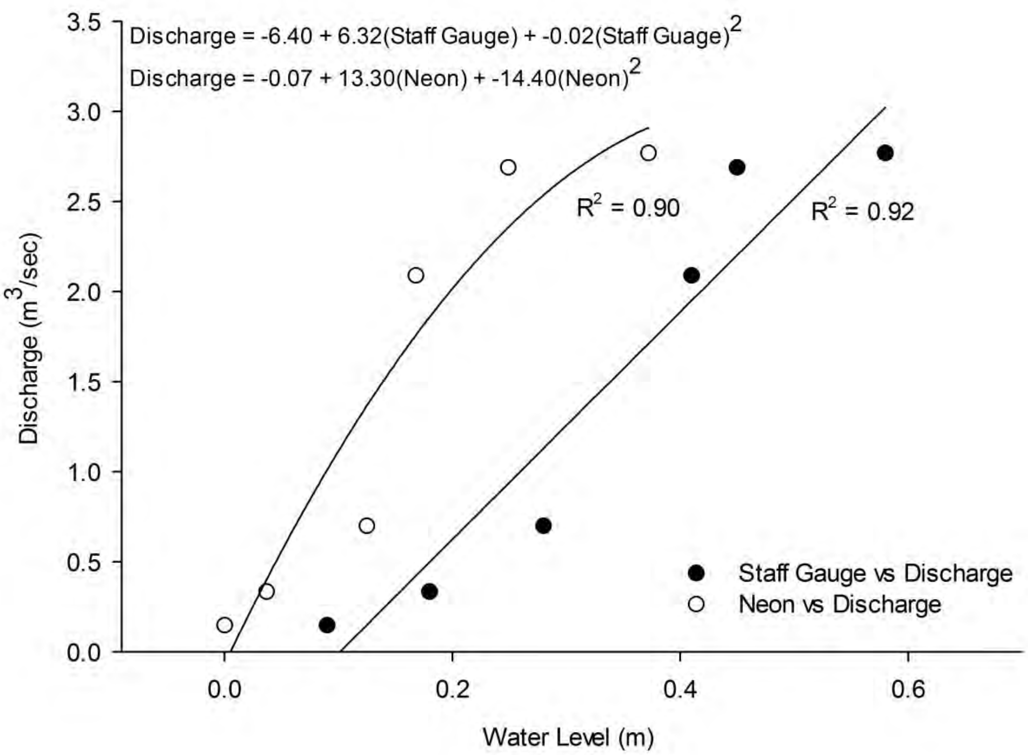

Figure 11: Discharge water level relationship at Ole Creek.

Potential error of stream discharge measurements was assessed by conducting replicate measurements. The results of these replicates are provided in Table 9.

Table 9: Analysis of Replicate Discharge Sampling at Ole Creek.

Date of Measurements	Total Discharge (m^3/s) Replicate		Difference (m^3/s)	Notes
	1	2		
May 27, 2012	2.697	2.844	0.147	
April 30, 2013	0.171	0.125	0.046	1 at Bridge, 2 at Neon
June 20, 2013	2.387	1.796	0.591	
August 27, 2013	0.621	0.788	0.167	
		Mean Difference:	**0.238**	

Regional Stream Discharge

In 2011, before stream gauging stations were installed, a review of available discharge data from other streams in the region was conducted to see if discharge from other streams could help interpret monitoring results from this study. 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 at this location would be somewhat representative of regional conditions. Discharge data from the Nation River in 2011 were compared to the average discharge from the previous 10 years. Nation River discharge in 2011 was below average, which conflicts with what was observed in the tributaries of this monitoring program, particularly at the southern sites, where flows were very high. It may be that the characteristics of the catchment of the Nation River (i.e., size, slope, location) are not representative of the tributaries of this study; therefore, Nation River discharge data were not included or interpreted in this report.

BC Hydro calculates total daily inflow into the reservoir via a mass-balance approach given that the reservoir elevation and total discharge (at W.A.C. Bennett Dam) are known. These data were provided by BC Hydro, and are shown graphically in Figure 12.

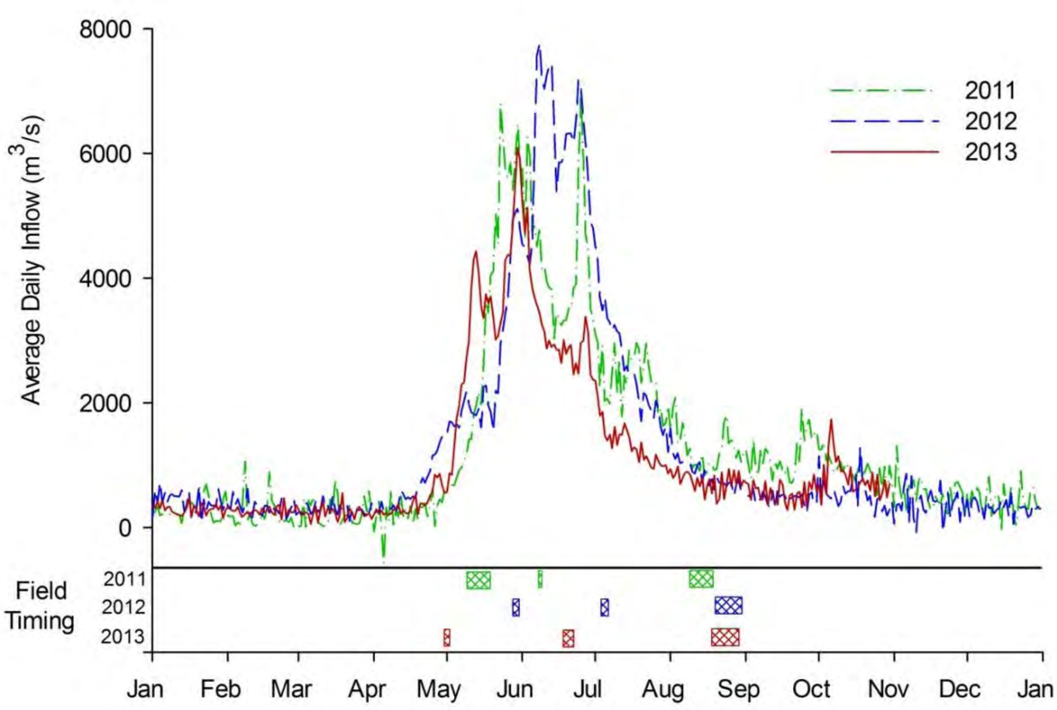

Figure 12: Calculated average daily reservoir inflow based on mass-balance; data provided by BC Hydro.

Generally, the mass balance data provided in Figure 12 corresponds very well to the tributary elevation data provided in Figure 6 and Figure 9. This suggests that the flow regimes of the subject tributaries are similar to regional trends.

3.2 Amphibian Searches

Time-constrained searches for amphibians were conducted during the spring and summer site visits in 2011 but only in spring in 2012 and 2013. CPUE was greater in 2013 than in 2012 and 2011 (Tables 10-12). In 2013, amphibian search effort was constrained to areas where there was a realistic potential for effects to amphibian habitat as a result of the enhancement works; namely, the drawdown zone and near the stream mouths. In previous years (2011 and 2012), amphibian habitat in upstream areas also was evaluated. If water in amphibian habitats is directly connected to a tributary, then increases in fish density could potentially have an adverse effect on amphibian populations through increased predation on aquatic life-stages. Within the lower one kilometre reach of each stream, amphibian habitat with water that was directly connected to the stream channel was not observed.

In 2013, 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, Factor Ross and Ole creeks. Wood frogs were observed at Factor Ross and Ole creeks. Egg-masses of long-toed salamander were observed near Six Mile Creek in 2011. No eggs or other life-stages of long-toed salamander have been observed in other years or tributaries.

CPUE of amphibians was greatest at Ole Creek compared to the other tributaries. The habitat sampled at Ole Creek was adjacent to where the stream enters the reservoir at high reservoir levels (site OA1, Appendix A, Map 3). The site included habitat along the reservoir shoreline where terrestrial vegetation ends and large amounts of LWD typically accumulate at the top of the drawdown zone. This area was sometimes flooded during site visits between 2011 and 2013 when the reservoir level was high but high densities of amphibians (e.g., 12 wood frogs and one western toad in 2013) were found in the terrestrial vegetation near the shoreline during lower reservoir levels.

At Six Mile Creek, most of the amphibian search effort was focused on a wetland located approximately 60 m upstream of the stream mouth at full pool of the reservoir, above the left downstream bank of the stream (site SA2, Appendix A, Map 2). Columbia spotted frog adults and tadpoles were often observed at this site. CPUE of adult amphibians at Six Mile Creek was comparable between 2011 and 2013.

CPUE was lowest at Lamonti Creek compared to the other tributaries. Very little good quality amphibian habitat was observed near the mouth of Lamonti Creek and most of the area searched was very dry. CPUE of amphibians at Factor Ross Creek increased between 2011 and 2013 but the number of amphibians observed was small in all years (Tables 10-13).

Amphibian data from 2013 are provided in Table D3 (Appendix D).

Table 10: Summary of Amphibian Search Effort at Four Williston Reservoir Tributaries in 2013.

Site	Search Effort		# Amphibians Caught/Observed*	Catch per Unit Effort	
	Area (m^2)	Time (min)		(#/Area x100 m)	(#/min)
Six Mile Creek	7500	150	6	0.018	0.040
Lamonti Creek	5600	120	1	0.080	0.008
Factor Ross Creek	1650	120	5	0.303	0.042
Ole Creek	2500	120	13	0.520	0.108

***Not including tadpoles**

Table 11: Summary of Amphibian Search Effort at Four Williston Reservoir Tributaries 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 12: Summary of Amphibian Search Effort at Four Williston Reservoir Tributaries 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**

Table 13: Catch-Per-Unit-Effort (CPUE) of Amphibians at Four Williston Reservoir Tributaries by Year.

Site	CPUE (#/min.)		
	2011	2012	2013
Lamonti Creek	0.01	0.01	0.01
Six Mile Creek	0.01	0.03	0.04
Factor Ross Creek	0.00	0.02	0.04
Ole Creek	0.05	0.02	0.11

***Not including tadpoles**

3.3 Visual Assessment of Tributary Access Blockage

Obvious physical barriers to fish access were not observed within the drawdown zone or near the mouths of any of the tributaries during the spring site visits (April 29 to May 1). Details of the visual assessments at each of the tributaries are given below. In general, the early spring assessments were conducted at very low reservoir elevations and low stream discharge. Visual assessments were also conducted in June during medium to high stream discharge and low to medium reservoir elevations, and in August at low stream discharge and high reservoir elevation (near full pool). There is not any specific concern that reservoir levels during June or August would create a fish access issue given the hydrograph (Figure 3); this was done for comparative purposes to contextualize the tributary mouth conditions over the summer season. Overall, there were no obstructions or stream flows near the stream mouth or in the drawdown zone that would likely impair or prevent fish passage at any of the tributaries during any of the site visits in 2013. Photographs from the reference locations in 2013 and additional photographs showing habitat near the stream mouth and drawdown zone are shown in Appendix D (Photos 13 to 45).

Six Mile Creek

During the May 1, 2013 site visit, there were no physical barriers to fish passage (Appendix B, Photograph 13). The channel was only slightly braided but appeared unstable as the banks were composed of fine materials that were continuously eroding (Appendix B, Photograph 16). The stream length through the drawdown zone was 650 m during this site visit (i.e., the distance from the end of the confined stream channel with vegetated banks to the reservoir level). Cover was minimal in the drawdown zone but did exist in the form of a few scattered pools (generally between 0.5 m and 0.8 m deep). The morphology is dominated by a long riffle with no cover or velocity relief. No fish were observed within the drawdown zone.

On the June 18, 2013 site visit, there were no physical barriers to fish passage (Appendix B, Photograph 14). The stream near the mouth consisted of a single channel considered to be suitable depth (>10 cm) and velocity for fish passage. The stream length through the drawdown zone was approximately 100 m during this site visit. No fish were observed.

During the August 17, 2013 assessment, there were no physical barriers to fish passage (Appendix B, Photograph 15). The reservoir level was high enough that the drawdown zone was inundated. The stream channel near the mouth had adequate depth and suitable velocity for fish passage and was free of obstructions that could impair fish passage. No fish were observed in the stream near the mouth. Fish habitat near the mouth of the stream is depicted in Appendix B, photographs 13 to 20.

Lamonti Creek

During the May 1, 2013 site visit there were no physical barriers to fish passage (Appendix B, Photograph 21). The stream length through the drawdown zone was approximately 530 m and the substrate was composed of fines with scattered gravels and cobbles. Cover was limited and was provided by a very few scattered woody debris pieces (Appendix B, Photograph 24). No pools large enough to provide cover and/or velocity relief were noted along this section. Two fish (a sculpin and a juvenile salmonid) were observed trapped in an isolated pool at the mouth of Lamonti Creek.

During the June 17, 2013 site visit, there were no physical barriers to fish passage (Appendix B, photographs 22 and 26). There were two channels in the stream near the mouth, but both channels were of sufficient depth (>10 cm) and suitable velocity for passage of salmonids. There was no woody debris in the channel that would impair fish passage. No fish were observed.

During the August 19, 2013 site visit, there were no physical barriers to fish passage (Appendix B, Photograph 23). The stream near the mouth consisted of a single channel that was considered to be suitable depth (>10 cm) and velocity for fish passage, and there was no woody debris in the channel that would impair fish passage. No fish were observed.

During the May 1, 2013 site visit, reservoir levels were very low and it was noted that Lamonti Creek flows into Six Mile Creek before reaching the reservoir (Appendix B, Photograph 25). This had not previously been observed because when more of the drawdown zone is inundated, the confluence is flooded and the streams each join the reservoir independently. The confluence is located downstream of the area on Six Mile Creek that is planned for enhancement and therefore does not affect the suitability of Lamonti as a control site for the monitoring program. However, if stream conditions change and any blockages form downstream of the confluence during low reservoir levels, fish access to both Lamonti and Six Mile would be affected. For this reason, it is important to monitor stream conditions and passability downstream of the confluence at times when reservoir levels are low enough to expose the confluence during the spring migration period.

Ole Creek

During the April 30, 2013 site visit, there were no physical barriers to fish passage. Though no obvious physical barriers were noted, and none are assumed, a portion of the channel (at the creek mouth) was obscured by snow and ice at the time of the survey and was therefore not assessed (Appendix B, Photograph 29). Flow across the drawdown zone consisted of a channel dominated by sand with scattered gravels and cobbles. The stream length through the drawdown zone was approximately 150 m and steeper gradient than at Six Mile and Lamonti creeks. It appeared that there may have been multiple channels; however, all but one was still obscured by ice (Appendix B, Photograph 36). Cover was extremely limited through the observable section and was made up by very few scattered large cobbles and small boulders as well as some woody debris (Appendix B, Photograph 37). No deep pools were noted.

During the June 20, 2013 site visit, there were no physical barriers to fish passage. There was some large woody debris in a corner near the stream mouth but most of the channel was unobstructed (Appendix B Photo 34,) and most of the wood was on the stream bank or reservoir shoreline. The stream near the mouth consisted of a single channel of suitable depth (>10 cm) and velocity for fish passage.

During the August 23, 2013 site visit there were no physical barriers to fish passage. The stream near the mouth consisted of a single channel were considered to be suitable depth (>15 cm) and velocity for fish passage. There was very little woody debris in the stream channel. Both banks were covered in large amounts of large woody debris but all the wood was clear of the water and not overhanging so woody debris did not affect passage or provide cover.

Factor Ross Creek

During the April 30, 2013 site visit, there were no physical barriers to fish passage at the mouth or in the drawdown zone (Appendix B, Photograph 38). A complete assessment was not possible because the bay was obscured by ice. A considerable amount of woody debris was noted at the stream mouth but water appeared to have adequate depth beneath the debris jam to allow for fish passage. The stream length through the drawdown zone was approximately 250 m of shallow riffle habitat with little or no cover. The substrate consisted primarily of fine sandy substrate with scattered cobbles.

During the June 19, 2013 site visit, there were no physical barriers to fish passage. There was a large amount of large woody debris on the stream bank and the shoreline of the reservoir but almost no wood in the stream channel near the mouth or floating in the bay of the reservoir nearby (Appendix B, photographs 39 and 41). The stream near the mouth consisted of a single channel of suitable depth (>10 cm) and velocity for fish passage.

During the August 25, 2013 site visit, there were no physical barriers to fish passage (Appendix B, Photograph 40). There was very little woody debris in the stream channel near the mouth. There was a small amount of wood floating in the bay and on the stream bank. The stream near the mouth consisted of a single channel considered to be suitable depth (>20 cm) and velocity for fish passage.

3.4 Spawner Surveys

Stream lengths assessed during the spawner surveys conducted June 17 to 20, 2013 were 1.9 km for Six Mile Creek, 1.4 km for Lamonti Creek, 1.9 km for Ole Creek, and 1.2 km for Factor Ross Creek. Redds or spawners were not observed in any of the four tributaries in 2013. Visibility was <3.0 m in three of four tributaries (Table 14), and the turbidity and relatively high discharge likely reduced the observers' ability to see fish. Only Lamonti Creek had water that was clear enough to see >3.0 m. Water temperatures measured with an alcohol thermometer during the spawner surveys ranged from 6.0 to 8.0°C (Table 14), which agrees with measurements from the stream gauging stations (Section 3.1).

Snorkelling was conducted at select locations during the spawner surveys, especially in pools where it was safe to snorkel and where spawners could be holding or resting while migrating upstream. Very few fish were observed while snorkelling during the spawner surveys (Appendix D, Table D4). In Six Mile Creek, one Mountain Whitefish (estimated fork length 22 cm) was observed. At Lamonti Creek, the only fish observed while snorkelling was a Bull Trout (estimated fork length 15 cm). In Ole Creek, one juvenile Rainbow Trout and one sculpin (*Cottus* sp.) were observed while snorkelling. Snorkelling was not conducted in Factor Ross Creek during the spawner surveys because of very turbid water and poor visibility. Underwater visibility was not measured on Factor Ross Creek because snorkelling was not conducted but visibility was estimated to be less than 1.0 m.

The locations and spatial areas of suitable spawning gravels within the surveyed sections of each stream are provided in Appendix D, Table D5. In general, there was very little suitable spawning gravel in the assessed reaches of the tributaries: Six Mile Creek (43.0 m^2 total), Lamonti Creek (11.0 m^2 total), Factor Ross Creek (11.25 m^2 total), and Ole Creek (4.75 m^2 total).

Table 14: Summary of spring 2013 spawner survey in Williston Reservoir study tributaries.

Tributary	Date Surveyed	Approximate Stream Length Surveyed (km)	Water Temperature (°C)	Snorkelling Visibility (m)
Lamonti	June 17, 2013	1.4	8.0	>3.00
Six Mile	June 18, 2013	1.9	7.0	2.70
Factor Ross	June 19, 2013	1.2	6.0 – 7.0	Not measured (<1.0)
Ole	June 20, 2013	1.9	6.0	2.65

3.5 Juvenile and Small-Bodied Fish Survey

Catches of fish by electrofishing were low for most species in all four streams. Less than seven individuals large enough to tag of each species were caught in all streams (Table 15). Abundance estimates from the Bayesian model were larger than Petersen estimates, and had narrower confidence intervals in all cases (Table 16). For two 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 Ole 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. 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 to validate the method and provide the context of other fish populations when interpreting changes before and after enhancement.

Table 15: Mark-resight Data used for Fish Abundance Estimates for four Williston Reservoir Tributaries in 2013.

Stream	Species	1st Sample (Electrofishing)	2nd Sample (Snorkelling)		
		M	u	m	n
Six Mile	Bull Trout	2	4	1	5
Lamonti	Bull Trout	1	16	1	17
Lamonti	Rainbow Trout	2	13	1	14
Ole	Bull Trout	6	36	0	36
Factor Ross	Mountain Whitefish	1	83	1	84
Factor Ross	Bull Trout	5	14	0	14

Key: M = 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

Table 16: Bayesian Population Estimates from Mark-resight Data Compared to Traditional Petersen Mark-recapture Estimates and Snorkelling Observations in 2013.

Stream	Species	Bayesian Estimate				Snorkelling Obs.		Traditional Petersen			
		Mean	LCI	UCI	Mean/100m²	#	#/100m²	Mean	LCI	UCI	Mean/100m²
Six Mile	Bull Trout	27.5	6.4	117.9	4.0	5	0.7	10	3	195	1.4
Lamonti	Bull Trout	41.1	17.4	116.1	7.3	17	3.0	17	3	671	3.0
Lamonti	Rainbow Trout	52.1	17.0	158.0	9.3	14	2.5	28	5	1106	5.0
Ole	Bull Trout	97.2	44.1	221.8	18.1	36	6.7	n/a	n/a	n/a	n/a
Factor Ross	Mountain Whitefish	120.3	85.4	208.8	34.5	84	24.1	84	15	3318	24.1
Factor Ross	Bull Trout	71.8	20.0	224.5	20.6	14	4.0	n/a	n/a	n/a	n/a

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

The same mark-resight method was used in 2012 and 2013 so that data from these years are comparable and provide two years of data prior to habitat enhancements. The different sampling methods for fish population abundance in 2011 make it difficult to compare the results to subsequent years. In 2011, two or 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. In 2011 the sampling sites included the entire stream width and all habitat types, whereas sampling in 2012 and 2013 included only pools and low-velocity habitats. Thus, catch per unit effort in fish per unit area ($\#/m^2$) is available for all years, but the difference in habitats makes these measures unsuitable to compare overall abundance in the streams between 2011 and 2012-2013.

In 2013, all marked fish that were observed during snorkelling were found at the same site where they were captured and released. In 2012, all marked fish that were observed were located in the same site where they were tagged and released for Six Mile, Ole and Factor Ross creeks. In Lamonti Creek in 2012, 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. Overall, observations of marked fish in 2012 and 2013 indicate very little movement of fish among sites after tagging and release. Fish that had previously been tagged in 2012 were not re-captured by electrofishing or observed snorkel surveying during 2013.

Bayesian population estimates varied for most species-stream groups between 2012 and 2013 (Table 17). With small numbers of marked fish and resighted fish, small differences in numbers can have large effects on capture probabilities and population estimates. Capture efficiencies varied between 2012 and 2013 but were comparable in most cases (Table 18).

All the sculpin captured in 2011 to 2013 were identified as Prickly Sculpin *(Cottus asper)*. Although Slimy Sculpin (*Cottus cognatus*) are also known to occur in some watersheds surrounding Williston Reservoir, none have been observed in the four study tributaries during this monitoring program. Because it was not possible to reliably identify sculpin to the species level for fish that were observed but not captured while electrofishing and snorkelling, all sculpin are grouped together as in the summaries below; however, it is likely that most, if not all, of the sculpin observed were Prickly Sculpin.

Table 17: Comparison of Bayesian Population Estimates Based on Mark-Resight Data for Four Williston Reservoir Tributaries in 2012 and 2013.

Stream	Species	2012				2013			
		Mean	LCI	UCI	Mean/100m²	Mean	LCI	UCI	Mean/100m²
Six Mile	Bull Trout	n/a	n/a	n/a	n/a	27.5	6.4	117.9	4.0
Six Mile	Rainbow Trout	28.3	20.2	55.6	10.1	n/a	n/a	n/a	n/a
Lamonti	Bull Trout	22.3	7.2	81.8	11.0	41.1	17.4	116.1	7.3
Lamonti	Rainbow Trout	10.0	5.1	33.9	4.9	52.1	17.0	158.0	9.3
Ole	Bull Trout	123.9	65.7	221.2	32.5	97.2	44.1	221.8	18.1
Factor Ross	Mountain Whitefish	n/a	n/a	n/a	n/a	120.3	85.4	208.8	34.5
Factor Ross	Bull Trout	59.1	14.5	179.2	14.6	71.8	20.0	224.5	20.6

Table 18: Comparison of Estimated Capture Probabilities from Bayesian Mark-Resight Model for Four Williston Reservoir Tributaries in 2012 and 2013.

Stream	Species	Estimated Capture Probability	
		2012	2013
Six Mile	Bull Trout	n/a	0.34
Six Mile	Rainbow Trout	0.74	n/a
Lamonti	Bull Trout	0.49	0.54
Lamonti	Rainbow Trout	0.61	0.39
Ole	Bull Trout	0.31	0.49
Factor Ross	Mountain Whitefish	n/a	0.74
Factor Ross	Bull Trout	0.36	0.37

Six Mile Creek

In 2013, fish caught or observed in Six Mile Creek by backpack electrofishing or snorkelling included Bull Trout, Mountain Whitefish, Rainbow Trout and sculpin (Tables 19 and 20). Sculpin sp. comprised the greatest proportion of the electrofishing catch, followed by Rainbow Trout and Bull Trout. Rainbow Trout, however, comprised the vast majority of the fish observed during the snorkel survey, a trend that was also observed in 2012.

The abundance estimate for Bull Trout in Six Mile Creek was 27.5 (credibility interval [CI]: 6.4-117.9). This abundance estimate corresponded to a density of 4.0 fish/100 m² in the pool and low velocity habitats sampled. Although Rainbow Trout were the target species, abundance was not estimated for this species in Six Mile Creek in 2013 because of insufficient data. CPUE of Rainbow Trout while snorkelling was greater in 2012 (7.1 fish/100 m²) than in 2013 (4.2 fish/100 m²). The same species were caught or observed in Six Mile

Creek in 2012 and 2013 with the exception that Burbot (*Lota lota*) were only captured and observed in 2012 and not in 2013.

During the night-time fry survey on Six Mile Creek, habitat was searched at 10 sites, which totaled a stream length of 89.5 m. At all sites combined, 38 Rainbow Trout fry were observed and the CPUE was 0.42 fry/m. One Bull Trout fry (CPUE: 0.01 fry/m) and one sculpin (CPUE: 0.01 fish/m) were observed. In addition, one 70-mm Rainbow Trout and one 90-mm Bull Trout were also observed but were assumed to be older than age-0 and were not included in the CPUEs. Fry survey data are provided in Appendix D, Table D6.

Table 19: Catch-Per-Unit-Effort (CPUE) during Electrofishing in Six Mile Creek in 2012 and 2013.

Species	2012					2013				
	# Caught	# Obs.	# Caught + Obs.	CPUE (#/sec)	CPUE (#/100m²)	# Caught	# Obs.	# Caught + Obs.	CPUE (#/sec)	CPUE (#/100m²)
Arctic Grayling	0	0	0	0	n/a	0	0	0	0.0000	0.0000
Bull Trout	4	0	4	0.0019	n/a	2	0	2	0.0010	0.2773
Burbot	2	0	2	0.0009	n/a	0	0	0	0.0000	0.0000
Kokanee	0	0	0	0	n/a	0	0	0	0.0000	0.0000
Mountain Whitefish	0	0	0	0	n/a	0	0	0	0.0000	0.0000
Rainbow Trout	2	0	2	0.0009	n/a	2	2	4	0.0019	0.5546
Sculpin sp.	6	6	12	0.0056	n/a	3	3	6	0.0029	0.8319

Notes: Obs.= Fish observed but not captured; the area (m²) sampled by electrofishing was not measured at Six Mile Creek in 2012.

Table 20: Catch-Per-Unit-Effort (CPUE) during Snorkel Surveys in Six Mile Creek in 2012 and 2013.

Species	2012		2013	
	#	CPUE (#/100m²)	#	CPUE (#/100m²)
Arctic Grayling	0	0.0	0	0.0
Bull Trout	0	0.0	5	0.7
Burbot	0	0.0	0	0.0
Kokanee	0	0.0	0	0.0
Mountain Whitefish	0*	0.0	11	1.6
Rainbow Trout	20	7.1	29	4.2
Sculpin sp.	1*	0.4	5	0.7

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

Lamonti Creek

In both 2012 and 2013, fish species caught or observed in Lamonti Creek by backpack electrofishing or snorkelling were Bull Trout, Rainbow Trout, and Sculpin sp. (Tables 21 and 22). Mountain Whitefish were caught by electrofishing in 2011 (Golder 2012) but were not caught or observed in 2012 or 2013. The number of Rainbow Trout and Bull Trout observed during snorkel surveys was greater in 2013 than in 2012, but the CPUE for these species were nearly identical because a greater number of sites was surveyed in 2013 than in 2012 (Table 22).

The abundance estimate for Bull Trout in Lamonti Creek was 41.1 (credibility interval [CI]: 17.4-116.1). This abundance estimate corresponded to a density of 7.3 fish/100 m² in the pool and low velocity habitats sampled. The estimated density of Bull Trout was greater in 2012 (11.0 fish/100 m²) than in 2013 (7.3 fish/100 m²).

The abundance estimate for Rainbow Trout in Lamonti Creek was 52.1 (credibility interval [CI]: 17.0-158.0). This abundance estimate corresponded to a density of 9.3 fish/100 m² in the pool and low velocity habitats sampled. The estimated density of Rainbow Trout was greater in 2013 (9.3 fish/100 m²) than in 2012 (4.9 fish/100 m²).

During the night-time fry survey on Lamonti Creek, habitat was searched at 28 sites, which totalled a stream length of 140.0 m. At all sites combined, 10 Rainbow Trout fry were observed and the CPUE was 0.07 fry/m. Six sculpin were observed and the CPUE was 0.04 fish/m. Bull Trout fry were not observed during the fry survey on Lamonti Creek.

Table 21: Catch-Per-Unit-Effort (CPUE) during Electrofishing in Lamonti Creek in 2012 and 2013.

Species	2012					2013				
	# Caught	# Obs.	# Caught + Obs.	CPUE (#/sec)	CPUE (#/100m²)	# Caught	# Obs.	# Caught + Obs.	CPUE (#/sec)	CPUE (#/100m²)
Arctic Grayling	0	0	0	0.0000	0.00	0	0	0	0.0000	0.0000
Bull Trout	1	0	1	0.0009	0.28	1	0	1	0.0005	0.1783
Burbot	0	0	0	0.0000	0.00	0	0	0	0.0000	0.0000
Kokanee	0	0	0	0.0000	0.00	0	0	0	0.0000	0.0000
Mountain Whitefish	0	0	0	0.0000	0.00	0	0	0	0.0000	0.0000
Rainbow Trout	2	1	3	0.0027	0.85	2	1	3	0.0014	0.5348
Sculpin sp.	1	2	3	0.0027	0.85	3	1	4	0.0018	0.7130

Notes: Obs.= Fish observed but not captured

Table 22: Catch-Per-Unit-Effort (CPUE) during Snorkel Surveys in Lamonti Creek in 2012 and 2013.

Species	2012		2013	
	#	CPUE (#/100m²)	#	CPUE (#/100m²)
Arctic Grayling	0	0.0	0	0.0
Bull Trout	7	3.4	17	3.0
Burbot	0	0.0	0	0.0
Kokanee	0	0.0	0	0.0
Mountain Whitefish	0	0.0	0	0.0
Rainbow Trout	5	2.5	14	2.5
Sculpin sp.	0	0.0	1	0.2

Ole Creek

Fish species observed in Ole Creek by backpack electrofishing or snorkelling were Bull Trout, Mountain Whitefish, Rainbow Trout, and sculpin (Tables 23 and 24). The species of fish caught and CPUEs while electrofishing and snorkelling in Ole Creek were similar in 2012 and 2013. In both years, most fish observed were Bull Trout, with smaller numbers of Mountain Whitefish, Rainbow Trout, and sculpin. In 2013, two large Bull Trout (~50 cm) with spawning colouration were incidentally observed while walking upstream during the spawner survey, and another large Bull Trout (~40 cm) was observed while electrofishing. In addition, two large Kokanee (>30 cm) were incidentally observed while walking upstream during the electrofishing survey. Kokanee were also observed in 2012 and large Bull Trout spawners were previously observed in Ole Creek in 2011 (Golder 2012, 2013a).

The abundance estimate for Bull Trout in Ole Creek was 97.2 (credibility interval [CI]: 44.1-221.8). This abundance estimate corresponded to a density of 18.1 fish/100 m² in the pool and low velocity habitats sampled, which was less than the estimated density in 2012 (32.5 fish/100 m²). Abundance was not estimated for any other species because sample sizes were too small.

During the night-time fry survey on Ole Creek, habitat was searched at 24 sites, which totaled a stream length of 81.5 m. At all sites combined, one Rainbow Trout fry was observed and the CPUE was 0.01 fry/m. Bull Trout fry were not observed during the fry survey but one larger Bull Trout (estimated ~80 mm) was observed. Sculpin were not observed during the fry survey on Ole Creek.

Table 23: Catch-Per-Unit-Effort (CPUE) during Electrofishing in Ole Creek in 2012 and 2013.

Species	2012					2013				
	# Caught	# Obs.	# Caught + Obs.	CPUE (#/sec)	CPUE (#/100m²)	# Caught	# Obs.	# Caught + Obs.	CPUE (#/sec)	CPUE (#/100m²)
Arctic Grayling	0	0	0	0.0000	0.00	0	0	0	0.0000	0.0000
Bull Trout	13	3	16	0.0091	4.20	6	2*	8	0.0025	1.3658
Burbot	0	0	0	0.0000	0.00	0	0	0	0.0000	0.00
Kokanee	0	1	1	0.0006	0.26	0	0*	0	0.0000	0.0000
Mountain Whitefish	0	0	0	0.0000	0.0000	1	1	2	0.0006	0.3414
Rainbow Trout	1	1	2	0.0011	0.52	0	0	0	0.0000	0.0000
Sculpin sp.	2	2	4	0.0023	1.05	0	0	0	0.0000	0.0000

Notes: Obs.= Fish observed but not captured; * = two large Kokanee (>30 cm) and one large Bull trout (~40 cm) were observed in the stream while conducting electrofishing but as these fish were not within sampled sites they are not included in the CPUE.

Table 24: Catch-Per-Unit-Effort (CPUE) during Snorkel Surveys in Ole Creek in 2012 and 2013.

Species	2012		2013	
	#	CPUE (#/100m²)	#	CPUE (#/100m²)
Arctic Grayling	0	0.0	0	0.0
Bull Trout	31	8.1	36*	6.7
Burbot	0	0.0	0	0.0
Kokanee	0	0.0	0	0.0
Mountain Whitefish	4	1.0	2	0.4
Rainbow Trout	2	0.5	2	0.4
Sculpin sp.	0	0.0	1	0.2

Notes: * = Two large Bull Trout (~50 cm) with spawning colouration were observed holding in the current while conducting the snorkel survey but as these fish were not within sampled sites they are not included in the CPUE.

Factor Ross Creek

Arctic Grayling, Bull Trout, Mountain Whitefish, Rainbow Trout, and sculpin were caught or observed in Factor Ross Creek during electrofishing and snorkelling (Tables 25 and 26). Heavy rains prior to the August 27, 2013 snorkel survey on Factor Ross Creek resulted in high discharge, turbid water, and low visibility, which could have affected CPUE. CPUE of Bull Trout was greater in 2013 than in 2012 for electrofishing (3.44 vs. 0.74 fish/100 m² respectively) and snorkelling (4.0 vs. 2.7 fish/100 m² respectively). Mountain Whitefish were the species most frequently observed while snorkelling in both 2012 and 2013, but CPUE of Mountain Whitefish was more than twice as large in 2013, which could have been related to the very high stream discharge during the survey. The very large number (84) of Mountain Whitefish was likely related to high stream flows caused by heavy rain on August 27. Mountain Whitefish appear to have been displaced from holding areas by very fast stream flow, and were observed in large numbers swimming wherever the current was slowest, despite the increased turbidity which reduced visibility. Catch and species diversity in 2012 and 2013 were much higher than in 2011, when only sculpin and Mountain Whitefish were caught (Golder 2012). Two Kokanee were captured near the stream mouth by electrofishing in Factor Ross Creek in 2012 but none were captured or observed in 2013.

CPUE of Rainbow Trout in Factor Ross Creek was low (<1 fish/100 m² for electrofishing and snorkelling) in both 2012 and 2013. In both years, small sample sizes did not allow estimates of abundance using the Bayesian mark-resight model.

Of the four study tributaries, Factor Ross Creek is the only one where Arctic Grayling have been observed in the three years of this study (2011-2013). CPUE of Arctic Grayling was very low (<0.4 fish/100 m²) in 2012 and 2013 and small sample sizes did not allow estimates of abundance using the Bayesian mark-resight model.

The abundance estimate for Bull Trout in Ole Creek was 71.8 (CI: 20.0-224.5). This abundance estimate corresponded to a density of 20.6 fish/100 m² in the pool and low velocity habitats sampled, which was greater than the estimated density in 2012 (14.6 fish/100 m²).

The abundance estimate for Mountain Whitefish in Ole Creek was 120.3 (CI: 85.4-208.8). This abundance estimate corresponded to a density of 34.5 fish/100 m² in the pool and low velocity habitats sampled. Mountain Whitefish abundance and density were not estimated in 2012 because of insufficient recaptures.

During the night-time fry survey on Factor Ross Creek, habitat was searched at 17 sites, which totalled a stream length of about 50 m. No fry or other life-stages were observed during the survey. During one of the two nights of fry surveys on Factor Ross Creek, flows were very high and turbid due to rainfall, which likely affected observer efficiency and habitat suitability at most sites.

Table 25: Catch-Per-Unit-Effort (CPUE) during Electrofishing in Factor Ross Creek in 2012 and 2013.

Species	2012					2013				
	# Caught	# Obs.	# Caught + Obs.	CPUE (#/sec)	CPUE (#/100m²)	# Caught	# Obs.	# Caught + Obs.	CPUE (#/sec)	CPUE (#/100m²)
Arctic Grayling	1	2	3	0.0024	0.56	0	0	0	0.0000	0.00
Bull Trout	3	1	4	0.0033	0.74	7	5	12	0.0057	3.44
Burbot	0	0	0	0.0000	0.00	0	0	0	0.0000	0.00
Kokanee	2	0	2	0.0016	0.37	0	0	0	0.0000	0.00
Mountain Whitefish	0	0	0	0.0000	0.00	1	0	1	0.0005	0.29
Rainbow Trout	0	0	0	0.0000	0.00	0	0	0	0.0000	0.00
Sculpin sp.	3	0	3	0.0024	0.56	3	0	3	0.0014	0.86

Table 26: Catch-Per-Unit-Effort (CPUE) during Snorkel Surveys in Factor Ross Creek in 2012 and 2013.

Species	2012		2013	
	#	CPUE (#/100m²)	#	CPUE (#/100m²)
Arctic Grayling	1	0.2	1	0.3
Bull Trout	11	2.7	14	4.0
Burbot	0	0.0	0	0.0
Kokanee	0	0.0	0	0.0
Mountain Whitefish	42	10.4	84	24.1
Rainbow Trout	1	0.2	3	0.9
Sculpin sp.	1	0.2	1	0.3

4.0 DISCUSSION

4.1 Climate and Physical Habitat Data

The satellite-transmitting stream level and temperature logging stations on Six Mile and Ole creeks provide important data and context to help interpret changes in amphibian and fish ecology over time. Temperature and discharge can be used in future years to help plan the timing of spawner and fish abundance surveys.

For both Six Mile and Ole creeks, discharge during the spring spawning period (May and June) was much greater in 2012 than in 2013. Anecdotally, discharges were also very high in 2011 but the stream discharge gauging stations were not yet installed at that time. During the late-summer period when the mark-resight fish population surveys were completed, discharge was slightly greater in 2013 than in 2012 for Six Mile and Ole creeks. The smaller snowpack in 2013 than in 2012 resulted in lower peak discharges in 2013, but more gradual snow melt likely resulted in higher late-summer flows in 2013 than in 2012. Although there was some difference in late-summer discharge among years, all years likely represent discharges within the typical range of variability in late-summer conditions, based on observed flows during sampling compared to the size and shape of the stream channel.

Water temperature in Six Mile Creek was warmer in 2013 than in 2012, which was likely related to the larger snowpack and higher discharge in 2012. In Ole Creek, water temperature was similar in 2012 and 2013. Water temperature in both streams had annual peaks in daily average temperatures of less than 12°C, which occurred in July or August. The streams are cold, barely reaching the ideal water temperature range (7 to 18°C) for cool-water fish species such as Rainbow Trout during summer (McPhail 2007). In addition, water temperature in these small streams can fluctuate rapidly depending on weather, which has implications for temperature-dependent life-history processes such as spawning and incubation, as well as growth and survival of juvenile fishes.

Williston Reservoir elevation was greater than the historical (1973-2011) average in 2011 and 2012 and lower than historical average in 2013. Reservoir elevations are likely influenced by snowpack, weather, and tributary discharges, as well as hydropower operations. Reservoir elevation, in combination with tributary discharge, likely has an important impact on tributary accessibility for adfluvial fish as it affects the size of drawn down area, the nature of the stream in the drawdown zone, and potential debris blockages at the mouth. Reservoir level will also be an important co-variate to consider when interpreting changes in amphibians before and after habitat enhancements, as potential amphibian habitats (including sites sampled during this study) may be flooded, near the reservoir, or a large distance away from water, depending on the reservoir elevation.

4.2 Amphibians

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 drawdown 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).

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, but it may be rainfall, fed by sub-surface flow from 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. 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. High densities of Columbia spotted frogs (adults and tadpoles) in the wetland near the mouth of Six Mile Creek (site SA2) suggest that this area provides good amphibian habitat but the proposed habitat enhancements (KWL 2011) are unlikely to affect this area.

Habitat near the stream mouth and reservoir shoreline at Ole Creek (site OA1) appears to have relatively high densities of amphibians (wood frogs and western toads), which should be considered when implementing habitat enhancements. Woody debris at the Ole Creek mouth may provide cover for amphibians. Enhancement works designed to limit or remove woody accumulation in the bay could therefore reduce the quality of amphibian habitat.

4.3 Spawner Surveys and Tributary Access

In the three years of the monitoring study (2011-2013), redds have not been observed on any of the four tributaries and only one Rainbow Trout spawner has been observed during the spring surveys (Six Mile Creek in 2012). Rainbow Trout fry (age-0) or parr (age-1+) were present in all four study tributaries, suggesting spawning by this species. Based on fry surveys, the density of Rainbow Trout fry was highest in Six Mile Creek (0.42 fry/m), followed by Lamonti Creek (0.07 fry/m). The density of Rainbow Trout fry and juveniles during fry surveys in Ole Creek (one fry observed) and Factor Ross Creek (one juvenile observed) was much lower than in Six Mile and Lamonti creeks. Although Arctic Grayling were not observed in the study tributaries during the spring spawner surveys between 2011 and 2013, Arctic Grayling that potentially were adults based on size were observed or caught in Factor Ross Creek in 2012 and 2013. It is unknown whether Arctic Grayling spawned in

Factor Ross Creek during this study, and whether the individuals observed represent a stream-resident or adfluvial population. Arctic Grayling would be expected to spawn at water temperatures near 4°C, which could be in May or June in the study creeks, based on the temperature logging information.

Spring-spawning Rainbow Trout and Arctic Grayling were the target species for spawner surveys and habitat enhancements. However, the results also suggest use of the study tributaries by fall spawning species. Young-of-the-year and/or juvenile Bull Trout were present in all four tributaries. Observations of large adults (>40 cm), some with spawning colouration, in Ole and Factor Ross creeks in 2011 and 2013 provide further evidence of spawning by Bull Trout in these streams. These large Bull Trout were likely spawners from an adfluvial population because it is unlikely that stream-resident fish would be that large. Although no young-of-the-year Mountain Whitefish or obvious spawners of this species were observed in the study tributaries, the large number of juveniles, which were likely age-1 and age-2 fish based on size, indicate that this species also spawns in Six Mile, Ole, and Factor Ross creeks. Large Kokanee in spawning colouration were observed in Ole Creek in 2012 and 2013, and were captured while holding in the stream near the mouth of Factor Ross Creek in 2012. These observations raise the possibility that Kokanee may be spawning in the two northern study creeks. Kokanee spawn in the fall, usually when water temperature drop below 12°C; migration can start as early as late July (McPhail 2007). In Williston Reservoir, stocked Kokanee in the Parsnip and Peace reaches are thought to spawn in September whereas Kokanee in the Finlay River likely spawn in October to November (Langston and Zemlack 1998).

Any impediments to tributary access for fish, such as perched mouths and debris blockages, would most likely be a problem in the early spring (April and May) when the reservoir level and stream levels are both very low but also when water temperature is very cold (0 to 1°C). Therefore, tributary access for adfluvial spawners is not likely an issue for fall spawners, including Bull Trout and Kokanee, and is potentially a problem for spring spawners like Rainbow Trout and Arctic Grayling. Conversely, fish may not be attempting to access the streams during April and May, or earlier, when water temperatures are very cold. During our site visits in early spring (late-April to May), spring (June to early July), and summer (late August) in 2011 to 2013, there have been no visible impediments to tributary access. Debris blockages or flows that were too shallow or fast for fish passage within the drawdown zone or near the stream mouth have not been observed at any site visit between 2011 and 2013. The reservoir level was higher than normal in the first two years of study in 2011 and 2012 (Golder 2012, 2013a) and therefore tributary access was less likely to be a problem compared to years with lower reservoir levels. Stream discharge was greater than normal in 2011 and 2012 (based on snowpack data), which also would be expected to be associated with reduced likelihood of impediments to fish access to tributaries. In 2013, the reservoir level was lower than the historical average, and discharge was near average (based on snowpack data and levels at stream gauging station). More of the drawdown zone was exposed during the spring spawner survey in 2013, compared to 2011 and 2012, but no obvious barriers or impediments to fish access were observed in any of the study tributaries.

Although barriers to passage were not observed, it does not necessarily mean that the habitat and flows in the drawdown zone could not limit fish access to the tributaries. For instance, habitat in the drawdown zone was generally poor quality, consisting primarily of fast-flowing riffles with little cover, pools or resting areas. Although these reaches likely do not exceed the physiological limits of fish passage for salmonid species, fish passage also depends on behavioural factors (Binder and Stevens 2004), and it is possible that flows or habitat in the drawdown zone could act as a deterrent to fish passage, even though suitable spawning, feeding or rearing habitats exist further upstream. The proposed enhancements and monitoring program are necessary to test this hypothesis.

The failure to observe spawners and redds in most of the study tributaries should not be interpreted as evidence that spawning did not occur because of the limited spatial and temporal scope of the surveys. Spawner surveys from 2011 to 2013 were conducted on one day for each creek. 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 large number of spawners but an early survey or 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 for monitoring the abundance of spawning, such as weekly surveys over the whole potential spawning period or a fish fence, would be preferred but may not possible given the remote locations of the sites and available budget. If only one day of effort per stream is possible, 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 effort in year based on a one day survey (Gallagher et al. 2007). As limited spawning activity has been observed in the lower reaches of the study streams, we recommend extending surveys further upstream where spawning may be occurring, but continuing surveys in the lower reaches for comparability to pre-enhancements years.

The number of fish observed and the CPUE while snorkelling was much lower during the 2013 spring spawner survey than during the 2013 summer fish population sampling. Possible explanations for lower snorkelling CPUE during the spring spawner survey include: 1) fish are more easily observed at night (summer survey) than in the day (spawner survey); 2) fish are more easily observed during low flows (summer survey) than during high flows (spawner survey); and, 3) larger numbers of fish are present in the pool and low velocity habitats surveyed during the summer than in spring (likely temperature and feed dependant). Regardless of the reason for lower snorkelling CPUE in the spring than in the summer survey, snorkelling remains a potentially useful method to improve detection of adult spawners in the study tributaries. It is recommended that snorkelling continue to be used, where possible, during spawner surveys in future years. Random sampling of snorkel sites will likely not be possible because of limited habitats where the method is feasible. Snorkelling at select areas where it is feasible to do so, may improve detection of adult spawners that are holding or migrating upstream prior to spawning and recording the total effort (number of sites and spatial area) will allow comparison to future years.

4.4 Juvenile and Small-Bodied Fish Survey

4.4.1 Methodology

The mark-resight method used in 2012 and 2013 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 and 2013 than in 2011. Even so, the numbers of fish caught or observed in 2013 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 the mark-resight model. When sampling streams with low fish densities like the Williston tributaries, it is likely important to sample a large spatial area to mark and resight enough fish to produce accurate estimates of recapture probability and abundance. The stratified Bayesian mark-resight model was a good method to estimate abundance of fish species with relatively low catches and varying catchability. Analysis in future years of the study can incorporate all years in the model and assess the effects of habitat enhancement on population estimates. The fact that fish were rarely resighted outside of the site of capture and release suggests that the assumption of a closed-population is valid for these study sites.

The wide confidence intervals surrounding population estimates could make it difficult to demonstrate statistically significant changes before and after the habitat enhancements. For example, the Bull Trout estimate in Lamonti Creek in 2013 was 41.1 with a credibility interval of 17.4 to 116.1. For an increase in Bull Trout that would result in non-overlapping credibility intervals, which would be considered statistically significant, an estimate of 274.2 with a credibility interval of 116.1 to 774.7 would be necessary, which represents an increase of 667%. This calculation assumes that the credibility intervals increase proportionally with the point estimates, which may not be the case, as greater numbers of fish and recaptures could improve precision of estimates. However, this example demonstrates that very large increases in fish abundance may be required in order to demonstrate a statistically significant change after habitat enhancement, given the large uncertainty surrounding abundance estimates. For this reason, it is recommended that before-after comparisons for this study also interpret effect sizes (e.g. % change), instead of only dichotomous hypothesis tests, as Bradford et al. (2005) recommended for effectiveness monitoring for habitat enhancements.

The night-time fry survey conducted in 2013 provided a simple but effective way to improve monitoring of young-of-the-year salmonids in the study tributaries. Fry were often present in different habitats than those sampled by electrofishing and snorkelling (i.e., very shallow stream margins), and fry were less susceptible to electrofishing or observation by snorkelling than larger juveniles. The fry surveys will likely be most relevant for Rainbow Trout fry, which were the most abundant species observed during the surveys, but other species including Arctic Grayling, Bull Trout and Mountain Whitefish also could be observed. It is recommended that fry surveys be continued in future years of the study, in conjunction with the night-time snorkel surveys. The data should provide a good index of how well suitable habitat are seeded with salmonid fry and can be compared to years following habitat enhancements. Moving the Rainbow Trout spawner survey to later during spring and expanding the field program to include night-time snorkel surveying could provide more information on fish presence and could provide an opportunity to observe Arctic Grayling fry (if present) in slow-water margins of the study streams.

In 2013, fish were marked using surgical sutures to attach the fluorescent yarn instead of the fish hooks used in 2012. In both years, there were no noticeable differences in behaviour between tagged and un-tagged fish, based on limited underwater observations. However, sutures are smaller in weight and size and are therefore thought to be less invasive and less likely to influence swimming, behaviour or energetics of tagged fish, when compared to fish hook tags. For these reasons, fluorescent yarn attached with sutures is the recommended method for fish tagging in future years of the monitoring program. Fish that had previously been tagged in 2012 were not observed during snorkel surveys during 2013, which is not surprising given the relatively small number of fish tagged during 2012 (26 fish in all four tributaries combined).

4.4.2 Study Objectives

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 and 2013 provides a good assessment of abundance and diversity of fish in the study streams to compare to future years after habitat enhancement. In cases where sample sizes were 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 may not create a substantial amount of new habitat or affect upstream habitat. 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.

4.4.3 Fish Communities Prior to Habitat Enhancements

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. Ole and Factor Ross creeks are the tributaries thought to be susceptible to debris jam blockages. Fish caught or observed in Ole Creek were mostly Bull Trout, with smaller numbers of Rainbow Trout and Mountain Whitefish. 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 to 2013. In comparison, Factor Ross Creek had large numbers of Bull Trout and Mountain Whitefish, with smaller numbers of Rainbow Trout.

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 to 2013). 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 not in other streams because of access-blockages during the spawning period or other reasons.

Low densities of the target species, Rainbow Trout and Arctic Grayling, were observed in the study tributaries between 2011 and 2013. One potential reason for this result is that tributary access blockages or impediments are limiting adfluvial spawning and usage of the tributaries by the target species. Based on the results of the monitoring program to date, this is unlikely although it is possible flows in the drawdown zone could be a behavioural deterrent to tributary access from the reservoir. An alternative explanation is that habitat or resources in the study tributaries are limiting populations of the target species. Habitats may be less suitable for Rainbow Trout and Arctic Grayling and more suitable for species such as Bull Trout and Mountain Whitefish, which are found in relatively larger numbers in some of the tributaries. For instance, water temperatures in the tributaries range from ~5 to12°C during summer and Bull Trout are most likely to be found and have the highest growth rates (depending on food availability) at 12°C or lower (Dunham et al. 2003). A detailed analysis of Rainbow Trout and Arctic Grayling habitat preferences, and detailed habitat assessments in upstream areas of the study tributaries would be required to assess potential habitat limitation of target species but is beyond the scope of the current monitoring program.

5.0 RECOMMENDATIONS

Based on the results of the 2011 to 2013 monitoring program, 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. Rainbow Trout may be travelling further up the stream systems to spawn (particularly in Six Mile Creek). 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 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 night snorkelling is also used during surveys to improve detection of adult fish. The night snorkelling addition to the program would add an extra day of assessment for each stream but could also add value in the potential detection of adult or fry Arctic Grayling, especially in Factor Ross Creek.
- 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 (as was done in 2013) and would include photographs at reference points at each stream mouth.
- As recommended in the report from the Year 1 of the study in 2011 (Golder 2012) and in consultation with BC Hydro, songbird and vegetation monitoring were not conducted in 2012 and 2013. 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. 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.).
- Continue to use the mark-resight method involving electrofishing and snorkelling to estimate abundance of the fish in the study streams.

- Continue to collect discharge information in order to refine the stage-discharge models. We recommend that at least five more field discharge measurements be conducted at various water levels (particularly at intermediate water levels). The BC RISC (1999) standards recommend ten measurements annually, though we acknowledge that this may not be practicable or necessary for this monitoring program. The level of refinement required will depend on the intended future use of the data; therefore, guidance from BC Hydro is requested. Continued maintenance and use of the stage-discharge curve requires that periodic discharge measurements be conducted such that changes in the morphology of the streams over time (i.e., accretion or erosion of substrate) are captured in the model.
- Rainbow Trout and Bull Trout fry counts during the late-summer night-time snorkel surveys should be continued in future years of the study. An Arctic Grayling fry count should be considered for during a night-time snorkel survey during the early summer Rainbow Trout spawner survey.
- With the refined enhancement designs now incorporating more soil and woody debris in mounds that elevate the structures close to the stream mouths to above the full pool level, there is potential for vegetation establishment over an expanded area at each treatment stream mouth. This could provide an opportunity to incorporate other components of the management questions such as those related to 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 focused within the drawdown zone and near the stream mouths where potential impacts from the enhancement works are plausible. Amphibian habitat near the mouths of Six Mile and Ole creeks identified in this report should be considered when implementing habitat enhancements.
- A Level 1 Habitat Assessment has not been completed due to the limited inferred value with the changes to the monitoring program. The habitat assessment was replaced by photo reference monitoring upstream, across, and downstream of the mouth of each tributary. 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. However, continuation of the photo reference monitoring is recommended, with tracking of noted habitat changes discussed within annual reports. As-built tributary access enhancement designs should include mapping of pool features in the two test streams within the inundation zone and perhaps for a distance of 6x the average channel width upstream of the highest gradient enhancement structure. The mapping should be completed with a mapping-grade topographical survey system.

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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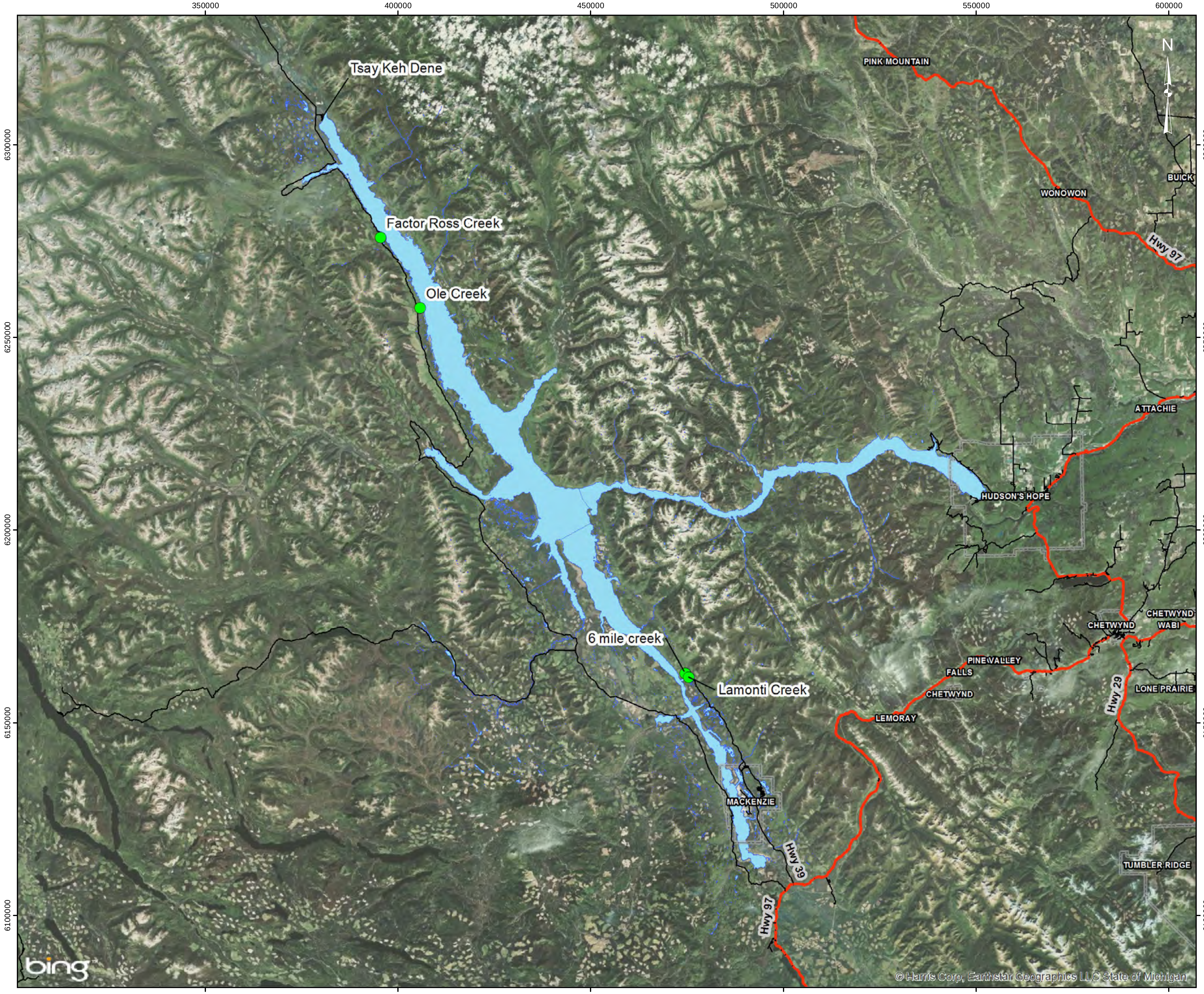
APPENDIX A

Maps



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- SITE LOCATION
- HIGHWAY
- ROAD
- MUNICIPALITY

REFERENCE

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   (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

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GIS	AL	17 Oct. 2012	MAP: 1	
CHECK	DR	25 Oct. 2013		
REVIEW	DJA	28 Oct. 2013		

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- PHOTO REFERENCE LOCATION
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- ELECTROFISHING / SNORKEL SITES (2013)
- GAUGING STATION

REFERENCES

Survey Data Obtained From Field Observations.
Base imagery obtained from Bing Maps for ArcGIS Published by Microsoft Corporation, Redmond, WA, 2013.
Bing Map Imagery date March 2001 to July 2004.
Bing Map Image is to be used for sourounding detail reference only,
Bing Map Image is Not to Scale.
Datum: NAD83 Projection: UTM Zone 11

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW
0	25OCT2013	Original Plan Prepared	TS	BEJ	DR	DJA

PROJECT

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

TITLE

SIX MILE CREEK

Golder Associates

PROJECT No.		11-1492-0016
DESIGN	TS	24-OCT-11
CADD	BEJ	25-OCT-13
CHECK	DR	25-OCT-13
REVIEW	DJA	28-OCT-13

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MAP: 2

LEGEND

- PHOTO REFERENCE LOCATION
- AMPHIBIAN SEARCH SITES (2013)
- ELECTROFISHING / SNORKEL SITES (2013)

REFERENCES

Survey Data Obtained From Field Observations.
Base imagery obtained from É BC Hydro all rights reserverd.
Imagery date 2009.
Image is to be used for sourounding detail reference only,
Image is Not to Scale.
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SCALE METRES

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW
	25OCT2013	Original Plan Prepared	TS	BEJ	DR	DJA

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

TITLE

LAMONTI CREEK

Golder Associates

PROJECT No.		11-1492-0016	FILE No. 11-1492-0016_5200_MAP3
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CHECK	DR	25-OCT-13	MAP: 3
REVIEW	DJA	28-OCT-13	

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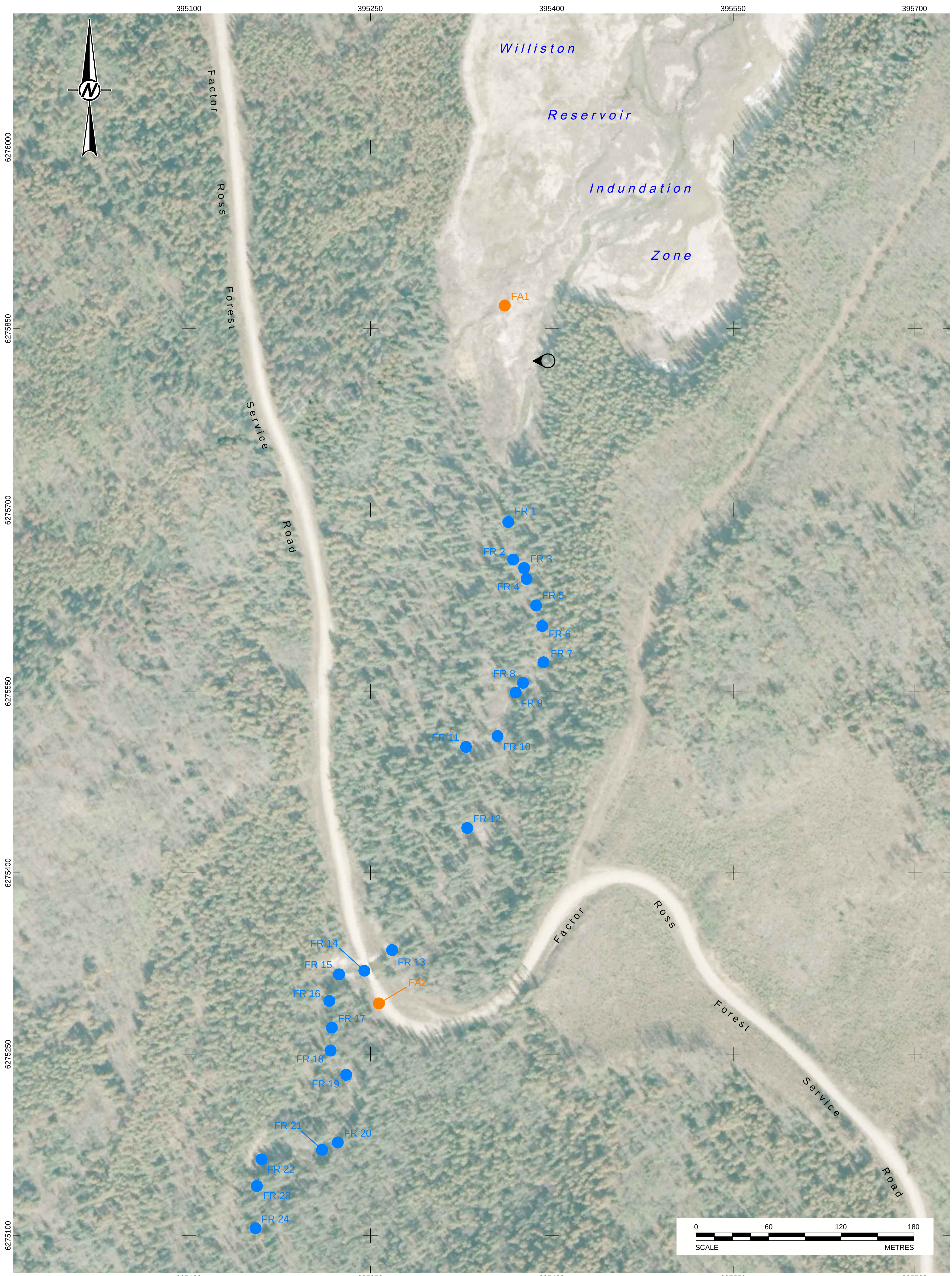

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- ELECTROFISHING / SNORKEL SITES (2013)

REFERENCES

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Base imagery obtained from É BC Hydro all rights reserverd.
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REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW
0	25OCT2013	Original Plan Prepared	TS	BEJ	DR	DJA

PROJECT

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

TITLE

FACTOR ROSS CREEK

Golder Associates

PROJECT No.		11-1492-0016
DESIGN	TS	24-OCT-11
CADD	BEJ	25-OCT-13
CHECK	DR	25-OCT-13
REVIEW	DJA	28-OCT-13

FILE No. 11-1492-0016_5200_MAP4

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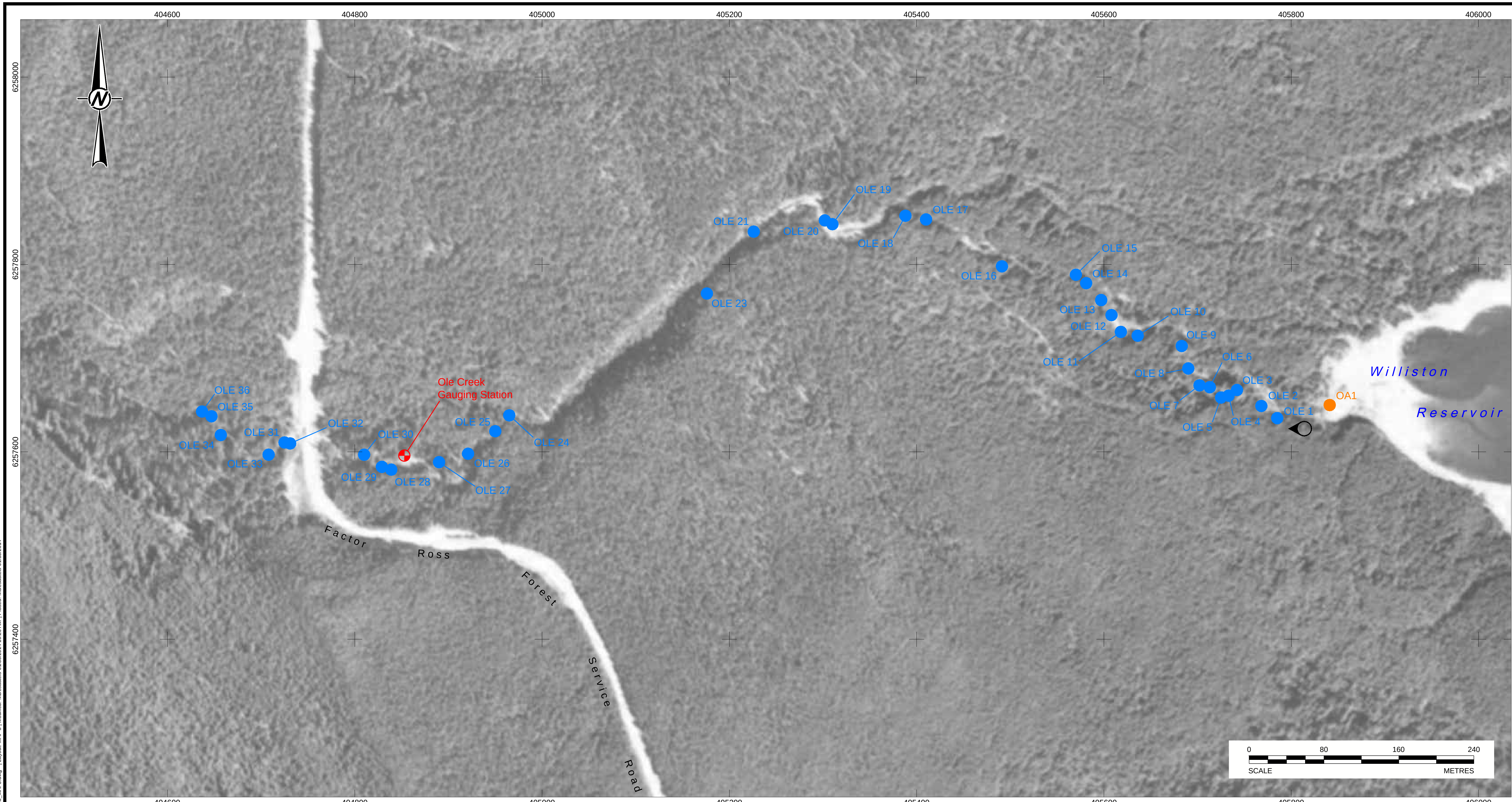
MAP: 4



LEGEND

- PHOTO REFERENCE LOCATION
- AMPHIBIAN SEARCH SITES (2013)
- ELECTROFISHING / SNORKEL SITES (2013)
- GAUGING STATION

REFERENCES

Survey Data Obtained From Field Observations.
Base imagery obtained from Bing Maps for ArcGIS Published by Microsoft Corporation, Redmond, WA, 2013.
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Bing Map Image is to be used for souroundina detail reference only,
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REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW
1	25OCT2013	Original Plan Prepared	TS	BEJ	DR	DJA

PROJECT

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

TITLE

OLE CREEK

Golder Associates

PROJECT No.		11-1492-0016	FILE No. 11-1492-0016_5200_MAP5
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CHECK	DR	25-OCT-13	MAP: 5
REVIEW	DJA	28-OCT-13	

APPENDIX B

Photographs

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

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

Photograph 3: Bull Trout tagged with fluorescent yarn attached with a surgical suture at site SM3 on Six Mile Creek during the Williston Reservoir Tributary Enhancement Monitoring in 2013.

Photograph 4: Bull trout tagged with fluorescent yarn attached with a surgical suture at site SM9 on Six Mile Creek during the Williston Reservoir Tributary Enhancement Monitoring in 2013.

Photograph 5: Rainbow Trout tagged with fishing hook and yarn at site SM10 on Six Mile Creek during Williston Reservoir Tributary Enhancement Monitoring in 2012.

Photograph 6: Arctic Grayling tagged with fishing hook and yarn at site FR12 on Factor Ross Creek during Williston Reservoir Tributary Enhancement Monitoring in 2012.

Photograph 7: Kokanee tagged with fishing hook and yarn at site FR1 on Factor Ross Creek during Williston Reservoir Tributary Enhancement Monitoring in 2012.

Photograph 8: Burbot tagged with fishing hook and yarn at site SM1 on Six Mile Creek during Williston Reservoir Tributary Enhancement Monitoring in 2012.

Photograph 9: Bull Trout fry caught while electrofishing in Factor Ross Creek in 2013. Fry were too small to be tagged using the suture and yarn method.

Photograph 10: Example of a tagged Rainbow Trout observed underwater during night snorkelling survey in 2012.

Photograph 11: Example of habitat searched during night-time fry survey. A Rainbow Trout fry was observed at this site on Lamonti Creek.

Photograph 12: Example of habitat searched during night-time fry survey on Lamonti Creek.

Photograph 13: Six Mile Creek on May 1, 2013 from photo reference location (azimuth = 165°; downstream).

Photograph 14: Six Mile Creek on June 18, 2013 from photo reference location (azimuth = 165°; downstream).

Photograph 15: Six Mile Creek on August 16, 2013 from photo reference location (azimuth = 165°; downstream).

Photograph 16: Example of representative habitat in the drawdown zone of Six Mile Creek on May 1, 2013.

Photograph 17: Six Mile Creek near the mouth, looking downstream on June 18, 2013.

Photograph 18: Six Mile Creek near the mouth, looking upstream on June 18, 2013.

Photograph 19: Six Mile Creek on June 18, 2013 from photo reference location (azimuth = 60°; upstream).

Photograph 20: Six Mile Creek on August 16, 2013 from photo reference location (azimuth = 60°; upstream).

Photograph 21: Lamonti Creek on May 1, 2013 from photo reference location (azimuth = 270°; downstream).

Photograph 22: Lamonti Creek on June 17, 2013 from photo reference location (azimuth = 270°; downstream).

Photograph 23: Lamonti Creek on August 19, 2013 from photo reference location (azimuth = 270°; downstream).

Photograph 24: Example of representative habitat in the drawdown zone of Lamonti Creek on May 1, 2013.

Photograph 25: Confluence of Six Mile and Lamonti creeks facing west at lake edge on May 1, 2013.

Photograph 26: Lamonti Creek, near the mouth, looking downstream on June 17, 2013.

Photograph 27: Lamonti Creek on August 19, 2013 from photo reference location (azimuth = 200°; upstream).

Photograph 28: Lamonti Creek on June 17, 2013 from photo reference location (azimuth = 200°; upstream).

Photograph 29: Ole Creek on April 30, 2013 from photo reference location (azimuth = 80°; downstream).

Photograph 30: Ole Creek on June 20, 2013 from photo reference location (azimuth = 80°; downstream).

Photograph 31: Ole Creek on August 23, 2013 from photo reference location (azimuth = 80°; downstream).

Photograph 32: Ole Creek on June 20, 2013 from photo reference location (azimuth = 10°; across channel).

Photograph 33: Ole Creek on August 23, 2013 from photo reference location (azimuth = 80°; downstream).

Photograph 34: Ole Creek, near the mouth, looking downstream on June 20, 2013.

Photograph 36: Example of habitat in the drawdown zone of Ole Creek on April 30, 2013. Note the channel was only partially observable due to ice. This is assumed to be the main channel, though it appeared to be braided under the ice to the right of the photo.

Photograph 37: Ole Creek flowing into Williston Reservoir on May 1, 2013. Note the habitat is a continuous shallow riffle with little or no cover. This was the steepest observed section.

Photograph 38: Factor Ross Creek on April 30, 2013 from photo reference location (azimuth = 340°; downstream). Note minor braiding and habitat made up of continuous shallow riffle with little or no cover.

Photograph 39: Factor Ross Creek on June 19, 2013 from photo reference location (azimuth = 340°; downstream).

Photograph 40: Factor Ross Creek on August 25, 2013 from photo reference location (azimuth = 340°; downstream).

Photograph 41: Factor Ross Creek on June 19, 2013 looking downstream from the stream mouth.

Photograph 42: Factor Ross Creek on June 19, 2013 from photo reference location (azimuth = 280°; across).

Photograph 43: Factor Ross Creek on August 25, 2013 from photo reference location (azimuth = 280°; across).

Photograph 44: Factor Ross Creek on June 19, 2013 from photo reference location (azimuth = 220°; upstream).

Photograph 45: Factor Ross Creek on August 25, 2013 from photo reference location (azimuth = 220°; upstream).

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. Methods were nearly identical in 2012 and 2013, with minor differences and recommendations for future study years noted below.

Sampling Sites

Sampling reaches in the four study streams were from the mouth to 1.4 km to 2.0 km upstream (Appendix A, Maps 2-5). 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). In 2013, snorkel surveys were conducted at all sites where electrofishing was conducted, with the exception of a few sites that were not snorkelled because of logistical constraints. This was a slight change from methods in 2012. In 2012, snorkelling was conducted at sites where fish had been marked and released, sites adjacent to where marked fish were released, and if time permitted, additional randomly selected electrofishing sites. In future years of the study, it is recommended that all electrofishing sites be sampled by snorkelling, as was done in 2013. Because the monitoring program will compare density estimates and numbers of fish per unit area, this difference in the number of sites snorkelled in 2012 and 2013 is not expected to affect comparability of the data between years.

UTM coordinates were recorded for all electrofishing and snorkelling sites. Sites were also marked with high-visibility flagging tape to help locate sites in the night-time during snorkel surveys. For sites that were long or had a less obvious start and end, flagging tape was placed at the upstream and downstream 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 and weighed with an electronic scale (± 1 g). Fork length (total length in the case of sculpins [*Cottus* spp.]) was measured to the nearest 1 mm.

Fish were marked with fluorescent yarn that was attached through the flesh directly behind the dorsal fin using a surgical suture (size 2-0 non-absorbable monofilament with 24 mm 3/8 circle cutting needle), tied using a surgeon's knot consisting of a double throw and one to two single throws depending on fish size. Approximately 1-2 cm of fluorescent yarn should be trailing from the suture after being attached (e.g. Appendix B, Photo 4). 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 fluorescent yarn tag clearly visible if the fish is seen, but not make the fish drastically more visible than unmarked fish.

In 2012, fish were marked behind the dorsal using a size 18 barbed fishing hook that had fluorescent yarn tied around the shank. In both 2012 and 2013, there were no noticeable differences in behaviour between tagged and un-tagged fish, based on limited underwater observations. However, sutures are smaller in weight and size and are therefore thought to be less invasive and less likely to influence swimming, behaviour or energetics of tagged fish, when compared to fish hook tags. For these reasons, fluorescent yarn attached with a suture is the recommended method for fish tagging in future years of the monitoring program.

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. For salmonids, fry were not tagged because they were too small but all other size-classes were tagged using the suture-yarn method described above. After processing, tagged fish were released at the capture site. Photographs of different sizes and species of fish that were tagged during the surveys are provided in Appendix B (Photos 3 to 10).

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. PG13-85702) 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 positioned themselves at various angles around the debris to view as much of the area as possible. Caution was used when surveying near debris jams, which were surveyed from downstream if possible. In areas with high flows or debris, the second observer acted 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 not 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. 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. Visibility was quantified by recording the horizontal distance at which a 30 cm yellow ruler was visible underwater by the snorkelers. Objects of known size were 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 were reasonably 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 10 (Appendix B).

Fry Surveys

Although salmonid fry were often observed incidentally in the margins of the study streams at night, relatively small numbers of salmonid fry (<5 per tributary) were captured by electrofishing or observed by snorkel survey in sampling sites in 2012. For this reason, an additional visual survey was conducted in 2013 in conjunction with the night-time snorkel survey, to improve detection of salmonid fry and provide an index of the number of young-of-the-year fish (especially Rainbow Trout) to compare to years following habitat enhancement. Fry surveys were conducted at the same time as the night-time snorkel surveys by the crew member who was recording notes, while the other two crew members snorkeled the site. Fry surveys were conducted adjacent to the snorkeling sites in areas that provided good habitat for salmonid fry, based on professional judgement. Although habitat variables were not measured, habitats considered suitable for fry were characterized by water depths less than 20 cm and water velocities less than 0.1 m/s, and were typically near the stream margin (McPhail 2007). Photographs of representative habitat searched during fry surveys are in Appendix B (Photos 11 and 12). If there was no suitable fry habitat in the vicinity of the snorkelling site, then a fry survey was not conducted at that sample site. For each site, the number of fry observed, estimated fork lengths, and the linear distance of shoreline surveyed was recorded. Surveys were conducted from downstream to upstream using a flashlight or headlamp to scan the habitat for fry. Whenever possible, a sub-sample of observed fry was captured with a small dip-net to confirm species identification. Although fry survey sites were not randomly selected, they likely provide a reasonable representation of suitable fry habitat in the study tributaries. The data will be used to quantify how well suitable young-of-the-year habitats were seeded with fry, and compared to years following habitat enhancement.

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APPENDIX D

Supplementary Figures and Data Tables

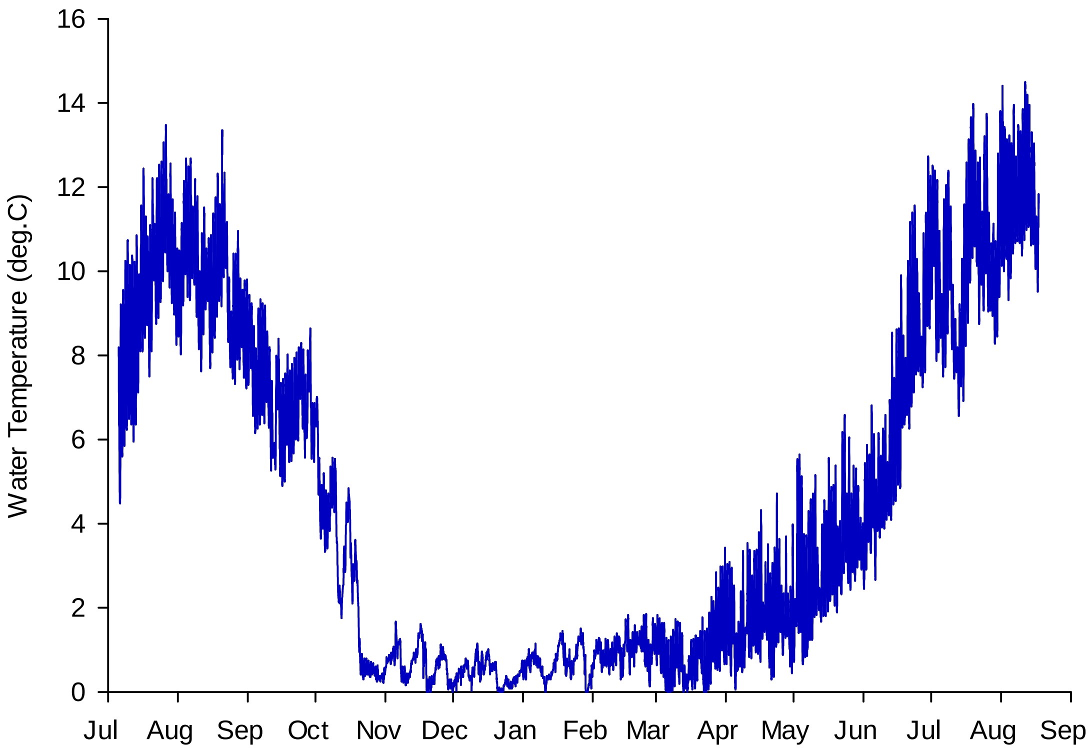

Figure D1: Water Temperature As Recorded By The Backup Logger (Onset® Hobo Water Temp Pro V2) In Six Mile Creek.

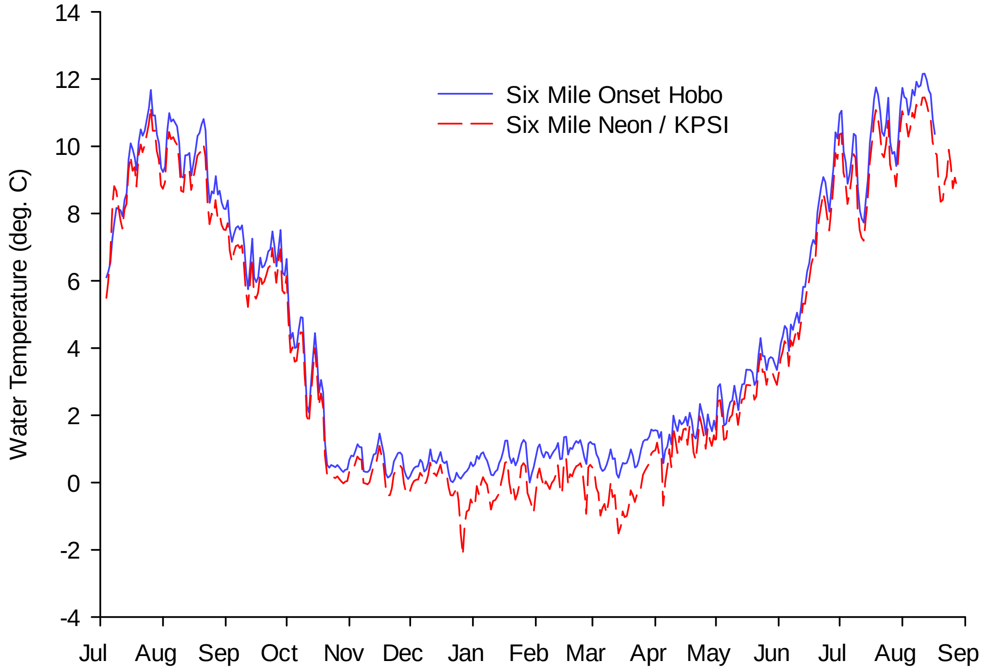

Figure D2: Water Temperature Recorded By The Backup Temperature Logger (Onset® Hobo Water Temp Pro V2) And By The Satellite Transmitting Probe (Neon/KPSI) At The Gauging Station On Six Mile Creek Throughout The Deployment Period (July 2012 – August 2013).

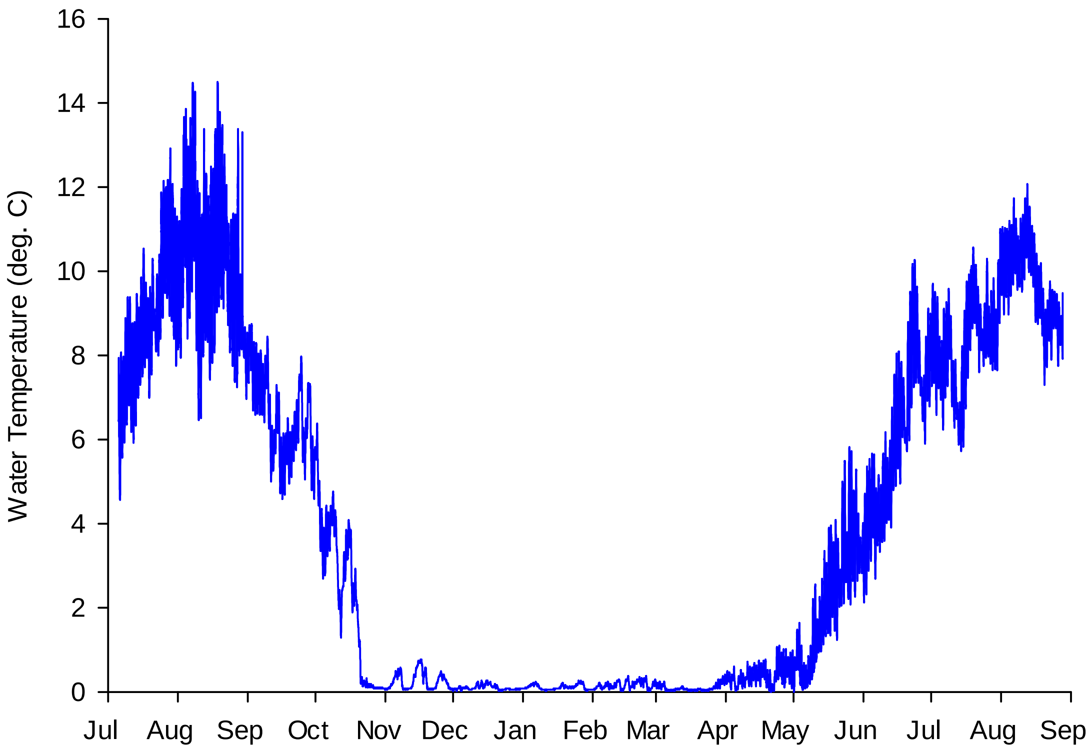

Figure D3: Water Temperature As Recorded By The Backup Logger (Onset® Hobo Water Temp Pro V2) In Ole Creek.

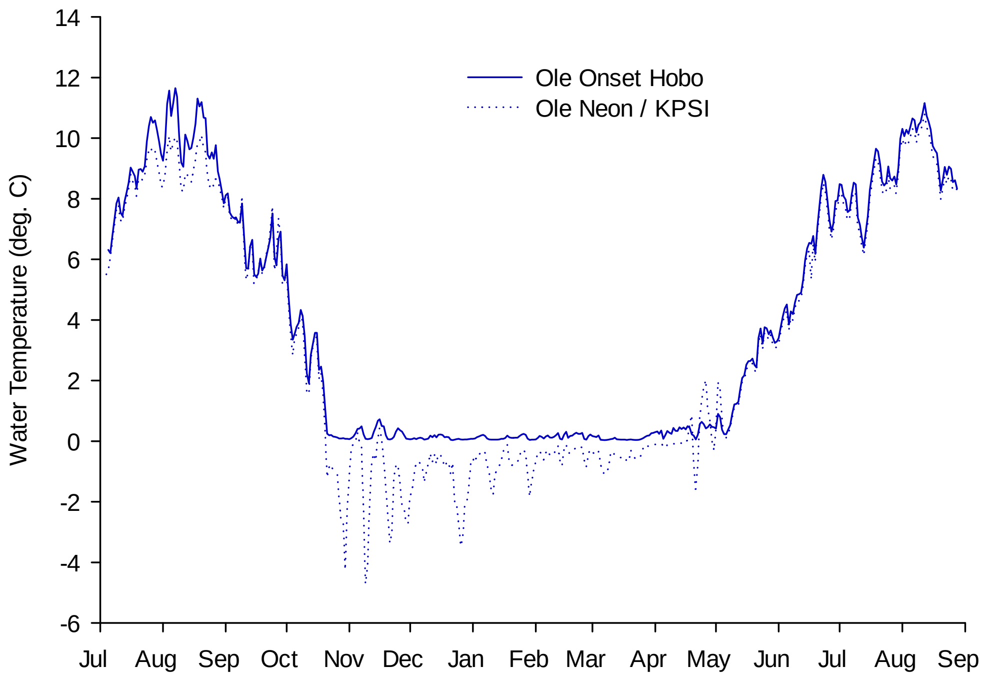

Figure D4: Water Temperature Recorded By The Backup Temperature Logger (Onset® Hobo Water Temp Pro V2) And By The Satellite Transmitting Probe (Neon/KPSI) At The Gauging Station On Ole Creek Throughout The Deployment Period (July 2012 – August 2013).

Table D1: Locations of Sample Sites for Backpack Electrofishing and Snorkel Surveys in Four Williston Reservoir Tributaries in 2013.

Site Name	Zone	Easting	Northing	Habitat Complexity	Comment
SM1	10U	474621	6162883	Low	RDB
SM2	10U	474591	6162929	Low	RDB
SM3	10U	474630	6163013	Low	LDB
SM4	10U	474644	6163042	Low	LDB
SM5	10U	474589	6163117	Medium	LDB
SM6	10U	474540	6163304	Low	LDB
SM7	10U	474489	6163376	Low	RDB
SM8	10U	474564	6163420	Medium	LDB
SM9	10U	474578	6163409	Medium	LDB
SM10	10U	474671	6163476	Medium	LDB
SM11	10U	474663	6163494	Low	LDB
SM12	10U	474641	6163511	Low	LDB - left side channel
SM13	10U	474632	6163505	High	RDB - right side channel
SM14	10U	474599	6163536	Medium	LDB - right side channel
SM15	10U	474612	6163549	Medium	LDB - right side channel
SM16	10U	474559	6163659	Low	LDB - left side channel
SM17	10U	474535	6163639	Medium	RDB - right side channel
SM18	10U	474495	6163647	Low	RDB
SM19	10U	474487	6163675	Low	RDB
SM20	10U	474496	6163717	Medium	LDB
SM21	10U	474496	6163750	Medium	RDB
SM22	10U	474476	6163830	Medium	RDB
SM23	10U	474470	6163851	Medium	RDB
SM24	10U	474464	6163925	High	Under log jam
SM25	10U	474448	6163945	Medium	Whole width
SM26	10U	474408	6163981	Low	RDB
SM27	10U	474403	6164045	Low	Middle of creek
SM28	10U	474412	6164096	Low	RDB
SM29	10U	474415	6164125	Low	Whole pool; photos 162-166
SM30	10U	474425	6164137	Low	Centre of Creek
SM31	10U	474475	6164175	Medium	Whole pool
SM32	10U	474490	6164182	Medium	2 pools over width of creek
LAM1	10U	475329	6161950	Low	Whole creek
LAM2	10U	475389	6161978	Medium	Whole creek
LAM3	10U	475414	6161991	Medium	LDB
LAM4	10U	475430	6161984	High	Whole creek
LAM5	10U	475453	6161977	Medium	RDB at lower whole creek u/s

Site Name	Zone	Easting	Northing	Habitat Complexity	Comment
LAM6	10U	475482	6161931	Medium	RDB
LAM7	10U	475499	6161929	Medium	RD - side pool
LAM8	10U	475514	6161916	Medium	LDB
LAM9	10U	475539	6161935	High	RDB
LAM10	10U	475626	6161939	Medium	RDB
LAM11	10U	475646	6161942	Medium	LDB
LAM12	10U	475716	6161926	Medium	LDB
LAM13	10U	475761	6161928	High	LDB under LWD
LAM14	10U	475840	6161917	Medium	Whole creek (2 pools)
LAM15	10U	475872	6161855	Low	Whole creek
LAM16	10U	475872	6161828	Low	Whole channel under bridge
LAM17	10U	475890	6161826	Low	Whole channel
LAM18	10U	475916	6161817	Medium	RDB
LAM19	10U	475932	6161810	Low	RDB
LAM20	10U	475950	6161801	High	LDB and small pool
LAM21	10U	475997	6161789	Low	Whole channel
LAM22	10U	476052	6161824	Medium	Whole channel
LAM23	10U	476082	6161800	Medium	Right channel
LAM24	10U	476085	6161797	Low	LDB
LAM25	10U	476094	6161785	Low	Mid channel and log
LAM26	10U	476106	6161784	Low	RDB
LAM27	10U	476122	6161807	Low	RDB
LAM28	10U	476140	6161809	Medium	Whole channel
LAM29	10U	476159	6161800	Low	LDB
LAM30	10U	476234	6161816	Low	RDB
LAM31	10U	476276	6161817	Low	Whole channel
OLE1	10V	405785	6257636	Medium	LDB
OLE2	10V	405768	6257649	Medium	RDB and whole creek at north end
OLE3	10V	405742	6257666	High	Whole creek
OLE4	10V	405733	6257660	High	RDB and South RDB pool
OLE5	10V	405725	6257658	Low	2 pools; 1st at RDB of right side channel; 2nd at RDB at LDB channel
OLE6	10V	405713	6257669	Medium	LDB of left side channel and north pool
OLE7	10V	405702	6257671	High	LDB of left side channel and upper pool
OLE8	10V	405690	6257689	Low	Whole pool left side of channel
OLE9	10V	405683	6257713	Low	Right side channel
OLE10	10V	405636	6257724	Low	RDB side pool
OLE11	10V	405618	6257728	Low	Middle of channel
OLE12	10V	405608	6257746	Low	LDB

Site Name	Zone	Easting	Northing	Habitat Complexity	Comment
OLE13	10V	405597	6257762	Medium	LDB 2 pools
OLE14	10V	405581	6257780	High	Whole creek
OLE15	10V	405570	6257789	High	Whole creek and upper pool
OLE16	10V	405491	6257798	Medium	RDB and upper pool
OLE17	10V	405410	6257848	Medium	Whole creek
OLE18	10V	405388	6257852	Medium	Whole creek
OLE19	10V	405310	6257843	Medium	RDB and upper pool
OLE20	10V	405302	6257847	Medium	LDB of left channel
OLE21	10V	405226	6257835	Low	
OLE23	10V	405176	6257769	Low	Whole creek at d/s end of canyon
OLE24	10V	404965	6257639	Low	Immediately above canyon
OLE25	10V	404950	6257622	Low	LDB
OLE26	10V	404921	6257598	Medium	Whole channel behind falls
OLE27	10V	404890	6257589	Medium	Left channel
OLE28	10V	404839	6257581	Low	RDB of left channel; whole right channel
OLE29	10V	404829	6257584	Medium	Whole channel
OLE30	10V	404810	6257597	High	Whole channel
OLE31	10V	404725	6257610	Medium	Whole channel
OLE32	10V	404731	6257609	Low	RDB
OLE33	10V	404708	6257597	Medium	RDB
OLE34	10V	404657	6257618	Low	RDB
OLE35	10V	404647	6257638	Medium	Most of channel on LDB and u/s RDB
OLE36	10V	404637	6257643	Low	RDB
FR1	10V	395364	6275690	Medium	Mid-stream boulder
FR2	10V	395368	6275659	Low	Mid-stream boulder
FR3	10V	395377	6275652	Low	LDB
FR4	10V	395379	6275643	Low	RDB
FR5	10V	395387	6275621	Low	LDB and RDB
FR6	10V	395392	6275604	Medium	RDB
FR7	10V	395393	6275574	Low	RDB
FR8	10V	395376	6275557	Low	Mid-stream boulder and log
FR9	10V	395370	6275549	Medium	2 x LDB + RDB
FR10	10V	395355	6275513	Low	LDB
FR11	10V	395329	6275504	Low	RDB 3 small pools
FR12	10V	395330	6275437	Medium	RDB logjam
FR13	10V	395268	6275336	Low	RDB-2 side eddies
FR14	10V	395245	6275319	Low	RDB
FR15	10V	395224	6275316	Low	RDB

Site Name	Zone	Easting	Northing	Habitat Complexity	Comment
FR16	10V	395216	6275294	Low	Middle of channel in eddie
FR17	10V	395218	6275272	Medium	Whole channel
FR18	10V	395217	6275253	Medium	RDB
FR19	10V	395230	6275233	Medium	RDB
FR20	10V	395223	6275177	High	Whole channel
FR21	10V	395210	6275171	Low	RDB
FR22	10V	395160	6275163	Medium	Whole channel
FR23	10V	395156	6275141	Medium	RDB
FR24	10V	395155	6275106	High	RDB and LDB (not middle)

Table D2: Staff Gauge Readings, Water Levels From Satellite-Transmitting Probe, and Discharge From Velocity and Depth Measurements at Six Mile and Ole Creeks in 2012 and 2013.

Date	Time	Staff Gauge (m)	Discharge (m^3/s)	Water level (m)
Six Mile Creek				
May 27, 2012	16:00	0.84	14.18*	n/a
July 4, 2012	15:30	0.61	6.40	0.404
August 21, 2012	11:15	0.31	0.99	0.107
April 29, 2013	15:45	0.27	0.84	0.090
June 18, 2013	15:45	0.64	6.45	0.469
August 17, 2013	18:00	0.30	1.03	0.131
Ole Creek				
May 27, 2012	13:30	0.58	2.77	0.372
July 5, 2012	16:45	0.45	2.70	0.249
August 26, 2012	15:12	0.18	0.33	0.037
April 30, 2013	11:00	0.09	0.15	0.00009
June 20, 2013	16:10	0.41	2.09	0.168
August 27, 2013	9:10	0.28	0.70	0.125

* Discharge measurement on May 27, 2012 is suspect, may be a measurement error, and was not used in discharge-water level regression.

Table D3: Amphibians Caught or Observed During Time-Constrained Searches Near Four Williston Reservoir Tributaries in 2013.

Tributary	Species	#	SVL (mm)	Weight (g)	Captured/Observed
Lamonti	Western Toad	1	42	11	Captured
Six Mile	Columbia Spotted Frog	1	51	9	Captured
Six Mile	Columbia Spotted Frog	1	27.5	2	Captured
Six Mile	Columbia Spotted Frog (Tadpoles)	9	10	n/a	Observed
Six Mile	Columbia Spotted Frog	1	26	n/a	Captured
Six Mile	Columbia Spotted Frog	1	27	2	Captured
Six Mile	Columbia Spotted Frog	1	38	13	Captured
Six Mile	Columbia Spotted Frog	1	48	15	Captured
Factor Ross	Wood Frog	1	26	3	Captured
Factor Ross	Western Toad	1	78	44	Captured
Factor Ross	Western Toad	1	72	49	Captured
Factor Ross	Wood Frog	1	29	3	Captured
Factor Ross	Wood Frog	1	28	n/a	Observed
Ole	Wood Frog	1	~25	n/a	Observed
Ole	Western Toad	1	39	n/a	Captured
Ole	Wood Frog	1	32	n/a	Captured
Ole	Wood Frog	2	~40	n/a	Observed
Ole	Wood Frog	1	44	4	Captured
Ole	Wood Frog	1	~35	n/a	Observed
Ole	Wood Frog	1	41	8	Captured
Ole	Wood Frog	1	~45	n/a	Observed
Ole	Wood Frog	1	23	<1	Captured
Ole	Wood Frog	1	36	6	Captured
Ole	Wood Frog	1	26	<1	Captured
Ole	Wood Frog	1	40	7	Captured

Table D4: Universal Transverse Mercator (UTM) Coordinates And Dimensions Of Areas Snorkeled During Spawing Surveys In Four Williston Reservoir Tributaries, June 17 To 20, 2013.

Tributary	UTM Coordinates			Dimensions (m)		Area (m^2)	Fish observed	Comment
	Zone	Easting	Northing	X	Y			
Six Mile	10 U	474605	6162896	2	1	2	No	Under log
Six Mile	10 U	474589	6163102	1.5	1	1.5	No	Behind tree and rocks
Six Mile	10 U	474655	6163485	3	2	6	No	Left side channel
Six Mile	10 U	474639	6163512	5	3	15	No	LDB, side channel
Six Mile	10 U	474634	6163505	7	3	21	No	RDB, main channel near log jam
Six Mile	10 U	474604	6163521	1	2	2	No	Mid-stream after sand bar
Six Mile	10 U	474604	6163521	4	2	8	No	Mid-stream after sand bar
Six Mile	10 U	474598	6163535	2	2	4	No	LDB next to sandbar
Six Mile	10 U	474557	6163657	8	8	64	No	Mid-stream of left channel
Six Mile	10 U	474493	6163756	4	4	16	No	RDB
Six Mile	10 U	474464	6163890	2	2	4	No	LDB, small log jam
Six Mile	10 U	474464	6163920	3	3	9	No	Mid-stream near large log jam
Six Mile	10 U	474448	6163947	3	2	6	No	Mid-stream and LDB
Six Mile	10 U	474474	6164163	2	0.5	1	No	Upstream of large log jam
Six Mile	10 U	474474	6164163	1	3	3	1 Mountain Whitefish	Upstream of large log jam
TOTAL						**162.5**		
Lamonti	10 U	476001	6161785	1	2	2	No	Upstream of 2012 site LAM17
Lamonti	10 U	476016	6161793	1	1	1	No	Pool behind mid-stream boulder
Lamonti	10 U	476043	6161802	2	1	2	1 Bull Trout	Mid-stream pool behind log with root-wad
Lamonti	10 U	476072	6161765	1	3	3	No	RDB behind log
TOTAL						**8**		
Factor Ross								Snorkelling not conducted in Factor Ross (poor visibility)
TOTAL						**0**		
Ole	10 V	405762	6257656	3	2	6	No	OLE19 site from 2012
Ole	10 V	405728	6257664	0.5	1	0.5	No	
Ole	10 V	405728	6257664	2	1	2	No	
Ole	10 V	405653	6257730	4	5	20	No	OLE25 site from 2012
Ole	10 V	405639	6257728	1	2	2	No	
Ole	10 V	405588	6257787	1.5	1	1.5	No	40 cm tall pour-over.
Ole	10 V	405575	6257793	2	3	6	No	
Ole	10 V	405490	6257808	2	1	2	1 Sculpin sp.	OLE32 site from 2012.
Ole	10 V	405490	6257808	2	1	2	No	

Tributary	UTM Coordinates			Dimensions (m)		Area (m^2)	Fish observed	Comment
	Zone	Easting	Northing	X	Y			
Ole	10 V	405309	6257861	2	5	10	No	
Ole	10 V	405177	6257786	3	2	6	No	Pool at downstream end of canyon.
Ole	10 V	404551	6257655	3.5	2	7	1 Rainbow Trout	Pool under large rock pour-over
Ole	10 V	404443	6257702	0.5	1	0.5	No	Pool behind log
Ole	10 V	404443	6257702	1	2.5	2.5	No	Pool behind log
Ole	10 V	404401	6257694	0.5	0.5	0.25	No	Pool behind log
TOTAL						**68.25**		

Table D5: Universal Transverse Mercator (UTM) Coordinates And Dimensions Of Gravel Substrates Suitable For Rainbow Trout Spawning That Were Observed During Spawner Surveys June 17 To 20, 2013 In Four Tributaries Of Williston Reservoir.

Tributary	UTM Coordinates			Snorkeled?	Dimensions (m)		Area (m^2)	Comment
	Zone	Easting	Northing		X	Y		
Six Mile	10 U	474670	6163460	No	1	2	2	LDB on bend
Six Mile	10 U	474655	6163485	Yes	3	2	6	LDB side channel after log jam
Six Mile	10 U	474639	6163512	Yes	1.5	3	4.5	LDB side channel, tail-out of pool
Six Mile	10 U	474604	6163521	Yes	1	2	2	mid-stream after sandbar
Six Mile	10 U	474604	6163521	Yes	4	2	8	mid-stream after sandbar
Six Mile	10 U	474557	6163657	Yes	2	4	8	mid-stream left channel and LDB
Six Mile	10 U	474493	6163756	Yes	1	3	3	RDB
Six Mile	10 U	474464	6163890	Yes	1	2.5	2.5	LDB, small log jam
Six Mile	10 U	474432	6163976	No	1	1	1	LDB
Six Mile	10 U	474489	6164175	No	2	3	6	midstream to LDB
TOTAL							**43**	
Lamonti	10 U	475330	6161949	Yes	2	1.5	3	Pool with spawning gravel
Lamonti	10 U	475451	6161979	Yes	4	2	8	Tailout of pool with spawning gravel
TOTAL							**11**	
Factor Ross	10 V	395243	6275316	No	1	6	6	
Factor Ross	10 V	395215	6275257	No	1	1.5	1.5	Near LWD on RDB
Factor Ross	10 V	395142	6275160	No	2.5	1.5	3.75	RDB
TOTAL							**11.25**	
Ole	10 V	405201	6257815	No	1	2	2	
Ole	10 V	405177	6257786	Yes	2	1	2	Pool at downstream end of canyon
Ole	10 V	404626	6257630	No	0.5	1.5	0.75	LDB
TOTAL							**4.75**	

Note: LDB= Left downstream bank; RDB= Right downstream bank.

Table D6: Site information and fish observed during night-time fry surveys at four tributaries of Williston Reservoir in 2013. Fry surveys were conducted in close proximity to snorkel sites, when there suitable fry habitat nearby. See Table D1 for locations of snorkel sites.

Tributary	Date	Snorkel Site	Length (m)	# Fish observed				Comments (habitat, location, etc)
				Total	RB	BT	CC	
Six Mile	19-Aug-13	SM19	26	18	16	1	1	16x RB approx. 30mm, 1x BT approx. 60mm, 1x CC approx. 50mm
Six Mile	19-Aug-13	SM18	15	0	0	0	0	Observed less cobbles and more fine silts and sediment
Six Mile	19-Aug-13	SM20	10	0	0	0	0	On cobble flood channel on RDB
Six Mile	19-Aug-13	SM21	8.5	3	3	0	0	RDB. 3x RB approx. 30mm
Six Mile	19-Aug-13	SM22	8	2	2	0	0	RDB. 2x RB approx. 30mm
Six Mile	19-Aug-13	SM23	5.5	8	8	0	0	Downstream of SM23. RDB. 8x RB approx. 30mm
Six Mile	19-Aug-13	SM24	4	2	2	0	0	Downstream of SM24. RDB under tree cover. 2x RB approx. 30mm
Six Mile	19-Aug-13	SM25	3.5	4	3	1	0	No current. 2x RB approx. 30mm, 1x BT approx. 90mm
Six Mile	19-Aug-13	SM26	1.5	1	1	0	0	Approx. 20m south of SM26. 1x RB approx. 70mm
Six Mile	19-Aug-13	SM26	7.5	4	4	0	0	At SM26. 4x RB approx. 30mm
Total			**89.5**	**42**	**39**	**2**	**1**	
Lamonti	20-Aug-13	LAM1	12	0	0	0	0	RDB. Observed approx. 30 Caddis fly larvae.
Lamonti	20-Aug-13	LAM2	6.5	2	0	0	2	RDB. 2x CC were approx. 50mm and 60mm.
Lamonti	20-Aug-13	LAM3	7	0	0	0	0	RDB and middle of the creek - not good habitat.
Lamonti	20-Aug-13	LAM4	4	0	0	0	0	LDB appeared to be best habitat but still considered low value fry habitat. Upper pool not suitable habitat.
Lamonti	20-Aug-13	LAM5	7	1	0	0	1	LDB. Whole creek is good habitat. 1x CC was approx. 50 mm
Lamonti	20-Aug-13	LAM6	10.5	2	2	0	0	2x RB approx. 30 mm. LDB is very high value habitat.
Lamonti	20-Aug-13	LAM7	-	0	0	0	0	Whole pool sampled
Lamonti	20-Aug-13	LAM9	3.5	0	0	0	0	Whole creek sampled
Lamonti	20-Aug-13	LAM10	5	0	0	0	0	LDB
Lamonti	20-Aug-13	LAM11	4	0	0	0	0	-
Lamonti	20-Aug-13	LAM12	2	0	0	0	0	RDB
Lamonti	20-Aug-13	LAM14	4	0	0	0	0	LDB

Tributary	Date	Snorkel Site	Length (m)	# Fish observed				Comments (habitat, location, etc)
				Total	RB	BT	CC	
Lamonti	20-Aug-13	LAM15	3.5	1	0	0	1	LDB
Lamonti	21-Aug-13	LAM17	4.5	0	0	0	0	RDB
Lamonti	21-Aug-13	LAM18	3.5	0	0	0	0	RDB
Lamonti	21-Aug-13	LAM19	2	0	0	0	0	LDB - minimal suitable habitat
Lamonti	21-Aug-13	LAM16	2.5	0	0	0	0	RDB
Lamonti	21-Aug-13	LAM20	2.5	0	0	0	0	LDB - high percent cover pool and high value fry habitat
Lamonti	21-Aug-13	LAM21	3	0	0	0	0	LDB
Lamonti	21-Aug-13	LAM22	6.5	0	0	0	0	LDB
Lamonti	21-Aug-13	LAM23	2.5	0	0	0	0	LDB
Lamonti	21-Aug-13	LAM24	3	1	1	0	0	1x RB approx. 30 mm (Photos 206-207)
Lamonti	21-Aug-13	LAM25	6	1	1	0	0	Photos 208-213 1x RB 30mm. RDB of left side channel
Lamonti	21-Aug-13	LAM26	11.5	1	0	0	1	LDB 1x CC fry 15 mm
Lamonti	21-Aug-13	LAM27	5	1	0	0	1	1x CC fry approx. 10mm. RDB and pool
Lamonti	21-Aug-13	LAM28	7	2	2	0	0	Photos 214 and 215 - showing high value habitat for fry. 2x RB approx. 30mm. Center of pool to RDB
Lamonti	21-Aug-13	LAM29	4.5	1	1	0	0	1x RB approx. 30 mm. RDB
Lamonti	21-Aug-13	LAM30	1	1	1	0	0	1x RB approx. 30 mm. RDB. This site was approx 30 m south of LAM 30
Lamonti	21-Aug-13	LAM31	6	2	2	0	0	2x RB approx. 30 mm. Middle of pool to RDB
Total			**140**	**16**	**10**	**0**	**6**	
Ole	24-Aug-13	OLE1	-	0	0	0	0	Not suitable habitat
Ole	24-Aug-13	OLE2	7	0	0	0	0	LDB
Ole	24-Aug-13	OLE3	-	0	0	0	0	Not suitable habitat
Ole	24-Aug-13	OLE4	1.5	1	1	0	0	1x RB approx. 30 mm. RDB pool
Ole	24-Aug-13	OLE5	2	0	0	0	0	RDB - low value fry habitat
Ole	24-Aug-13	OLE6	3.5	0	0	0	0	Better fry habitat - searched LDB
Ole	24-Aug-13	OLE7	2	0	0	0	0	Upper pool
Ole	24-Aug-13	OLE8	3.5	0	0	0	0	LDB

Tributary	Date	Snorkel Site	Length (m)	# Fish observed				Comments (habitat, location, etc)
				Total	RB	BT	CC	
Ole	24-Aug-13	OLE9	2	0	0	0	0	LDB of right side channel and RDB
Ole	24-Aug-13	OLE10	7	0	0	0	0	Pool
Ole	24-Aug-13	OLE11	6	0	0	1	0	RDB Side pool. 1x BT approx. 80mm
Ole	24-Aug-13	OLE12	3	0	0	0	0	LDB
Ole	24-Aug-13	OLE13	2	0	0	0	0	LDB
Ole	24-Aug-13	OLE14	1	0	0	0	0	LDB
Ole	24-Aug-13	OLE15	-	0	0	0	0	Not suitable habitat
Ole	24-Aug-13	OLE16	1	0	0	0	0	RDB
Ole	24-Aug-13	OLE17	-	0	0	0	0	Not suitable habitat
Ole	24-Aug-13	OLE18	4	0	0	0	0	-
Ole	24-Aug-13	OLE19	-	0	0	0	0	-
Ole	24-Aug-13	OLE20	11	0	0	0	0	-
Ole	25-Aug-13	OLE24	2	0	0	0	0	LDB (opposite of OLE 24)
Ole	25-Aug-13	OLE25	3.5	0	0	0	0	RDB
Ole	25-Aug-13	OLE26	-	0	0	0	0	Large pool at waterfall. Not suitable habitat
Ole	25-Aug-13	OLE27	4	0	0	0	0	Side pool between OLE 26-27.
Ole	25-Aug-13	OLE28	2	0	0	0	0	RDB of left side channel and RDB of right side channel
Ole	25-Aug-13	OLE29	1.5	0	0	0	0	Side channel
Ole	25-Aug-13	OLE30	-	0	0	0	0	Big pool - not suitable habitat
Ole	25-Aug-13	OLE31	3	0	0	0	0	RDB
Ole	25-Aug-13	OLE32	-	0	0	0	0	Not suitable habitat
Ole	25-Aug-13	OLE33	4.5	0	0	0	0	Whole pool - lateral transect
Ole	25-Aug-13	OLE34	2.5	0	0	0	0	D/S of OLE 34 by approx. 10m. LDB
Ole	25-Aug-13	OLE35	2	0	0	0	0	RDB
Ole	25-Aug-13	OLE36	-	0	0	0	0	Flow was too fast - not suitable habitat
Total			**81.5**	**1**	**1**	**1**	**0**	
Factor Ross	26-Aug-13	FR1	-	0	0	0	0	Not suitable fry habitat - current is too fast

Tributary	Date	Snorkel Site	Length (m)	# Fish observed				Comments (habitat, location, etc)
				Total	RB	BT	CC	
Factor Ross	26-Aug-13	FR2	-	0	0	0	0	Not suitable fry habitat - current is too fast
Factor Ross	26-Aug-13	FR3	1	0	0	0	0	-
Factor Ross	26-Aug-13	FR4	1	0	0	0	0	
Factor Ross	26-Aug-13	FR5	3.5	0	0	0	0	
Factor Ross	26-Aug-13	FR6	-	0	0	0	0	LDB not suitable fry habitat and RDB too deep. Unsafe to get to for fry survey
Factor Ross	26-Aug-13	FR7	4	0	0	0	0	Pool on RDB - good habitat but nothing observed
Factor Ross	26-Aug-13	FR8	5.5	0	0	0	0	RDB (2.5 m site length) and LDB (3 m site length) observed
Factor Ross	26-Aug-13	FR9	4.5	0	0	0	0	LDB
Factor Ross	26-Aug-13	FR10	3.5	0	0	0	0	LDB. Two GPS waypoints taken for accuracy check
Factor Ross	26-Aug-13	FR11	-	0	0	0	0	Not suitable fry habitat
Factor Ross	26-Aug-13	FR12	-	0	0	0	0	RDB pool. Rest of site was too dangerous to sample
Factor Ross	27-Aug-13	FR13	2.5	0	0	0	0	LDB - current was fast. Limited suitable habitat.
Factor Ross	27-Aug-13	FR14	4.5	0	0	0	0	RDB and small side pool.
Factor Ross	27-Aug-13	FR15	4	0	0	0	0	RDB
Factor Ross	27-Aug-13	FR16	-	0	0	0	0	Current too fast - not suitable habitat
Factor Ross	27-Aug-13	FR17	-	0	0	0	0	Current too fast - not suitable habitat
Factor Ross	27-Aug-13	FR18	2	0	0	0	0	RDB
Factor Ross	27-Aug-13	FR19	1.5	0	0	0	0	RDB
Factor Ross	27-Aug-13	FR20	1	0	0	0	0	Small pool on LDB. Very little suitable habitat - current very fast
Factor Ross	27-Aug-13	FR22	3	0	0	0	0	RDB
Factor Ross	27-Aug-13	FR23	5	0	0	0	0	RDB
Factor Ross	27-Aug-13	FR24	2	0	0	0	0	RDB
Factor Ross	27-Aug-13	FR21	1.5	0	0	0	0	LDB. Low value habitat and current was fast.
Total			**50**	**0**	**0**	**0**	**0**	

Legend: RB=Rainbow Trout; BT=Bull Trout; CC= Sculpin species; RDB=Right downstream bank; LDB=Left downstream bank; D/S=downstream; U/S=upstream

APPENDIX E

Model Code for Population Estimate

```
## 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.
## Code written by Sima Usvyatsov 18 October 2012 and modified by David Roscoe 15 October 2013

rm(list=ls())
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=6, N = c(2,1,2,6,1,5), n = c(1,1,1,NA,1,NA), u = c(4,16,13,36,83,14)) ### order of creeks/species: Six Mile BT, Lamonti BT, Lamonti RB, Ole BT, Factor Ross MW, Factor Ross BT.
## Initial values
inits <- function() list(U = c(50,80,80,100,200,80), p = c(0.5, 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())

print(out,dig=3)
```

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