Peace Project Water Use Plan

Williston Trial Tributaries

Implementation Year 6

Reference: GMSMON-17

Study Period: April 2016 to March 2017

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GMSMON-17: Williston Trial Tributaries
Year 6 – Final Report

Report submitted to:

BC Hydro, Water License Requirements **Attn: Toby Jones, Natural Resource Specialist**

Submitted by:

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Cover photo: Six Mile Creek overview photo showing the earth berm and section of channel stabilized by this project, 27 June 2016. © C. Smith, DWB Consulting Services Ltd.

EXECUTIVE SUMMARY

The GMSMON-17 project is scheduled as a 10-year monitoring program to assess the effectiveness of mitigation tributary enhancement projects for improving fish and wildlife habitat at select sites along the Williston Reservoir. Potential mitigation stream sites were selected after an extensive review and priority assessment of tributaries along the Williston Reservoir in 2009.Four sites were included in this study that include Six Mile Creek, Lamonti Creek, Ole Creek, and Factor Ross Creek. Mitigation works included the construction of earth berms and installation of other habitat features at two of the four sites, Six Mile and Ole Creek. Construction was completed in 2014 following 3-years of pre-construction monitoring. This is the Year 6 report following 3-years of post-construction monitoring since 2014.

This report falls under the Tributary Enhancement Management Plan that is guided through the GMSMON-17 Terms of Reference (TOR). The GMSMON-17 effectiveness monitoring program is designed to collect data and guide research on the potential response of fish and other indicator groups, including changes to their habitat, in relation to tributary enhancement work. Collecting data and implementing a study design to determine if the mitigation works improved fish passage and habitat was an overarching goal of this project. This is a trial project, so the monitoring component was also used to improve on potential monitoring techniques and increase knowledge of wildlife use in the Draw Down Zone (DDZ) with an emphasis on birds and amphibians. This report gives a comprehensive synthesis of the data and observations that were collected on the streams, riparian areas, draw down zone habitat, fish, birds, amphibians, and plants to address the management questions. The information is summarized through tables and maps of fish, redds, birds, amphibians, plants, and habitat features that were surveyed.

Seven management questions are investigated to determine if the mitigation works had an effect fish, wildlife, vegetation, and associated habitat. The initial plan was to execute a Before-After-Control-Impact (BACI) experimental design. Problems with experimental design and other mitigating factors resulted in a descriptive study with low inferential power. Sample sizes were too small to achieve statistical inference on the research management questions, in particular relation to questions about abundance and relating this data back to the treatment effect (i.e., construction of the mitigation structures). As such, the management questions could not be fully answered. However, partial answers were achieved, new techniques were developed to monitor fish habitat, and an extensive database on fish, wildlife, plants, and their environment was collected, summarized, and has value in terms of giving a better understanding of the species that were investigated. The data is summarized in a format that can be used in future research projects.

Extensive environmental data was also collected and analyzed in this research initiative. High resolution orthophotos achieving 5-7 cm resolution were obtained by seasonal flights of an Unmanned Aerial Vehicle (UAV) with ground control through post-construction study years 4-6. LiDAR data was flown at the study sites in 2011, which provided a baseline pre-construction remote sensing image. The remote sensing data was used to digitize and map stream habitat. A new technique was developed and is described in this report that uses a field based Channel Geomorphic Units (CGUs) system of classification to visually delineate and digitize stream features in a Geographic Information System (GIS). The remote sensing CGU approach was completed along the restoration portions and along the banks of the DDZ for Six Mile and Ole Creek across the study years.

Additional environmental information on precipitation and temperature from locally accessible weather stations was collected, analyzed, and compared in relation to fish and wildlife study observations. Data loggers were also installed at two hydrometric stations to continuously measure depth and temperature at the two mitigation streams. Smaller data loggers were installed at all sites to collect data on stream temperature in the post-construction surveys. Field crews also measured velocity and water depth at one cross section at the two mitigation streams. The stream hydrometric data was used to develop stage-discharge rating curves for Six Mile and Ole Creek. Stream velocity data are averaged in relation to reported nose velocities for spawning fish and this information is synthesized and discussed in relation to habitat quality.

Fish population monitoring included DDZ habitat mapping, rainbow trout visual spawning surveys. Estimations on fish diversity and abundance in the DDZ reach of each stream were provided in previous years of this study, but revision to the TOR (BC Hydro 2015) resulted in the removal of the juvenile fish sampling (mark-recapture) component and this was replaced by habitat availability surveys. Amphibians were inventoried using upland plots and DDZ transects in an effort to obtain estimates of abundance and diversity. Digital photographs of skin patterns are used to "fingerprint" individuals for mark-recapture analysis. Songbirds, waterfowl, and shorebirds were surveyed using breeding bird point counts, land-based observations, and nest searches. The avifaunal component and research management questions went far beyond the feasibility of this project, so a qualitative approach looking at presence and observations of habitat associations was adopted for birds. Riparian vegetation was monitored using annual quadrat sampling and aerial photo analysis.

Observations of fish species and detection of redds during snorkel surveys indicates that passage for rainbow trout, bull-trout, and mountain whitefish was maintained after construction of the mitigation structures. However, the mitigation structures may have increased stream velocity and may reduced the passage potential for burbot, sculpins, and kokanee as observations of these species was either low or absent upstream of the mitigation structures. The inference is based on comparison of the remote sensing CGU's across years indicating that the mitigation works created an extended run through the drawdown zone lacking pools, glides, or cover that would provide access and rests for species with lower swim endurance capabilities. The 2011 raster image did not provide sufficient resolution for detailed comparison of pre-construction CGU's, but resolution of stream channel banks could be digitized for comparison. The mitigation structures and stream banks have remained stable since construction of the mitigation structures. The mitigation structures have reduced the channel width and channel braiding is also reduced, which was one of the mitigation goals. There is some concern in terms of maintenance as debris has breached the earth berm structure at Ole Creek in Year 6, which may eventually lead to blockage at the site.

Amphibian survey data and the maps generated from this study provide a glimpse into the spatial configuration of the different species within and around the study areas. All species known to occur in the local area were detected in the DDZ. Wood frogs tend to be located within the organic veneer of the DDZ, whereas western toads are more widely distributed and seem to make effective use of the entire DDZ. Frogs and toads likely use the DDZ to fulfill most of their life history stages (e.g., breeding and foraging). Long-toed salamanders appear tend to utilized the periphery of the DDZ where leaf litter accumulates under debris and they can deposit eggs in isolated pools. Salamander eggs were detected in ponded areas of the DDZ at Six Mile during year 1 pre-construction surveys, but no further signs of breeding were witnessed despite repeated annual surveys in these areas. It is uncertain if salamander larvae could develop rapid enough to metamorphose prior to flooding in the DDZ unless the site is located in the upper reaches. The appropriate scale to extend the sampling of the research area outside of the DDZ remains a open as amphibians that breed in upland areas likely migrate into and out of the DDZ.

Western toads are the dominant amphibian species of the DDZ. However, the timing of surveys or potential fluctuations in the population cycle during study year 6 lead to few detections. Observations during year 5 indicate that their densities can be very high, but an unbiased estimation was not achieved using transects that would have otherwise permitted an estimation while accounting for imperfect detection. More survey time is needed to make effective use of nigh-time transect surveys in the DDZ. However, review of the digital imagery of skin patterns allowed us to fingerprint an individual that was captured at two separate occasions within the DDZ. This individual stayed in the DDZ and gained weight through a summer season (in between capture times), which provides direct evidence that suitable feeding habitat exists in the post-mitigation DDZ environment. We conclude that all expected species of amphibians use habitats in the drawdown zone, but they likely migrate into upland habitats to overwinter. As such, habitats in the DDZ are very important for amphibian abundance and persistence along the Williston Reservoir.

Terrestrial plants species that were identified during Year 6 ground sampling are known to be tolerant to flooding events or adapted to wet soils for a portion of or the entire growing season (e.g., dwarf scouring-rush, lady's thumb, common and swamp horsetail, bluejoint and water sedge). Flood tolerant herbs have colonized the areas impacted within the DDZ at the mitigation sites, but no firm conclusions could be reached on the abundance or diversity of plant species in specific relation to the earth berm structure. Dwarf scouring-rush has naturally colonized the substrate along the earth berms at Six Mile to replace the graminoids that were seeded post-construction. The grasses died at lower transects due to flooding at greater depth and for longer time than experienced at the upper transect sites where some survival is noted. This finding highlights that flood tolerant vegetation can colonize and survive on the mitigation earth berm structures. However, the level and scale of flooding and additional site specific factors, such as season, substrate, and topography are likely relevant as the berm structures at Ole Creek were not colonized as such.

The scale and footprint of the mitigation structures are too small to have any measurable impact on avian demographics. It is unlikely that the mitigation structure had any effect of biological consequence for birds to any degree greater than experienced in upland areas where land-use changes are noted in the surrounding landscape (e.g., logging). The avian research management questions were too broad in scope to be addressed even if there was substantial increase in research effort. Hence, this report only gives a brief summary on bird sightings and observations. Establishment of woody vegetation is the key factor that could potentially influence avian habitat, use, or demographics in the mitigation areas and there was no appreciable growth or change in this regard. However, a complete tabulated summary of bird species that were detected at point-count stations each year is included in this report.

The closing section of this report provides a summary of our conclusions and a tabulated summary of the progress towards addressing the management questions and hypotheses. A comprehensive review of the methods is provided and recommendations are given in an effort to assist and improve on this type of research. Recommendations on future study design considerations, considerations for research management questions, and a "lessons learned" summary for moving forward and improving these kinds of monitoring programs are provided. The habitat mapping exercise using the remote sensing CGU approach was probably the most useful outcome of this study, but a lack of data on channel depth and velocity precluded the generation of habitat suitability models or indices for fish. The overarching limitation in the study design is the lack of accounting for imperfect detection, which would require more research effort to obtain unbiassed estimates of abundance. CPUE is not recommended as an experimental test index in a BACI design without accounting for imperfect detection, establishing robust controls sites, or including sufficient replication in the study design.

Management Question	Able to Address the MQ?	Scope		Sources of Uncertainty
		Current Supporting Results	Suggested Modifications to Methods where Applicable	
Does access for spring spawners (i.e., rainbow trout and/or arctic grayling) improve as a result of enhancement?	Partial	Detection of rainbow trout, redds, and spawning activity above the modified channel. No physical barriers to fish passage have been observed. Bank slopes increased and channels narrowed through the draw-down zone at the mitigation sites.	• Annual sampling. • Measure flow and channel depth at multiple cross sections. • Implement spatially explicit sampling design with PIT tagging stations. • Run simulations for sampling design, effort, and power. • Modelling of channel flow with discharge data. • Add replicate control study sites. • Account for imperfect detection via applicable statistical methods.	• Arctic grayling has only been detected at Factor Ross Creek. • Identification of redds are primarily based on morphology rather than spawning use and may be subject to observer error (i.e., false positives). • Extent and rate of flow through the modified channel is unknown. • Replicates and controls for seasonal and temporal variation are inadequate. • CPUE without accounting for imperfect detection or proper experimental study design gives uncertain estimates of abundance. • Lack of statistical power.
Is the area and quality of fish habitat created by the tributary enhancement maintained over time?	Partial	Remote sensing data digitized in GIS indicates stability in modified channel sections.	• Annual survey. • Include fish habitat modelling (e.g., River2D) with required field collection data on flow. • Run simulations for sampling design, effort, and power. • Extend length of time for survey effort. • Aerial drone flights below canopy to classify habitat areas above DDZ.	• Variations in depth and flow along modified channel is unknown. • Area and quality of fish habitat cannot be objectively calculated without habitat suitability modelling. • Lack of statistical power.
Does riparian vegetation along tributaries increase in abundance and diversity as a result of	No	2 years of vegetation data (% cover and species diversity) from survey transects following	• None	• Variable reservoir operations • No characterization of DDZ vegetation prior to construction of enhancement

enhancement?		construction of enhancements.		
Does abundance and diversity of song birds (passerines) around tributaries change as a result of enhancement?	No	Annual songbird and waterfowl survey data.	• Larger effort required to specifically relate to treatment. • Remove from project scope or survey in final year of post-monitoring for signs of vegetation use / nesting.	• Scale of treatment impact minor relative to migratory range capabilities of study taxon. Effect size.
Does amphibian abundance and diversity in tributaries change as a result of enhancement?	Partial	Species detections plotted onto maps. One western toad recaptured remained in the DDZ between sampling times (summer Year 6) increased in weight and size.	• Annual survey using mark-recapture. • Expand geographic scale to cover the landscape to address population level effects (source vs. sink habitat). • Focus on western toads and wood frogs. • Additional controls for statistical independence required. • Run simulations for sampling design, effort, and power. • Adopt spatially explicit mark-recapture sampling design. • Extend time for early season DDZ transect surveys. • Monitor body size and condition. • Account for imperfect detection via applicable statistical methods. • PIT tagging for abundance capture-recapture monitoring.	• Scale of the minimal demographic unit of investigation is unknown. • Accounting for imperfect detection or proper study design gives uncertain estimates of relative abundance by CPUE. • Inference about actual population response to treatment is uncertain in relation to habitat use, selection, and performance. • Unknown if eggs are actually deposited into the reservoir. • Metapopulation migration (emigration / immigration) and demographic effect into / from upland habitat and DDZ is unknown. • Natural annual demographic or environmental variation. • Statistical power.
Does tributary enhancement change the area and quality of amphibian breeding habitat over time? If so, is the area and quality maintained over time?	No	Post-construction flooding of amphibian breeding wetland at Six Mile Creek. Evidence of decreased hydrological inputs due to flooding and seasonal saturation of stranded pools in DDZ where long-toed salamander egg deposition occurs.	• Annual monitoring: egg deposition, larvae growth and development. • Extend length of time for early season breeding period to monitor activity. • Add data loggers to wetlands in DDZ and Six Mile wetland.	• Migratory emigration / immigration from upland breeding habitat unknown (landscape metapopulation ecology). • Environmental condition at known breeding habitat unknown. • Natural annual demographic or environmental variation.

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Field work was completed by DWB and CBA staff. Habitat surveys were completed by Clayton Smith (DWB), Sara Sparks (DWB), and Colten Brule (DWB). Spawner surveys were completed by Clayton Smith (DWB) and Brad Turner (DWB). Vegetation sampling and mapping was completed by Allan Carson (CBA). Amphibian surveys were led by Mark Thompson (DWB), Jason Calvert (DWB), and Sara Sparks (DWB) with assistance from Colten Brule (DWB); Sara Sparks entered data and assisted with the analysis. Songbird, waterfowl, and shorebird surveys were completed by Karl Bachmann (CBA) with assistance from Allan Carson (CBA). The hydrological analyses (rating curves) were completed by Meagan Lavoie and reviewed by Emily Cheung P.Eng. (DWB). Vicki Prigmore (CBA) was Project Manager, Mark Thompson (DWB Senior Ecologist) was the Assistant Project Manager, and Brian Aitken (DWB Environmental Manager) was the Project Supervisor.

Additional field work support was provided by Chu Cho Environmental Ltd., a company owned by the Tsay Keh Dene First Nations. Chu Cho Environmental staff that provided assistance in Year 6 were Mike Tilson, Stephen Friesen, and Ranin Izony.

High resolution orthophotos for the four project sites (Six Mile, Lamonti, Ole, and Factor Ross Creeks) were provided by JR Canadian Mapping Ltd using data obtained using their UAV (Unmanned Aerial Vehicle).

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1 INTRODUCTION

1.1 Background

Hydroelectric reservoirs are regulated by retaining after spring flooding and release water to generate power during the fall and winter months. The action of filling and receding water levels creates an area along the shoreline that is subjected to frequent inundation and desiccation that is called the "Drawdown Zone" (Boyle 2012; DDZ). A water use planning process was initiated in 2001 to address BC Hydro's Peace region facilities. During consultations under the Peace Water Use Plan (WUP), the Consultative Committee (Committee hereafter) identified key issues relating to the operations and water-use along the Peace system. The issues were sorted into resource interest categories (Anon. 2003). Fish and wildlife were two of the key interest categories. An objective was set by the Committee to maximize the abundance and diversity of native fish populations and wildlife in riparian and wetland areas. A Williston Reservoir Integrated Management Plan (IMP) was developed that included six components, including a Tributary Enhancement Management Plan.

Large volumes of floating and surface woody debris are contained within the Williston Reservoir, which is a key management issue that the Tributary Enhancement Management Plan is partly designed to address. There is an estimated 105,260 m^3 of debris accumulated along the DDZ of the Williston reservoir that originates from crushed timber or forests that were not cleared in time for the original flooding (1968-1972) and receives input from continued logging and shoreline erosion (Thompson, Schofield & McDermid 2015). The debris is seasonally deposited along the shoreline and becomes refloated as reservoir levels rise and fall (Cubberley & Hengeveld 2010).

While Large Woody Debris (LWD) pieces provide important functional attributes for fish habitats in natural systems and are added to streams in reclamation works, the volume of LWD and hydrodynamics within the DDZ leads to a restriction of spawning migration access, scouring of shoreline that increases sedimentation, and erodes the amount of potentially available habitat (Langston & Blackman 1993; Aquatic Resources Limited 2002; Cubberley & Hengeveld 2010). Fish production increased after creation of the Williston Reservoir, but their numbers went into decline until a new stability was reached in the years following the initial flood. The potential for production gains in tributary systems is limited by access into streams that is restricted by the topography of reservoir or by floating debris that accumulates at the mouths of streams. The Committee reasoned that tributary restoration or enhancement projects designed to improve fish access into tributaries of the reservoir could be used to increase fish production and potentially benefit other flora and fauna through associated ecological pathways.

Cubberly and Hengeveld (2010) conducted a review of 64 Williston Reservoir tributaries to determine if they had access limitations due to debris or morphology. Nine candidate sites were identified for further investigation into the extent of fish access limitations and feasibility of access improvement demonstration projects. Conceptual designs were proposed and recommendations for implementation design and monitoring were provided for the two highest ranking sites in the Parsnip Arm (Cubberly and Hengeveld 2010). The final site selection included Ole Creek, on the west side of the Finlay Arm, and Six Mile Creek, on the east side of the Parsnip Reach.

Cubberly and Hengeveld (2010) inferred limited potential for fish access into Six Mile and Lamonti Creeks that was primarily limited by topographical and habitat constraints in the DDZ. The DDZ channel area was characterized as shallow, braided, no overhead cover, a fine sediment base, and homogenous habitat complexity compared to the riffle-pool sequence that exists above the DDZ. The risk of predation for downstream migration of juvenile fish was also ranked high due to a lack of cover and full exposure during low reservoir levels (Cubberly and Hengeveld 2010). Similar conditions exist at Lamonti, although the length of channel exposed during low reservoir levels is shorter. Fish access and habitat at Ole Creek and Factor Ross Creek were being primarily afflicted by high volumes of LWD that was causing blockage and scour (Cubberley & Hengeveld 2010).

This report falls under the Tributary Enhancement Management Plan that is guided through the GMSMON-17 Terms of Reference (TOR). Construction works were guided through the GMSWORKS-19 TOR that included inventory and prioritization of tributary sites for restoration works to improve access. GMSWORKS-19 includes implementation of restorative measures (e.g., active debris management or berm construction) and facilitation of monitoring programs to gauge the effectiveness of the engineered restoration measures. Construction of earth berms at each mitigation site was completed in 2014 following 3-years of pre-construction monitoring (Roscoe, Poupard & Arsenault 2014).

The GMSMON-17 project is scheduled as a 10-year monitoring program to assess the effectiveness of the demonstration tributary enhancement projects for improving fish and wildlife habitat (BC Hydro 2008) at select sites along the reservoir that were assessed by Cubberley and Hengeveld (2010). The GMSMON-17 effectiveness monitoring program is designed to collect data and guide research on the potential response of fish and other indicator groups, including changes to their habitat, in relation to the tributary enhancement work. This is a trial project, so the monitoring component is also being used to improve monitoring technique and increase knowledge of wildlife use of the DDZ, particularly for birds and amphibians. This report covers year 6 of the GMSMON-17 monitoring program in efforts to gauge the effectiveness of the restorative measures at Six Mile and Ole Creek. The methods and results from years 1-6 are reviewed, including data on the streams, habitat, environment stemming from surveys of fish, amphibians, and vegetation. Results are discussed in relation to the management research questions and hypotheses. Recommendations for moving forward and improving the monitoring program are also provided per conditions outlined in the TOR.

1.2 Overview of Site Enhancement Construction

The Williston Trial Tributary enhancement plans for both Six Mile and Ole Creeks are similar in concept with the shared objective to stabilize the channel within the DDZ and improve fish access. Construction was implemented under the guidance of Environmental Protection Plans (DWB, 2014abc). Approximately 650 m of stream construction work was completed in the DDZ of Six Mile Creek. The installation works (Kerr Wood Leidal and Associates Ltd 2011; DWB Consulting Services Ltd. 2014a; Kerr Wood Leidal and Associates Ltd 2014) included:

1) Lower reservoir berms:
   a) Layered and weighted with:
      i) One tonne grain bags filled with gravel and sand,
      ii) LWD pieces,
      iii) Gravels and,
      iv) Rocks;
   b) Gravel toe with rip rap base;
   c) Vegetated geogrid was pinned to the surface.

2) Lower reservoir, woody revetment log jams
   a) Stream bed materials (cobble, gravel and sand) were used to moor and armor the LWD.

3) Upper reservoir Earth berm
   a) Willow wattles layered along the stream bank edge surrounded by shoreline soil, sand, gravel;
   b) Weighted with LWD, boulders, rocks, and gravels;
   c) Gravel toe with rip rap base;
   d) Topped with vegetated geogrid (pinned), live willow stakes, and grass seed.

The Six Mile installments were confined to the eastern bank in parallel with the main channel and to prevent continued braiding of the channel through the DDZ. Field fit changes were made to the planned design and this resulted in an extension of the earth berm around a small beaver pond. The beaver pond is located along the eastern bank of the main channel at the northern-most transition of the DDZ. Large root wads were placed into the riparian area of the pond to potentially improve habitat for amphibians. Fish salvage was not required, but amphibians were salvaged from the pond and stream riparian area during active construction of the berm (DWB, 2014ab).

The Williston Trial Tributary enhancement works at Ole Creek involved construction works for approximately 250 m within the DDZ. Parts of the channel were isolated during construction and a single rainbow trout was salvaged. Woody debris was cleared from the DDZ prior to commencement of the main works. Surveys for amphibians were conducted and a single long-toed salamander was detected in a south bank debris pile approximately 10 m from debris clearing and berm construction site (DWB, 2014 cd). Field fit changes were made to the planned design as the channel had shifted from previous surveys. The installation works (Kerr Wood Leidal and Associates Ltd 2011, 2014; DWB Consulting Services Ltd. 2014b) included:

1) Lower reservoir berm
    a. Gravel and rock revetments.

2) Upper reservoir berm
    a. Layered with LWD;
    b. Vegetated geogrid pinned to the surface;
    c. Grass seed and live willow stakes.

3) Woody debris catcher
    a. Imported LWD pieces staked into the upper gravel-rock berm with the length extended vertically and on slope.

2 MANAGEMENT QUESTIONS AND HYPOTHESES

The monitoring objectives and hypotheses for GMSMON-17 were stated in the original TOR for the project (BC Hydro 2008). The TOR were reviewed after Year 4 to assess the effectiveness of the monitoring approach in addressing the management questions. Small sample sizes and large confidence limits in estimates of fish abundance is a primary concern. The likelihood of not detecting statistically significant changes in the study design (i.e., risk of a type II error) was considered too great a risk. Therefore, the management question and hypothesis in relation to changes in the abundance and diversity of fish were revised in the TOR (BC Hydro 2015). The revised TOR required a change in methods for the fish research that changed focus onto quantification of change in habitat that could be potentially associated with fish use and abundance.

The revised management questions are restated below along with a brief summary of how each hypothesis is addressed in the study design. The six key management questions in the GMSMON-17 TOR are:

1. Does access for spring spawners (i.e., Rainbow Trout and/or Arctic Grayling) improve as a result of enhancement?
2. Is the area and quality of fish habitat created by the tributary enhancement maintained over time?
3. Does riparian vegetation along tributaries increase in abundance and diversity as a result of enhancement?
4. Does abundance and diversity of song birds (passerines) around tributaries change as a result of enhancement?
5. Does amphibian abundance and diversity in tributaries change as a result of enhancement?
6. Does tributary enhancement change the area and quality of amphibian breeding habitat over time? If so, is the area and quality maintained over time?

The primary hypotheses about the ecological impacts are reframed from the TOR, in sequence to the management questions above and in null-hypotheses format, as follows:

H_{01}: Access to spawning habitat in the spring period – as measured by the proportion of modified channel area with sufficient depth for target fish passage - does not increase following enhancements to tributaries.
H_{02}: Total rearing area for fish does not increase following enhancement to tributaries.
H_{03}: Riparian vegetation abundance and diversity along the tributaries does not increase following enhancement to tributaries.
H_{04}: Amphibian abundance and diversity in and near tributaries does not change following tributary enhancement.
H_{05}: Total amphibian breeding area does not change following enhancement.
H_{06}: Song bird abundance and diversity near tributaries does not increase following tributary enhancement.

DWB and CBA also proposed an additional management question and hypothesis that was incorporated into the TOR (BC Hydro 2008; BC Hydro 2015):

7. Does abundance and diversity of waterfowl and shorebirds around tributaries change as a result of enhancement?

H_{07}: Waterfowl and shorebird abundance and diversity near tributaries does not change following tributary enhancement.

2.1 Monitoring Plan Overview

Baseline monitoring at the two construction sites and replicate stream locations commenced in 2011. The effectiveness monitoring approach is annual sampling of the indicator groups (fish, amphibians, birds, and riparian vegetation) at locations within each stream and in adjacent riparian areas at both the treatment and control sites. The replicate stream locations were included as control sites for a before-after-control-impact study following on recommendations that were included in the initial mitigation review and stream site selection assessment for this project (Cubberley & Hengeveld 2010). Environmental data is also gathered, including data from a hydrometric station installed for this project, manual stream flow and discharge measurements, stream temperature data loggers, high resolution orthophotos obtained by seasonal flights of an UAV with ground control, digital photographs at marked stations, and other variables collected by field crews during their surveys. LiDAR data was flown at the study sites in 2011.

Golder Associates Ltd. completed three years of pre-construction monitoring (Seebacher, Poupard & Arsenault 2012; Roscoe, Poupard & Arsenault 2013, 2014). Stream data loggers were installed at Six Mile and Ole Creek collecting information on temperature and stream depth and discharge rating curves were developed from this data. Vegetation transects were established in the first year of the program and suspended until after construction. Catch-per-unit-effort values were provided from time-constrained searches for amphibians. They inferred that amphibian population sizes were small and focused their surveys to the stream mouths in the DDZ. The bird sampling program was cancelled after the first year. Catch-per-unit-effort (CPUE) values from electrofishing and snorkeling surveys were tabulated and a mark-recapture program was used to provide comparative estimates of fish populations from 2012-2013 (Seebacher, Poupard & Arsenault 2012; Roscoe, Poupard & Arsenault 2013, 2014).

Construction of both tributary access enhancement demonstration projects (Six Mile and Ole Creeks) were completed in the spring of 2014 (Year 4). Construction was occurring during the first spring phase of what was planned as the initial phase of post-construction monitoring. Post-construction monitoring officially commenced later in the summer field season of 2014. Kerr Wood Liedal (KWL) completed the engineering design and survey for the mitigation construction works (KWL 2011, 2014).

DWB Consulting Services Ltd. (DWB) and Cooper Beauchesne and Associates Ltd. (CBA) re-instated the vegetation transects in the fourth year of monitoring (2014) and these continued until the sixth year (2016). The bird sampling program was re-instated and a waterfowl survey was added in the fourth year of monitoring (2014) and continued until the sixth year (2016). Methods for the amphibian sampling program were modified and sampling expanded into upland areas adjacent to the DDZ. UAV flights were flow to obtain high resolution orthophotos and Digital Elevation Models (DEMs) annual since the fourth year of monitoring; DEMs are only created for the berm construction stream sites, Six Mile and Ole Creek. Mark-recapture fish surveys continued in the fourth year, but were suspended thereafter for reasons explained below.

Fish population monitoring includes DDZ habitat mapping, rainbow trout visual spawning surveys, and fish diversity and abundance estimations in the DDZ reach of each stream. Revision to the TOR (BC Hydro 2015) resulted in the removal of the juvenile fish sampling (mark-recapture) component, which was replaced by habitat availability surveys. Amphibians have been inventoried using upland plots and DDZ transects to obtain estimates of abundance and diversity. Songbirds, waterfowl, and shorebirds have been surveyed using breeding bird point counts, land-based observations, and nest searches. The study design required to make a logical inference on the avifaunal hypotheses went beyond the feasibility of this project, so a qualitative approach looking at presence and observed habitat associations has been adopted. Riparian vegetation has been monitored using annual quadrat sampling and aerial photo analysis.

This report covers the third year of post-construction monitoring after installation of earth berms at Six Mile and Ole Creek within the Williston Reservoir. Lamonti and Factor Ross Creeks are monitored in parallel to the mitigation treatment sites. Seebacher *et al.* (2012) and Roscoe *et al.* (2013, 2014) summarize the pre-construction monitoring. Fish sampling methods in Year 1 (Seebacher, Poupard & Arsenault 2012) were based on a Generalized Random Tessellation Stratified (GRTS) survey design protocol (Stevens & Olsen 2004) with glide, pool, riffle, or rapid as habitat strata. However, the locations of strata used in the GRTS design is not clear. Kicknet sampling for fish eggs (none were detected), spawner snorkel surveys, angling with dry flies, and multiple-removal depletion electrofishing were all employed to capture fish.

Methods were revised since few fish were caught and precise estimates of fish abundance could not be calculated (Seebacher, Poupard & Arsenault 2012). Mark-recapture methods to estimate abundance were added in Year 2 (Roscoe, Poupard & Arsenault 2013, 2014). A larger area was sampled and while more fish were captured, the total number of fish caught was still low leading to large confidence intervals in the abundance estimates. Mark-recapture methods continued in Year 4 and were augmented by night snorkel surveys, which increased fish captures and detections. While confidence intervals in abundance estimates were lowered, the inferential capability of the study design was still compromised as statistical power remained low concerning hypotheses on abundance (MacInnis *et al.* 2015). The mark-recapture component was dropped in Year 5 where the research emphasis is to focus on fish habitat classification.

3 STUDY AREA

Williston Reservoir is located in northeastern British Columbia and was created by construction of the W.A.C. Bennett Dam at the head of the Peace River Canyon, about 20 km west of Hudson's Hope, B.C (BC Hydro 2007). The reservoir extends for about 260 km along the Rocky Mountain Trench from the Finlay River in the north to the Parsnip River in the south. The reservoir is generally divided into three geographic regions (from north to south): Finlay Reach, Peace Reach and Parsnip Reach (BC Hydro 2007).

The reservoir is located within the Sub-Boreal Spruce and Boreal White and Black Spruce biogeoclimatic zones (Meidinger and Pojar 1991). The Sub-Boreal Spruce zone is the dominant zone and occurs as two subzones and variants at lower elevations along most of the reservoir (Meidinger and Pojar 1991). The Boreal White and Black Spruce zone occurs only at the northern end of the reservoir in the Finlay Arm (Meidinger and Pojar 1991). The DDZ consists of large areas of mud, sand, and gravel flats with stranded large woody debris. Peripheral reservoir water levels vary annually with filling and drafting.

Study locations are mapped in Figure 1. The Six Mile Creek site is located approximately 40 kilometres north of Mackenzie, within Six Mile Bay on the east side of the Parsnip Reach. Lamonti Creek is located south and adjacently paired to Six Mile Creek as it flows into the same bay area. Ole Creek is located on west side of the Finlay Reach approximately 160 km north of Mackenzie. Factor Ross Creek is located on the west side of the Finlay Reach, approximately 20 km north of Ole Creek (Figure 1).

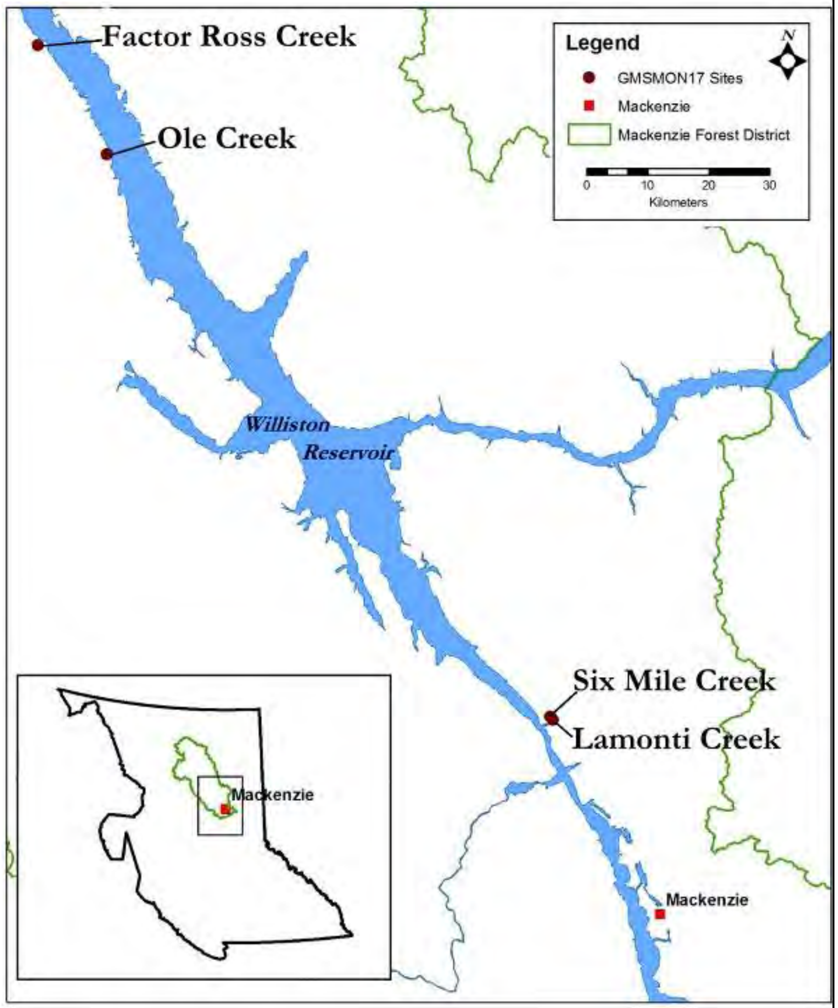

Figure 1. Map of the GMSMON-17 study sites.

4 METHODS

4.1 Environmental Conditions

Data recorded by the Neon stream gauging stations installed at Ole and Six Mile Creeks stations (MacInnis et al. 2016) includes water level, water temperature, and air temperature. Water level and temperature data were reviewed to gauge and schedule the Rainbow Trout spawner surveys accordingly. Additional HOBO TidbiT v2 Water Temperature Data Loggers were installed at each stream study site (**Table 1**).

Table 1. Coordinates and installation details for water temperature data loggers.

Site	UTMs			Date of Installation
	Zone	E	N	
Ole Creek	10 V	404853	6257596	June 25, 2015
Factor Ross Creek	10 V	395270	6275342	June 29, 2015
Six Mile Creek	10 U	474511	6163771	June 23, 2015
Lamonti Creek	10 U	475891	6161835	June 26, 2015

The Pacific Climate Impacts Consortium (PCIC) BC Station Data repository was reviewed for environmental station data nearest to the study sites. The PCIC data portal spatial filter was used to identify stations collecting applicable data covering the study years. Precipitation and surface snow depth was obtained from Environment Canada station ID: 1414, which is located in Mackenzie BC; several months of precipitation data was absent for 2013 and was filled in with data from a BC Parsnip River weather station ID: 2494. Precipitation data was summarized as monthly totals.

Precipitation data representative of the north Finlay Arm was obtained from BC Hydro station ID: 2473, which is located approximately 27 km NW from Factor Ross Creek. The nearest snowfall data station to the Finlay Arm sites was obtained from Aiken Lake station ID: 4A30P, which includes the snow water equivalence. Climatology data was imported into R (R Core Team 2016) to create plots and charts. The BC Ministry of Forests, Lands, and Natural Resource Operations River Forecast Centre was also accessed as needed for data acquisition and environmental charts.

4.2 Stream Velocity, Stage, and Discharge

Stream gauging stations were surveyed on May 3rd, 2016 at Six Mile Creek, and on May 4th, 2016 at Ole Creek. Multiple attempts at manual discharge measurements were required in 2016 due to higher than normal water conditions (Figure 2a). Manual discharge measurements were completed for Six Mile and Ole Creeks on June 27-28th, July 21-28th, and September 13-15th, 2016. Two replicate measurements were completed on each date using a Swoffer 2100 flow meter. Pulse counts were measured in 30 second intervals across the length of the stream in 0.65 m intervals to obtain velocity readings according to the manufacturers instructions. Average velocities were calculated for each sample date and crossing by investigating the graphed cross section and using only the levelled-out values through the center of the channel to avoid glides and slow velocity along the stream edge to coincide with the velocity that might be experienced by fish when spawning or entering the main channel to migrate.

Discharge rating curves for 2016 were created using the power trendline function in Excel. Data since Year 3 of the program was used to obtain the rating curve. The power trendline function is based on a nonlinear regression model. The Excel output formula was used to transform the power trendline to another graph by: $a=1/\alpha$ and $b=1/\beta$ to calculate $\gamma_i = a^b$. A new trend line was plotted for stage gauge values (h_i) starting from 0 m and using 0.05 m intervals according to the following: $Q = \gamma_i h_i^b$.

4.3 Aerial Imaging

Digital orthophotos were obtained from UAV flights with a target resolution of 5 cm ground sampling distance for all four sites. The UAV's were equipped with a Sony alpha 6000 DSLR 24-megapixel camera for collecting RGB photographs and a GPS/IMU (IMU = inertial measurement unit) for recording camera positions. The UAV was preprogrammed to fly a grid pattern at a cruise speed of 25 m/s and at an altitude calculated for optimal photo coverage and resolution for each respective area, depending on the terrain. Ground control stations were installed at each study site in 2014 and re-checked in 2016 prior to launch. The resolution of the ground sampling distance of the photos ranged from 5 to 7 cm. The UAV photos were post-processed using the GPS/IMU data to a geographical accuracy of 2-5 m, orthorectified, and mosaicked together. A 7-cm orthomosaic resolution was achieved. Flights dates are listed in Table 2.

Table 2. Flight dates for LiDAR and UAV orthophoto and DEM data collection.

Site	LiDAR 2011 Flight Date	UAV Flight Date		
		2014	2015	2016
Ole Creek	All sites covered from: May 15th until May 29th	June 16th	May 11th	May 23rd
Factor Ross Creek		June 17th	May 11th	May 5th
Six Mile Creek		June 18th	May 10th	May 6th
Lamonti Creek		June 19th	May 10th	May 4th

4.4 Fish Surveys

4.4.1 Tributary Access Assessment and Fish Habitat

The foreshore area of the Williston reservoir was inspected during the three main field visits in May, June, and September to assess potential barriers to fish passage and map habitat in the DDZ. Field maps were sketched for Six Mile and Lamonti Creek from full pool elevation (672 m) down to the confluence with the Williston Reservoir (elevation: 664.5 m) on May 3rd. Field maps were similarly sketched for Factor Ross and Ole Creek on May 4th. Channel boundaries, habitat types, and stream area were sketched by hand as field crews located features and measured their distance by tight chainage from a GPS reference point. Digital photographs were taken at points of interest and coordinates were recorded. Debris clusters, riffles, pools, boulders, and significant gradient changes were noted and a visual survey for fish was also completed. Photo documentation from the established reference locations and orientations near the mouth of each study stream was continued (see MacInnis *et al.* 2016).

4.4.2 Spawner Surveys

Rainbow Trout spring spawner surveys were completed once stream temperatures were consistently above 5°C in late June (temperatures were recorded at 9.0 to 9.5°C during the surveys). The surveys included all areas surveyed in previous years and an upstream extension that was added in Year 4. Patsuk Creek, a tributary of Six Mile Creek, downstream of the West Parsnip FSR was also included in the spawner surveys in Years 5-6.

Foot-based visual surveys were conducted at each study site from June 27-30th by two observers walking along one bank of the stream. One observer equipped with a dry suit, mask, and snorkel surveyed under water in locations where depth and water velocity permitted. The second observer was stationed downstream from the snorkeler and was equipped with a throw bag for safety. Coordinates of fish sightings and habitat features were recorded, entered into an Excel database, and imported into QGIS 2.18.1 for mapping purposes. MacInnis et al. (2015, 2016) provides additional detail on spawner survey data collection methods including stream survey areas and lengths that were replicated in Year 6. Fish data were imported into QGIS 2.18.1, sorted into layers, by site, and mapped accordingly.

4.5 Habitat Analysis: Digitizing Channel Geomorphic Units

DEM's were extracted from the 2014 and 2016 data; a DEM was not obtained from the UAV in 2015. Elevation cross sections to the wetted width were extracted from the DEMs and 2011 LiDAR data in AutoCAD. Orthophotos were imported into QGIS 2.18.1 to digitize habitat features. A Channel Geomorphic Units (CGUs) system of classification was used to visually delineate and digitize stream features along the restoration portions and along the banks of the DDZ for Six Mile and Ole Creek. There are no current or applicable stream CGU standards in BC's RISC standards for orthophoto interpretation or in the field classification. Hence, the CGU orthophoto digitizing and classification scheme (Table 3) was developed by review of the work cited in Table 4.

Table 3. The CGU classification system used for digitizing mesohabitats adjacent to stream restoration channel reaches. Table adapted from Maddock et al. (2007) and Wilkes (2014); falls, chutes, and ponded CGUs were not used.

CGU	Hydraulics	Brief Description
Side Channel	Varied, generally non-turbulent and slow.	Wetted channels, pools, and drainage areas within the DDZ that connect into the mainstem.
Turbulence	Turbulent and very fast.	Turbulent whitecaps within the mainstem caused by boulders, debris, or topography.
Cascade	Turbulent and very fast.	Highly turbulent series of short falls and small scour basins, frequently characterized by very large substrate sizes and a stepped profile; prominent features of bedrock and upland streams.
Riffle	Turbulent and moderately fast.	A shallow part of the stream where water flows swiftly over completely or partially submerged obstructions to produce surface agitation. Substrate is finer (usually gravel) than other fast water turbulent CGU's, and there is less white water, with some substrate breaking the surface.
Run	Less turbulent and moderately fast.	Moderately fast and shallow gradient with ripples on the surface of the water. Deeper than riffles with little if any substrate breaking the surface.
Glide	Non-turbulent and moderately slow.	Smooth 'glass-like' surface with visible flow movement along the surface; relatively shallow (compared to pools).
Pool	Non-turbulent and slow.	Relatively deep and normally slow flowing, with finer substrate. Usually little surface water movement visible. Can be bounded by shallows (riffles, runs) at the upstream and downstream ends. Sub-pool types were not discerned.
Braid	Varied.	Channel braiding away from the mainstem within the DDZ.
Vegetation or Debris	N/A	Vegetation overhang, large pieces of woody debris, or root wads below the top-of bank.
Wetland	Non-turbulent and stagnant.	The wetted area of stagnant ponded areas in the DDZ.

Table 4 Resources reviewed and citations for the CGU classification method.

Illustrations	Descriptions or definitions
Poole et al. (1997)	Fitzpatrick et al. (1998)
Fitzpatrick et al. (1998)	Maddock et al. (2007)
Tripp et al. (2009)	Buffington & Montgomery (2013)
Buffington & Montgomery (2013)	Wilkes (2014)

Orthophotos for each flight year (Table 2) were imported into QGIS 2.18.1; the 2011 LiDAR image was converted into an orthophoto image using AutoCAD. Separate CGU's layers were created for each year and CGU layers (Table 3) were manually digitized by MDT. White cap turbulence was marked first to assist in clarifying boundaries between riffles and runs. Layers were switched on and off to compare CGU classifications and spatial extents among years and used to calibrate or refine digitized features. QGIS 2.18.1 was used to filter data for mapping and measurements. The CGU habitat mapping process was completed only for Six Mile and Ole Creek. The DEM data provided a contour map to view elevations. Digitized habitat features were imported into Artweaver (Boris Eyrich Software, 2014) to draft field habitat maps over the digitized channels for comparative purposes.

4.6 Vegetation Surveys

A combination of air photo interpretation and ground sampling of terrestrial vegetation was used to describe terrestrial vegetation communities at the project sites (Province of British Columbia 2010, RISC 2010). The TEM standards (Ecological Data Committee & Ecosystems Working Group/Terrestrial Ecosystems Task Force 2010) were used to complete ground sampling of terrestrial vegetation as the plant species assemblages and soil profiles identified within the project sites were not consistent with the wetland classes described by Mackenzie & Moran (2004).

All photo interpretation was completed in 2-D softcopy using ArcGIS (version 9.3, ESRI 2008). Digital ortho-rectified low and high-resolution air photos taken of the project sites, provided by BC Hydro (approx. 100cm pixel resolution; 2011) and JR Canadian Mapping (5cm pixel resolution; 2014-2015), were used as the background layers for delineating polygons. Furthermore, field notes and photographs on vegetation composition and structure from informal inspections of the study sites prior to the air photo interpretation assisted with establishing and updating habitat classes.

A habitat classification scheme based on RISC (2003) was developed to classify all the habitat classes in the study area visible at the air photo resolution available as described in (MacInnis *et al.* 2016). The objective of the classification scheme is to identify and differentiate artificial structures and surfaces from undisturbed habitats at the enhancement sites. In Year 6, a qualitative assessment of the abundance and distribution of habitat and enhancement classes was completed in place of a more detailed re-delineation of habitat and enhancement class polygons. The qualitative assessment of abundance and distribution of habitat and enhancement classes was based on observations made during ground sampling and review of the UAV orthophotos. Vegetation cover and surface features were recorded and representative photographs of notable features were taken. Field and digitized data from Year 6 were qualitatively compared to the distribution and type of polygons delineated in Year 5 for signs of variation.

To aid in the interpretation of habitat classes and monitor any potential changes in the abundance and diversity of riparian vegetation, ground sampling transects were established at each of the enhancement and reference sites. Transect locations were selected to represent the various riparian features and ground conditions (i.e., soil substrates) located at each of the sites; thus each transect would aim to sample different habitats and were not designed as replicates. Transects at the enhancement sites were located on the earth berm structures or on areas disturbed by construction; surface substrates generally consisted of mineral soils (or in the case of Six Mile Creek, a single patch of organic soil) with slight to moderate slopes. Transects at the reference sites were located on natural features (i.e., benches and floodplains); surface substrates consisted of both organic and mineral soils with flat to slight slopes.

In Year 6 (2016), ground sampling was completed at ten of the previously established vegetation transects including three at Six Mile Creek, two at Lamonti Creek, two at Factor Ross Creek and three at Ole Creek. Ground sampling was completed between May 24-30, 2016. Some transects were flooded at the time of sampling: two transects at Lamonti Creek and one at Factor Ross Creek. A list of red- and blue-listed species know to occur in the Mackenzie Forest District was developed using the BC Conservation Data Base (CDC; May 2016) and reviewed prior to commencement of the field work. The species lists for GMSMON 15 project sites during Year 5 surveys (Airport Lagoon and Beaver Pond) were also reviewed (MacInnis, Prigmore & Carson 2016).

As in previous years where species identification was still problematic or where correct identification was particularly important (i.e., with a potential red-listed species), a plant taxonomy expert recommended by the BC Royal Museum was asked to confirm the initial result. Plants listed as rare or endangered at the provincial or federal level were recorded on a Rare Plant Observation Form and submitted to the BC Conservation Data Centre. Further details on vegetation classification methods are available in (McInnis *et al.* 2016).

4.7 Amphibian Surveys

Survey dates for each study location are listed in Table 5. Amphibians were notably absent during the first mid-May start date, so field crews returned to give more time for spring emergence. The Ministry of Environment, Lands and Parks Resources Inventory Branch (1998) Resources Inventory Standards Committee (RISC) methods for amphibians were reviewed and utilized for development of sampling design and technique. An up-to-date literature review on the techniques described in RISC methods was conducted for guidance, development, and improvement of the sampling design, including Hurlbert (1984), Dutilleul (1993), Seber & Thompson (1994), Olsen et al. (1997), Thompson (2012), Efford & Fewster (2013), Krebs

(2014), Christianson & Kaufman (2016), and Muñoz et al. (2016). Terrestrial plots established in Years 4-5 (see MacInnis *et al.* 2016) were surveyed using a two-person 10-minute timed search, but only if amphibians had been previously detected at the plot in previous survey years to direct effort toward night-time transects in the DDZ. Crews also conducted visual surveys by walking through the DDZ and inspecting wetted areas or in sites where water was ponded. Crews monitored for signs of activity and conducted spot checks under pieces of debris as they meandered between plots and transects. Incidental observations were recorded.

Table 5. Amphibian survey dates in 2016.

Site	Survey Dates		
Six Mile	15-16 May	24-25 May	26-29 July
Lamonti	15-16 May	24-25 May	26-27 July
Factor Ross	NA	30-31 May	21-22 July
Ole	NA	28-29 May	22-24 July

Images of DDZ habitat classes established from the vegetation survey work (see McInnis et al. 2016) were imported into GoogleEarth Pro as an image overlay and georeferenced. Transect locations and their bearings were pre-selected in the office to establish two 20 m transects in each vegetation communities. Transect locations for Six Mile are illustrated (Figure 2); coordinates and bearings for all other amphibian transects are included in Appendix 1. Field crews were given a 4-hr training session on the methods, including field cards, animal care, running line transects, and safety. Crews were supplied with a copy of Krebs (2014) chapter 5 on line transect methods as part of their training package. Field card (Appendix 2) included environmental collection fields for substrate, canopy cover, debris class counts [class 1-5 and s = stump; debris classes according to Keisker (2000)], distance to the nearest forested edge, distance to reservoir open water, and elevation.

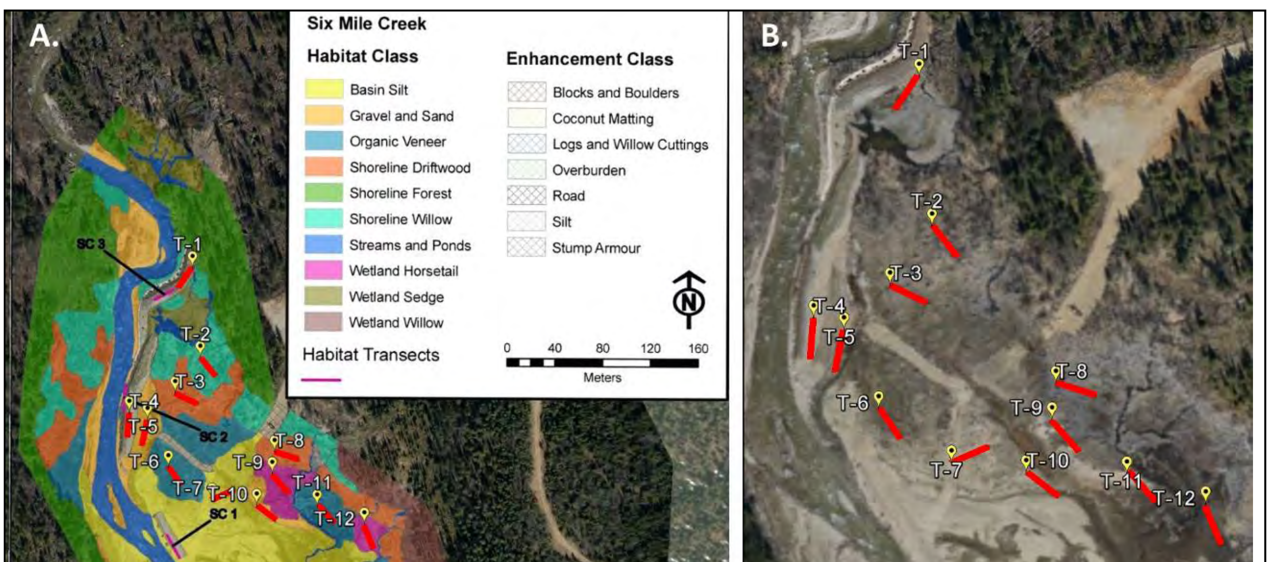

Figure 2. Locations of transects (T1 to T12) established in the Six Mile DDZ illustrated with (A) vegetation habitat classes and (B) transects overlaid onto an Orthophoto at the same locations, but viewed at a different scale.

Amphibian transects were established during daylight with the start and end points marked with flagging. Not all transects established in the office could be surveyed in the time allotted. Most of the DDZ was flooded in the second field trip (Table 5), so new transects were established and field fit where feasible. Transects were surveyed by a two-person field crew between 22:00 and 03:00 and were generally completed in 8 minutes or less. One person walked ahead to sight amphibians while the second person walking behind mark with a painted stone where the sighting occurred and bagged the amphibians. The perpendicular sighting distance and location from the start of the line-transect was measured for each sighting; following methods outlined in Krebs (2014). Hayne estimator density estimates were calculated using Ecological Methodology 7.2 software (Krebs, 2014) and Fourier series calculations were performed in excel using formulas in Krebs (2014)

Captured amphibians (BC Wildlife Act Permit PG14-94627) were photographed, weighed (nearest 0.1 to 0.01 g), and measured (nearest 0.1 mm). Larger adults (>1.5 g) were anesthetized using Oragel™ for processing. Coordinates were recorded using a Garmin GPS for all individuals captured or observed. A field card (Appendix 2) was completed for each individual captured.

4.7.1 Amphibian Data Analysis

Amphibian data entry for year 6 continued according to the policies and procedures outlined in our Data Management Plan (DMP), which is described in McInnis et al. (2016). The DMP follows on the British Ecological Society (British Ecological Society 2014) guidelines and is established to be compatible with the BC Ministry of Environment Wildlife Species Inventory census data entry requirements. All amphibian survey detections were entered into Excel and imported into R-stats for analysis per the BES (2014) guidelines. Ecological Methodology V7.2 software (Krebs 2014) was used for Haynes density estimates from line transects. The Photo Identification Methods (PIMs) approach (Caorsi, Santos & Grant 2012) was continued, but Gape Width (GW), Snout to Vent Length (SVL), or Snout to Urostyle Length (SUL) lengths were collected in the field using calipers to calibrate and test precision of photographic measurement. A paired t-test using R (R Core Team 2016) was used to compare measurements in the field versus data obtained by the PIM approach. The paired t-test included comparing PIM measurements of SVL or SUL from the dorsal versus ventral sides of each specimen; GW was always measured from the dorsal side.

Digital photographs of amphibians were catalogued and then uploaded into ImageJ (Ferreira and Rasband 2012) for processing, visualizing, and measurements. Photographed individuals were double-checked for species identifications that were recorded in the field. Gender was determined as in previous reports (MacInnis *et al.* 2016). Morphometric measurements for long-toed salamanders included SVL, GW, Snout to Gular Fold (SGF), Total Length (ToL), Vent Length (VL), Tail Length (TaL), and Body Area (BA). Morphometric measurements for anurans included SUL and GW; the acronym SULSVL is used in graphical outputs in reference to either SVL or SUL.

Images of individually photographed individuals were sorted into folders named by year, location, and a unique identifier that matched the individual into the database. The I3S analysis software (Speed et al. 2007) I3S pattern+ update was used for skin pattern recognition of long-toed salamanders and western toads[1]. Images from Six Mile and Lamonti were compared in a single database as the geographic separation is insufficient to discount migration of individuals between these locations.

The dorsum was used to annotate skin patterns of long-toed salamanders using the same three landmarks for annotation described in McInnis et al. (2016). The venter was used to annotate skin patterns of western toads using the same three landmarks for annotation described in McInnis et al. (2016). Three key landmarks were used that included the two posterior ends of the lip line and the vent. marking blotchy skin patterns according to an established rule: mark the center of each blotch on the ventral side, posterior to the gular fold, anterior to the pelvic patch, and avoid the limbs. Online video uploads provide demonstration of the I3S pattern+ method with examples of the pattern annotation process (https://www.youtube.com/watch?v=kxiLjryLQvo&t=6s).

[1] A video explaining the software is available: https://www.youtube.com/watch?v=ZVLBW71Jbms

4.8 Songbird and Waterfowl Surveys

Songbird and waterfowl surveys were conducted from May 24-30, 2016 and completed within four hours of sunrise. The approach adopted in Year 4 was repeated (see McInnis et al. 2016) using the 'modified' RIC standards (RIC 1999) for environmental conditions. Waterfowl and shorebird species and activity observations were mapped at any distance from the centre point of a circular 75-m radius survey area. Songbird species detected outside of the 75-m radius were recorded but not mapped. At Six Mile Creek, an additional 30-minute transect survey was also completed along the willows planted as part of the access enhancement project to look for evidence of avian use of this vegetation.

5 RESULTS

A detailed overview and graphed summary of environmental data is included in Appendix 3 for reference. Annual site reference photos are included in Appendix 4.

5.1 Fish Surveys

5.1.1 Tributary Access Assessment and Fish Habitat

The early spring assessments were completed at low reservoir elevations (664.5-664.8 m). The reservoir was ice-free and snow was absent. During the late June field visit, the reservoir was at a high level (669.8 m) and the streams flows had declined from the peak freshet values. In September, the streams were at very low discharge and the reservoir elevation was at 670.4 m and still rising. No physical barriers were observed within the DDZ at any of the stream sites surveyed in 2016. Average cross-sectional velocities is provided in Table 6. Raw data on velocity measurements are provided in Appendix 5.

Table 6 Average velocity readings recorded at a single cross section for two study sites.

Site Location	Date (dd/mm/yyyy)	Average Velocity (m/s)
Ole Creek	28/06/2016	0.64
Ole Creek	24/07/2016	0.62
Ole Creek	14/09/2016	0.52
Six Mile Creek	28/06/2016	0.50
Six Mile Creek	24/07/2016	0.28
Six Mile Creek	14/09/2016	0.48

5.1.1.1 Six Mile Creek

Habitat surveys were scheduled close to the annual minimum reservoir elevation. The 20-year average minimum occurs in April at an elevation of 658.3 m. The minimum level experienced in 2016 was 662.9 on April 8-9th and the reservoir elevation was at 664.5 m when surveys commenced on May 3, 2016. Field based habitat mapping (Appendix 6) was completed on a total of 452.1 m of stream channel during. Water levels were too high to safely complete the site photo references in May 2016, but no barriers were detected in all ensuing survey times (Appendix 4, Photos 1-6).

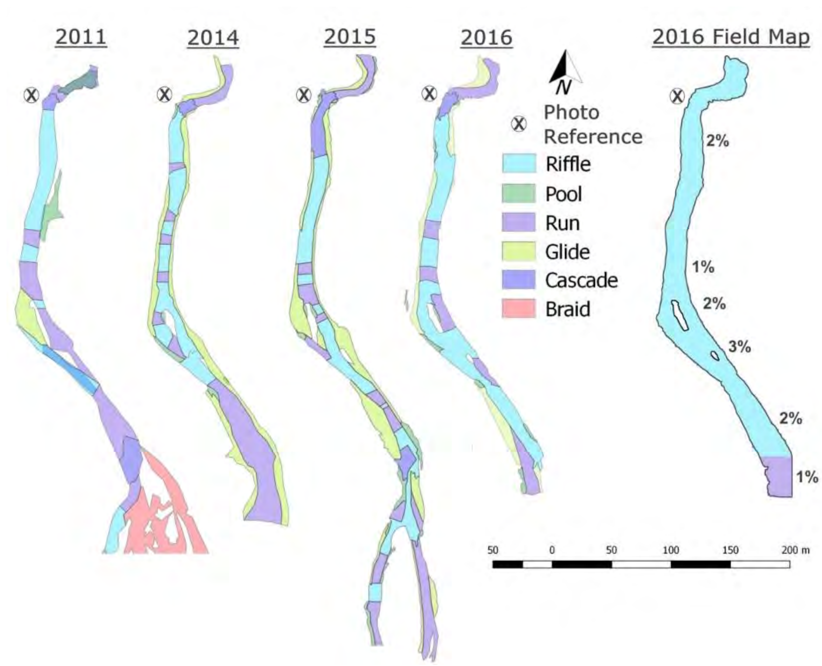

Figure 3. Comparative illustration of CGU classification annotated for Six Mile Creek using QGIS from the 2011 raster image (left), 2014-2016 UAV orthophotos (left to right), and the 2016 field based mapping super-imposed onto the 2016 channel (right). The 2016 field map includes noted changes in channel grade.

The QGIS based 2011 raster and 2014-2016 orthophoto CGU classification (Table 3) is illustrated in Figure 3. The main channel has a riffle-run pattern, which is typically classified as a long riffle with the southern outflow leading into the reservoir. While resolution in the 2011 raster image is less precise, a riffle channel morphology could be identified, but boundaries between runs-riffles could not be discerned. Channel braiding occurs at approximately 325 m into the DDZ in 2011 whereas a single braid occurs at approximately 400 m into the DDZ in 2015 (Figure 3). Side channels and surrounding areas of saturated soils are more extensive and numerous in 2011 (data not shown) and retain a generally consistent morphology from 2014-2016. The AutoCAD cross sectional profiles for Six Mile Creek (data not shown) indicate a stable channel bank location from 2014-2016 and a wider channel with more gradual banks leading to the water edge in 2011.

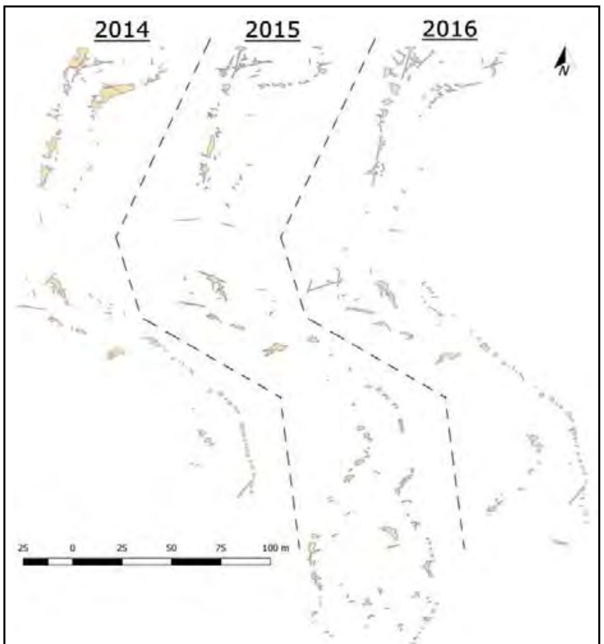

Figure 4. Outline of woody debris and vegetation overhang digitized in QGIS using the 2014-2016 orthophotos.

Digitized outlines of LWD and vegetation overhang at Six Mile Creek from 2014-2016 are illustrated in Figure 18. Resolution in the 2011 raster image was too coarse to digitize this CGU. More extensive cover occurs in the upper reach in 2014, but vegetation was in full bloom and may have caused the appearance of greater area. Vegetation and debris appear relatively stable on a macro level, while smaller pieces are shifting, being lost, or entering the system Overall, the debris and vegetation overhang CGU is relatively stable in pattern through the study years (Figure 4). LWD pieces that were secured into the earth berm structure are raised above and away from the channel and do not touch flowing water. Most LWD pieces (Figure 4) are situated outside and away from the wetted width of the channel.

5.1.1.2Lamonti Creek

Habitat surveys of Lamonti Creek were completed and a field map was created (Appendix 6). The field map illustrates a riffle-braid channel morphology with grades that range from 1-3%. Visual inspection of the orthophoto images through the study years (2011, 2014-2016) reveals a stable channel morphology. Side channels were more extensive, more saturated, and sandbars are flooded in 2016 relative to previous years. No fish were observed during the fish habitat assessment. No physical barriers were observed in the DDZ or at the photo monitoring point (Appendix 4, Photos 7-8). During the final stream visit on September 13, 2016 there was no stream length in the DDZ and no physical barriers to fish habitat were observed (Appendix 4, Photos 13-14).

5.1.1.3 Ole Creek

The AutoCAD cross sectional profiles for Ole Creek (data not shown) indicate a stable channel bank location from 2014-2016 and a wider channel with more gradual banks leading to the water edge in 2011. The main channel is primarily characterized as a long riffle (approximately 200 m) flowing east through the DDZ (Figure 5). A pool CGU is classified for the eastern outflow, which results from the confluence with the infilling reservoir. The exposed length in 2016 is similar to 2014. Extensive braiding is evident in 2011 compared to 2014-2016 (Figure 5). While resolution in the 2011 raster image does not give as precise detail as can be viewed from the 2014-2016 UAV orthophotos, the main channel with riffle morphology is identified, but is narrower. The reservoir level was exceptionally low in 2011 when the raster image was flown and gives an extended view of the main channel through the DDZ to the open reservoir prior to the mitigation works.

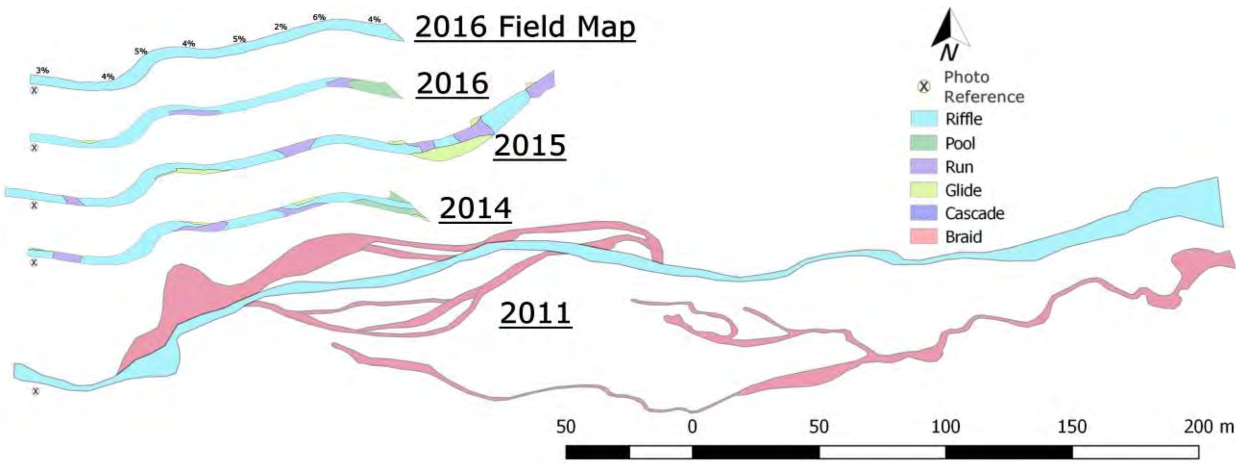

Figure 5. Comparative illustration of CGU classification annotated for Ole Creek using QGIS from the 2011 raster image (left), 2014-2016 UAV orthophotos (left to right), and the 2016 field based mapping super-imposed onto the 2016 channel (right). The 2016 field map includes noted changes in channel grade.

Digitized outlines of pieces of LWD and vegetation overhang at Ole Creek from 2014-2016 are illustrated in Figure 6. Resolution in the 2011 raster image was too coarse to digitize this CGU. Variation in the uppermost reach coverage in this CGU (Figure 6A) is largely due to forest cover and shadow that obscured the view and leads to imprecision in the digitizing process. However, some debris has accumulated along the northern bank and breached the log catcher (Figure 6B); this debris is not present in the 2015 orthophoto. Most of the debris pieces (Figure 4) are outside and away from the wetted width of the channel, but more pieces are contained in the channel compared to the pattern exhibited at Six Mile Creek.

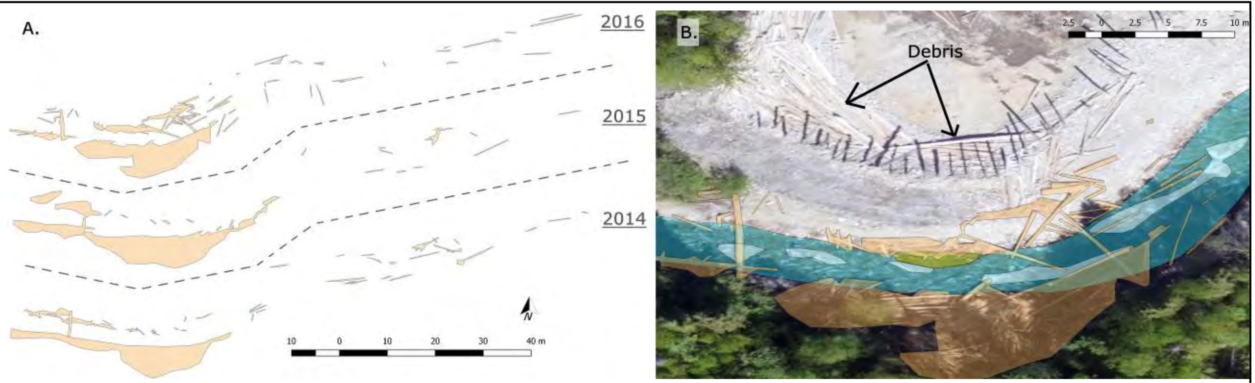

Figure 6. Outline of woody debris and vegetation overhang digitized for Ole Creek using QGIS using the 2014-2016 orthophotos (A). Upstream entry of Ole Creek into the DDZ in 2016 (B) where debris is accumulated on behind the debris catcher and breached sections below the top of bank; digitized CGU layers are turned on for the stream channel.

No physical barriers were observed in the DDZ or at the photo monitoring point (Appendix 4, Photos 15-16). During the final stream visit on September 14, 2016, there was no stream length in the DDZ and no physical barriers to fish habitat were observed (Appendix 4, Photos 21-22). No fish were observed during the field habitat assessment.

5.1.1.4 Factor Ross

Habitat surveys of Factor Ross Creek were completed and a field map was created (Appendix 6). The field map illustrates a riffle-run channel morphology with grades that range from 1-8%. Visual inspection of the orthophoto images through the study years (2011, 2015-2016) reveals a stable channel morphology; note that the 2014 orthophoto for this site was missed. There is little debris in the DDZ in 2011 and an accumulation in 2015. The debris accumulation in 2015 appears to have re-entered the reservoir and/or been raised and accumulated to the highest levels of the reservoir margin at this location. Large amounts of woody debris are accumulated near the photo reference site and have created a small pool. The debris jam does not form a barrier to fish passage and the pool may even provide habitat for fish. Side channels were more extensive, more saturated, and sandbars are flooded in 2016 relative to previous years. No fish were observed during the fish habitat assessment. No physical barriers were observed in the DDZ or at the photo monitoring point (Appendix 4, Photos 23-24). During the final stream visit on September 14th, 2016 there was no stream length in the DDZ and no physical barriers to fish habitat were observed (Appendix 4, Photos 27-28).

5.1.1 Spawner Surveys

Spawner surveys were conducted once the daily mean water temperatures in Six Mile and Ole Creeks were consistently above 5°C. Stream survey conditions are summarized in Table 6. More than 663 fish have been reported since commencement of the GMSMON-17 project; note that spawning data from Year 1-3 (Golder, 2012-2014) is described in terms of CPUE and habitat, but the location and raw count data of fish detections is not provided. There was a total detection of 77 fish, 2 redds, and 2 observations of possible spawning activity in 2016. The largest number of fish detections occur in Year 4 of the program prior to removing electrofishing from the methods (Table 7). Summary details of the spawner surveys are provided in Table 8. Raw data is supplied in Appendix 7. Locations of fish species, redds, and spawning activities are mapped in Appendix 8 for each site. The number of detections increased after the earth berm was constructed, but the increasing detection pattern occurs at the control sites as well (Appendix Maps 8-1 to 8-4). Spawning activities and redds were detected at the Parsnip reach sites only (Appendix Maps 8-1 to 8-2)

Table 7. Conditions during spring Rainbow Trout spawner surveys in Williston Reservoir study tributaries.

Site	Date Surveyed in 2016	Approximate Stream Length Surveyed (2014/2015/2016 in km)	Water Temperature (2014/2015/2016 in °C)	Horizontal Visibility (2015/2016 in m)
Six Mile	June 27	0.295 / 2.2 / 2.2	6.5 / 9.0 / 8.5	3.8 / 8.1
Lamonti	June 30	0. 290 / 1.4 / 1.4	5.5/ 9.5 / 8.0	7.8 / 5.4
Ole	June 28	0.165 / 2.1 / 2.1	6.0 / 9.5 / 8.5	6.7 / 3.9
Factor Ross	June 29	0.133 / 1.7 / 1.7	6.0 / 9.0 / 13.0	2.3 / 2.4

Table 8. Tabulated detections of fish species, redd, and spawning activity by year represented as percentage of total count (bottom row); data from 2011 and 2013 includes only a tally of observations outside of the spawning survey.

Year	Unknown	AG	BB	CC	RB	KO	MW	BT	CAS	Salmonid	Redd	Spawning
2011	1.1%	0.0%	0.0%	1.1%	1.4%	0.0%	4.1%	0.9%	0.3%	0.0%	0.0%	0.0%
2013	0.0%	0.0%	0.0%	1.1%	7.5%	0.0%	0.2%	0.3%	0.0%	0.0%	0.0%	0.0%
2014	0.9%	0.3%	0.2%	6.0%	22.0%	0.9%	17.2%	22.0%	0.2%	0.5%	35.7%	50.0%
2015	0.0%	0.0%	0.0%	0.0%	0.9%	0.0%	0.3%	0.2%	0.0%	0.0%	50.0%	0.0%
2016	0.0%	0.0%	0.0%	0.0%	3.2%	0.0%	7.4%	1.1%	0.0%	0.0%	14.3%	50.0%
All	13	2	1	54	232	6	193	162	3	3	14	4

Table 9. Rainbow Trout spawning detection survey data summary.

Site	Year	Spawning Habitat Area (m^2)	No. of Redds	No. of Rainbow Trout	Comments
Six Mile	2014	111	0	2	Two mature Rainbow Trout observed in area with no spawning habitat
	2015	84.9	3	4	Redds located upstream of Patsuk Creek confluence. Two of the Rainbow Trout observed in a large pool with no evidence of spawning activity.
	2016	83.3	0	15	Most RB detected in pools in reaches with good cover; only 2 RB individuals detected in main channel.
Patsuk	2014	212	0	0	
	2015	4.5[a]	0	0	
	2016	31.1	1	0	Field note identifies Redd as possible (i.e., morphology based, no fish associated) - potential for false positive.
Lamonti	2014	31.1	5	8	Rainbow Trout observations include 2 mature females and a spawning pair.
	2015	14.4	4	1	One adult Rainbow Trout observed on a Redd.
	2016	89.6	1	0	Redd flagged as potential (i.e., morphology based, no fish associated) - potential for false positive. Most spawning potential habitat near log jams with LWD. No fish observed during spawning survey.
Ole	2014	32.13	0	0	
	2015	18.5	0	2	Two Rainbow Trout in separate locations with no evidence of spawning activity.
	2016	164.8	0	0	Velocity through canyon is very strong with best spawning potential in side channels. Lots of fish observed (35-180 mm). Best spawning habitat was largely concentrated to one site (135 m^2).
Factor Ross	2014	34.8	0	0	Two mature fish observed, assumed to be salmonids
	2015	24.3	0	1	One Rainbow trout of approximately 200 mm length.
	2016	128.0	0	3	Few fish observed. Poor visibility with rain/cloud cover. Numerous debris jams. Best habitat u/s of bridge.

[a] – not all spawning habitat was recorded in 2015.

5.2 Vegetation Surveys

No significant changes in the overall abundance and diversity of vegetation or surface features were evident in Year 6 of the vegetative field study and observation through comparison of the enhancement to reference sites or in comparison to the previous year. There are no notable changes to the abundance and diversity of habitat and enhancement classes between Year 6 and Year 5. A summary of enhancement and habitat classes at the four project sites are provided in Table 10 and Table 11. The abundance and distribution of habitat classes in Year 6 are illustrated in Appendix 9.

Location of belt transects are tabulated in Appendix 10. Images and descriptions of the different habitat classes are provided in Appendix 11.

Table 10 Habitat classification summary for enhancement and reference sites in Year 6.

Year 6		Site			
Habitat Class	**Habitat Class Description**	**Six Mile Creek**	**Lamonti Creek**	**Ole Creek**	**Factor Ross Creek**
BS	Basin Silt	√	√	√	√
GS	Gravel and Sand	√	√	√	√
OV	Organic Veneer	√	√		√
SD	Shoreline Driftwood	√	√	√	√
SF	Shoreline Forest	√	√	√	√
SW	Shoreline Willow	√	√	√	√
SP	Streams and Ponds	√	√	√	√
WH	Wetland Horsetail	√			
WS	Wetland Sedge	√			
WW	Wetland Willow	√			

Table 11. Enhancement classification summary for Six Mile and Ole Creek sites in Year 6.

Year 5		Site	
Habitat Class	**Habitat Class Description**	**Six Mile Creek**	**Ole Creek**
BB	Blocks and Boulders	√	√
BL	Boulders and Logs		√
CM	Coconut Matting	√	√
LW	Logs and Willow Cuttings	√	
MM	Mixed Materials		√
OB	Overburden	√	√
RD	Road	√	
ST	Silt	√	
SA	Stump Armour	√	

Table 12. Number of polygons, mean and total area and percent area for habitat classes at enhancement and reference sites in Year 6.

Site	Habitat Class	Habitat Class Description	Number of Polygons	Area (ha)		
				Mean	Total	Percent of Total Area
Six Mile Creek	BS	Basin Silt	7	0.94	6.55	35.78
	GS	Gravel and Sand	12	0.08	0.93	5.05
	OV	Organic Veneer	9	0.17	1.49	8.16
	SD	Shoreline Driftwood	9	0.16	1.47	8.04
	SF	Shoreline Forest	4	0.85	3.42	18.66
	SW	Shoreline Willow	12	0.08	0.99	5.41
	SP	Streams and Ponds	3	0.82	2.45	13.39
	WH	Wetland Horsetail	3	0.07	0.20	1.09
	WS	Wetland Sedge	6	0.06	0.33	1.81
	WW	Wetland Willow	1	0.48	0.48	2.63
			66		**18.31**	**100.00**
Lamonti Creek	BS	Basin Silt	4	1.16	4.6382	28.16
	GS	Gravel and Sand	18	0.10	1.8727	11.37
	OV	Organic Veneer	6	0.35	2.0779	12.62
	SD	Shoreline Driftwood	4	0.22	0.8791	5.34
	SF	Shoreline Forest	3	1.45	4.3474	26.40
	SW	Shoreline Willow	2	0.33	0.6648	4.04
	SP	Streams and Ponds	4	0.50	1.9898	12.08
			41		**16.47**	**100.00**
Ole Creek	BS	Basin Silt	2	1.30	2.61	32.02
	GS	Gravel and Sand	10	0.14	1.35	16.60
	SD	Shoreline Driftwood	3	0.19	0.56	6.89
	SF	Shoreline Forest	2	1.34	2.69	32.99
	SW	Shoreline Willow	1	0.04	0.04	0.55
	SP	Streams and Ponds	1	0.89	0.89	10.90
			19		**8.14**	**100.00**
Factor Ross Creek	BS	Basin Silt	11	0.38	4.20	17.26
	GS	Gravel and Sand	3	0.91	2.72	11.18
	OV	Organic Veneer	2	0.28	0.56	2.30
	SD	Shoreline Driftwood	3	0.46	1.39	5.71
	SF	Shoreline Forest	2	4.44	8.88	36.48
	SW	Shoreline Willow	4	0.16	0.66	2.71
	SP	Streams and Ponds	1	5.93	5.93	24.36
			26	**0.94**	**24.34**	**100.00**

Vegetation established on the earth berm structures consisted of both live and dead shrubs and herbs. Survival varied where willow stem cuttings were planted. At Six Mile Creek, survival of willow stem cuttings appeared low (visual estimate of 5-10% live stems). At Ole Creek, all stem cuttings planted during Year 4 perished (with the exception of 1 cutting that displayed a single live shoot). Annual rygegrass (*Lolium perenne*) seeds germinated each study year and resulted in a combination of live grass cover and vegetation matting covered with dead grass where flooding occured. Native plant species (e.g., Norwegian cinquefoil [*Potentilla norvegica*], marsh water cress [*Rorippa palustris*]) are colonizing some of the enhancement structures at Six Mile and Ole Creek; of specific note was the high diversity colonizing the northern-most enhancement berm at Six Mile Creek (examples included fireweed [*Epilobium angustifolium*], thimbleberry [*Rubus parviflorus*], lady's thumb [*Persicaria maculosa*], smooth hawksbeard, common horsetail [*Equisetum arvense*] and Bicknell's geranium [*Geranium bicknellii*]). However, these incidental observations do not amount to substantial or biologically significant vegetation cover. Photographs illustrating vegetation within transects are provided in Appendix 12.

Images and descriptions of habitat classes as referenced herein are included in Appendix 9. A majority of the terrestrial plant species detected during ground sampling were common to habitat classes located in the upper elevations of the DDZ (e.g., habitat class OV and SD); areas in the lower elevations of the DDZ (e.g., habitat class SG, BS) were either sparsely vegetated or non-vegetated. Examples of the most common species detected along vegetation survey transects (observed at 3 or more transects) included grasses (Gramineae) sedges (*Carex* spp.), common horsetail, water sedge (*Carex aquatilis*) and purslane speedwell (*Veronica peregrina* var. *xalapensis*). Plant species common within the DDZ (but not necessarily observed along the survey transects) included bluejoint (*Calamagrostis canadensis*), swamp horsetail (*Equisetum fluviatile*), dwarf scrouring-rush (*Equisetum scirpoides*), Norwegian cinquefoil (*Potentilla norvegica*) and tower mustard (*Turritis glauca*).

A total of 28 species of herbs and one species of moss were recorded across the 10 vegetation transects. Average percent herb cover by transect ranged from 0% to 22.8% (Table 13). Average percent moss cover ranged from 0% to 0.6%. A summary of the terrestrial plant species and percent cover for each transect is provided in Table 13. The structural stage of vegetation on the benches was graminoid-dominated (2b) and sparse on areas near the main stream channel. The surface substrate on the benches appear to be soils of past forest cover, consisting of a decomposed organic layer overlaying mineral layers (Table 14); surface substrates along the main stream channels are mineral with little to no organic content (Table 14). A comprehensive tabulated summary of percent cover by plant species averaged across 10 quadrats is provided in Appendix 13.

Table 13 Vegetation cover for vegetation transects sampled at enhancement and reference sites in Year 6.

Site	Transect	No. herb species	Average % Herb cover	No. moss/ lichen species	Average % Moss/Lichen Cover	No. shrub species	Average % shrub cover
Six Mile Creek	SC 1	0	0	0	0	0	0
	SC 2	6	22.8	1	0.6	0	0
	SC 3	8	3.9	1	0.7	0	0
Lamonti Creek	LC 2	11	3.7	0	0	0	0
	LC 4	6	0.7	0	0	0	0
Ole Creek	OC 1	2	5.1	0	0	0	0
	OC 2	2	0.2	0	0	1	<0.1
	OC 3	0	0	0	0	0	0
Factor Ross Creek	FC 1	10	5.0	0	0	0	0
	FC 3	8	5.1	0	0	0	0

Values represent the number of species and the average % cover based on plot surveys completed in 2016.

Table 14 Site characteristics for vegetation transects sampled at enhancement and reference sites in Year 6.

Site	Transect	BGC Unit	Water Source[1]	Soil Moisture Regime[2]	Soil Nutrient Regime[3]	Successional Status[4]	Structural Stage[5]	Elevation (m)	Slope (%)	Aspect (°)	% Organic Matter[6]	% Rocks[6]	% Decayed Wood[6]	% Mineral Soil[6]	% Bedrock[6]	% Water[6]	Drainage[7]	Flood Regime[8]
Six Mile Creek	SC 1	SBSmk2	P	2	B	NV	1a	666	2	158	0	30	0	70	0	0	r	A
	SC 2	SBSmk2	P	2	B	NV	1a	671	2	182	60	10	2	28	0	0	r	F
	SC 3	SBSmk2	P	n/a	n/a	NV	1a	677	1	172	99	1	0	0	0	0	n/a	R
Lamonti Creek	LC 1	SBSmk2	F	5	A	DC	1a	663	1	210	0	7	1	87	0	5	r	A
	LC 2	SBSmk2	G	5	D	DC	2b	672	2	230	94	0	6	0	0	0	w	F
	LC 3	SBSmk2	F	1	A	NV	1a	670	1	294	0	65	1	34	0	0	f	A
	LC 4	SBSmk2	G	5	D	DC	2b	672	3	257	89	2	4	5	0	0	r	F
Ole Creek	OC 1	SBSmk2	P	2	B	NV	1a	680	38	188	0	30	30	70	0	0	r	R
	OC 2	SBSmk2	P	1	A	NV	1a	677	2	068	0	50	0	50	0	0	x	A
	OC 3	SBSmk2	G	3	C	NV	1a	675	4	048	0	8	55	37	0	0	r	A
Factor Ross Creek	FC 1	SBSmk2	P	5	D	DC	2b	676	1	014	25	15	8	52	0	0	r	A
	FC 2	SBSmk2	F	5	A	NV	1a	678	2	002	0	0	3	97	0	0	w	A
	FC 3	SBSmk2	P	5	D	DC	2b	677	1	012	87	0	3	10	0	0	w	A

[1] P=Precipitation, G=Groundwater, S=Snowmelt, F=Stream sub-irrigation and flooding, M=Mineral spring, T=Tidal, freshwater, E=Tidal, saltwater, Z=Permafrost
[2] 0=Very Xeric, 1 = Xeric, 2 = Subxeric, 3= Submesic, 4= Mesic, 5= Subhygric, 6=Hygric, 7=Subhygric, 8=Hydric
[3] A=Very poor, B=Poor, C=Medium, D=Rich E=Very rich, F=Saline
[4] NV=Non-vegetated, DC =Disclimax
[5] 2a= Forb dominated – includes non-graminoid herbs and ferns; 2b= Graminoid dominated – includes grasses, sedges, reeds, and rushes
[6] Values represent observations made in 2016, with the exception of LC1, LC3 and FC2 (flooded at the time of ground sampling); values for flooded transect are from 2014.
[7] v=very poorly drained, p=poorly drained =imperfectly drained, m=moderately well drained, w=well drained, r=rapidly drained, x = very rapidly drained
[8] A=annual flood, F=frequent flooding, O=occasional, R=rare flood

5.3 Amphibian Surveys

A total of 39 amphibians were observed or captured through the 2016 field season (Table 15). The amount detected in 2016 is only 17% of what was detected in 2015 and 46% of what was detected in 2014. Furthermore, the data reported in Table 13 includes detections >1 km away from the DDZ. A complete summary of night-time 20-m transects surveyed in the DDZ is provided in Appendix 1 and summarized in Table 16; environmental data is not reported for transects due to the low capture rates. A total of 5 western toads were detected among the transects and no other species were detected. Density estimates (i.e., relative abundance) were calculated, but are not reported as detection rates were too low (Table 16).

Table 15 Amphibian detections (observations + captures) by species and location and year.

Species	Six Mile			Lamonti			Ole			Factor			All Sites		
	2014	2015	2016	2014	2015	2016	2014	2015	2016	2015	2015	2016	2014	2015	2016
Western toad	19	31	8	3	6	6	6	41	3	3	40	4	31	118	21
Columbia spotted frog	6	4	0	1	1	0	0	4	0	3	38	0	10	47	0
Wood frog	6	0	3	0	1	0	1	8	0	14	26	4	21	35	7
Long-toed Salamander	5	0	6	0	1	0	1	2	0	10	8	4	16	11	10
Ranidae sp?	0	3	0	0	0	0	0	1	0	3	18	0	3	22	0
Totals	36	39	18	4	9	6	8	56	3	36	130	12	84	234	39

Table 16 Number of night-time drawdown 20 m transects surveyed followed (after the dash) by the number of detections by month in 2016.

Site	May	July
Six Mile	12-1	1-0
Lamonti	5-0	5-1
Ole	7-0	3-3
Factor	7-0	1-0

Results from the amphibian survey data is summarized in Appendix 14 and detection maps are provided in Appendix 15. Data from amphibian surveys in 2012-2013 are not summarized in the maps as the coordinates and number of individuals captured are not identified in Golder (2013, 2014). Only western toads were detected within the vicinity of the Six Mile (Appendix 13, Amphibian Map 1) and Ole Creek (Appendix 14, Amphibian Map 2) study areas in 2016, despite greater species richness detected in previous study years. Detections of amphibian species outside the main study area are mapped for Factor Ross Creek (Appendix 14, Amphibian Map 3).

One western toad was identified using the I3S pattern+ software as a recapture and moved 44.3 m from its original location (Appendix 14, Amphibian Map 2). The recaptured toad grew in mass and size from its first capture (weight = 3 g; SUL = 35.52 mm; GW = 11.98 mm) until its second capture (weight = 6 g; SUL = 44.90 mm; GW = 15.46 mm) nearly 2 months afterward. A statistical analysis on the methods of measurement is included in Appendix 16.

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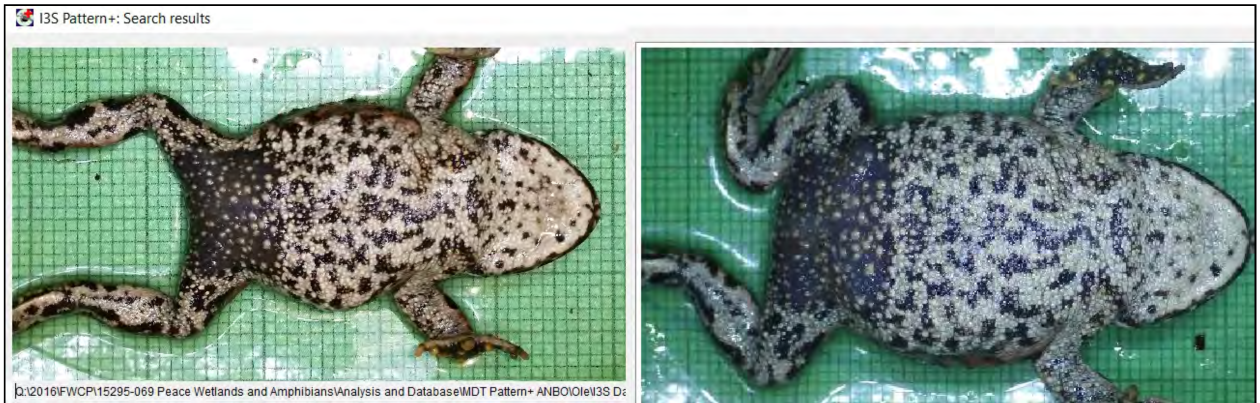

Figure 7 Screen capture from I3S pattern+ software showing a western toad that was captured June 18th, 2015 (left) and recaptured on August 6th, 2015. Note the matching skin pattern (left-right) and change in relative girth.

5.4 Songbird and Waterbird Surveys

Songbird and waterfowl abundance were higher in 2016 (130 detections including 141 individuals) than in 2014 (62 detections including 66 individuals) and 2015 (72 detections including 81 individuals; Table 17). Detections within the 75-m survey radius in Year 6 were higher at all 4 sites when compared to the previous year. No species at risk were detected in 2016. However, in 2015, the Cape May Warbler, a provincially blue listed species, was detected at Lamonti Creek.

Species richness within the 75 m survey radii was higher in 2016 (31 species) than in 2014 (27 species), but slightly lower than 2015 (33 species). A total of 18 species that were recorded during Year 4 or 5 surveys were not detected during the 2016 surveys and 10 species not detected in 2014 or 2015 were observed this year (Table 17). Olive-Sided Flycatcher and Cape May Warbler (provincially blue listed species) were observed at the sites in previous years but were not detected in Year 6 Table 18. Raw data for all post-construction avian survey data is tabulated into Appendix 17.

Table 17. Summary of all songbird, waterfowl, and shorebird detections at Six Mile, Lamonti, Ole, and Factor Ross Creeks in the 2014 – 2016 surveys.

Group	Metric	Site																	
		Six Mile 1			Six Mile 2			Lamonti 1			Lamonti 2			Ole			Factor Ross		
		2014	2015	2016	2014	2015	2016	2014	2015	2016	2014	2015	2016	2014	2015	2016	2014	2015	2016
Songbirds	Species	12	4	4	7	6	15	4	15	13	9	10	15	9	13	11	8	8	10
	Detections	17	4	6	9	8	25	6	19	20	9	10	23	12	17	20	11	10	15
Waterfowl	Species	2	1	0	-	-	1	1	4	0	0	-	1	1	0	0	1	1	0
	Detections	3	1	0	-	-	1	2	11	0	0	-	1	2	0	0	1	1	0
Shorebirds	Species	1	1	1	-	-	1	1	1	2	1	-	2	1	0	1	1	1	1
	Detections	8	6	8	-	-	1	4	4	7	1	-	6	1	0	2	2	3	6
Totals	Species	15	6	5	7	6	17	6	20	15	10	10	18	11	13	12	10	10	11
	Detections	28	11	14	9	8	27	12	34	27	10	10	30	15	17	22	14	14	21

Table 18. Summary of differences between species detected during the 2014 – 2016 surveys.

Detected in 2014 and 2015 but not in 2016		Detected in 2016 but not in 2014 or 2015
American Kestrel	Green-winged Teal	American Crow
Bald Eagle	Lesser Scaup	American Pipit
Black-backed Woodpecker	Northern Rough-winged Swallow	Barn Swallow
Black-capped Chickadee	Olive-sided Flycatcher	Canada Goose
Belted Kingfisher	Song Sparrow	Clay-colored Sparrow
Blackpoll Warbler	Unidentified Flycatcher	Common Yellowlegs
Cassin's Vireo	Unidentified Warbler	Golden-crowned kinglet
Common Merganser	Western Wood-Pewee	Lesser Yellowlegs
Common Raven		Northern Shoveler
Dusky Flycatcher		Wilson's Warbler

In Year 6, two species of waterfowl were detected at Six Mile and included Canada Goose and Northern Shoveler. Waterfowl were not detected at the other 3 sites. In Year 5, waterfowl species were detected at all sites with the exception of Ole Creek with species diversity and abundance highest at Lamonti Creek where Common Merganser, Lesser Scaup, Green-Winged Teal, and Canada Goose were detected. In Year 5, Common Merganser was also detected at Six Mile Creek and a single Common Loon was observed at Factor Ross Creek. In 2014, Goldeneye were observed at Lamonti Creek.

Three species of shorebirds were detected in Year 6 and included Spotted Sandpiper, Common Yellowlegs and Lesser Yellowlegs. Spotted Sandpiper were observed at all 4 sites. Common Yellowlegs were observed at Six Mile and Lesser Yellowlegs were observed at Lamonti. In Year 5, the only shorebird species recorded was the Spotted Sandpiper; they were detected at all sites with the exception of Ole Creek and were most abundant at Six Mile Creek.

6 DISCUSSION

6.1 Fish Habitat Classification

The CGU method was adopted in this study to primarily address research management question #2 (i.e., area and quality of habitat). Wilkes (2014) and Kasprak et al. (2016) provide comprehensive reviews on stream channel classification methods that were largely adopted in the GIS based CGU classification method used in this study. The purpose of the various classification schemes is to study and infer on hydrologic, geomorphic, or ecosystem (i.e., process) response to channel and flood-plain morphology (i.e., form). It is well known that agreement of CGU classification among field personnel is prone to subjective error and that there is natural variation in CGUs across seasons with changing hydrologic conditions (Poole *et al.* 1997). Poole *et al.* (1997) conclude that the CGU approach is not suited for time-trend stream monitoring and is better suited for larger scale watershed comparisons.

A greater level of detail in stream morphology can be extracted by using the GIS-CGU approach, including small pools and glides along channel edges. One of the key cited concerns for fish habitat quality at Six Mile Creek was the homogenous morphology “lacking complexity and functional variability associated with high value fish habitat” (Cubberly and Hengeveld 2010, p. 15). There was a noted break in the pool-riffle pattern, accumulation of fine sediments that could potentially restrict depth, and multiple channel braids; braiding is evident from the digitized 2011 LiDAR data for this site (Figure 3).

Augmenting field classification with remote sensing provides additional resolution to infer on linkages between form and process (Kasprak et al. 2016) and offers advantages over field based classification. The imagery provides a record of the stream CGU status that can be cross compared by personnel and it allows for a visual comparison of habitat quality over time. However, the 2011 LiDAR data did not have sufficient resolution for identifying LWD’s or turbulence (i.e., white caps) on the water surface, but was sufficient for a general overview of the channel morphology with lower confidence on CGU assignments.

While the GIS based CGU technique can be used to achieve greater resolution on relative habitat complexity, we were unable to determine if there are differences in CGU complexity pre-post construction. This problem is not only related to the poor resolution of pre-construction LiDAR imagery, but CGU’s are known to vary seasonally (Poole *et al.* 1997) and the precision of CGU boundaries for calculating area in a GIS may vary by the person doing the digitizing work, according to lighting conditions, or vegetation may obscure some features. These resolution factors are likely to contribute too much variance for qualitative time-series comparison of CGU areas. However, this method offers promise to more precisely stratify stream habitat for planning and preparing field-based sample design.

Habitat area changed as a result of the construction of the earth berms at Six Mile and Ole Creek, including more abrupt bank structure and a more defined main channel without braiding through the full extent that could be observed in the unflooded portions of the DDZ. There is a decline in side channel and flood-plain landform patterns as observed in the digitized data across study years for comparison (data not shown). The LIDAR to UAV Orthophoto data comparison indicates narrower and stable channel banks post-construction. These data suggest habitat may have improved in terms of available depth for fish passage, but precise measurement on channel depth was not obtained (discussed further below under recommendations). The 2014-2016 UAV orthophoto data on LWD was a useful exercise as it shows that debris movement remains active around the mitigation areas and has breached the debris catcher at Ole Creek.

Mitigation works at Ole Creek has changed the area and configuration of the channel, which was primarily a riffle with low banks causing flooding and braiding into the DDZ (Figure 5). The mitigation design at Six Mile has created an extended riffle-run channel morphology and braiding is eliminated (Figure 3), but the channel lacks cover and pools are either too small to capture for resolution in the digitizing process or mostly absent. The LWD was included in the design to provide fish habitat features (KWL 2014), such as creating pools, eddies, cover, refugia, or to increase invertebrate food supplies (Cubberley & Hengeveld 2010). However, the large logs that were installed within the earth berm at this site (KWL 2014) are situated above the wetted channel width and cannot provide stream habitat.

The post-construction channel morphology at Ole Creek is similar to Six Mile Creek with a riffle-run pattern; the pool noted at the eastern outflow for 2016 (Figure 5) is due to the confluence with the rise of the reservoir. Woody debris breached the debris catcher in 2016 (Figure 6), but has not caused blockage. However, piling of debris on the northern bank of the earth berm is cause for concern and future inputs will eventually reach a threshold, as the reservoir returns to peak flood conditions, and will enter the channel.

6.2 Fish Habitat Suitability

While CGU classification via remote sensing is amenable to quantitative analysis (e.g., Kasprak et al. 2016), precision and inter-personnel subjectivity still remains in the digitizing process. Precision of digitized CGU boundaries varies according to the lighting at the time of the flight, which changes the hue and angle of shadows in the orthophoto. Furthermore, a riffle and a run may appear distinct in a single time capture in aerial orthophotography, differentiated by more turbulent white cap versus smoother surface, that may appear less distinguished when viewed in real-time in the field. Canopy cover can also obscure channel boundaries, which was a problem for precise digitizing of the channel boundary at the entry point into the DDZ for Ole Creek.

Water velocity experienced by a fish is called the snout or nose velocity and are considered an important indicator for fish habitat suitability (Morantz *et al.* 1987; McPhail & Baxter 1996; Armstrong *et al.* 2003). While the velocity at the nose of a fish or at a redd was not measured, mean water velocity (Table 6) gives some indication of what might be experienced by fish in these streams. Bull trout spawning at redd sites average $0.35m^{-s}$ (McPhail & Baxter 1996). Water depths of 0.15-2.5 m and velocities of 0.3-0.9 m^{-s} and are normal for rainbow trout spawning habitat and kokanee tend to spawn at depths ranging from 6-37 cm and velocities ranging from 0.15-0.86 m^{-s} (McPhail 2007). Mountain whitefish are found in average water depths of 79 cm (range 60-100) and a water vel0city of 0.62 m^{-s} (range 0.30 to 0.80) (McPhail 2007). Stream depths and velocities at Six Mile and Ole Creek Table 6; Appendix 5) are within the range normal range of nose velocity for spawning trout and adult mountain whitefish. While fish are migrating above the DDZ after construction of the earth berm (see Appendix 8), there is little area for potential spawning as noted from field observations.

Stream depth and velocity values measured at the single cross section for discharge at Six Mile Creek align with a precipitous drop in HSI curves for young-of-the-year rainbow trout, but match a HSI value of 1.0 for mean depth and velocity requirements for juveniles and adults (Laliberte, Post & Rosenfeld 2014). Furthermore, detection of redds and spawning activity (Appendices 7-8) indicate that fish are passing through the new stream channel, but low detection of burbot, sculpins, and kokanee (Table 8) may suggest that sustained speeds required to pass through the >200 m of a riffle-run channel morphology (Figure 3) are insufficient for passage due to an absence of pools and cover. Data on swimming capabilities are available for fish species in this study (e.g., Taylor & Foote 1991; Parker 2000), but more detailed analysis would be required more generally to relate swimming capabilities to field conditions (e.g., Froude number) or to model passage in terms of HSI.

Extents of stream substrate, including boulders and classification of cobbles, gravels and fine materials are visible at the resolution of the UAV orthophotos from 2014-2016 and could be used in habitat suitability modelling (e.g., Koljonen *et al.* 2013); water clarity was also sufficient at the study locations for this type of exercise. However, bed material was not classified into GIS layers for spatial analysis in this study as additional data on depth and flow would be required for development of an applicable HSI. Nonetheless, there is no apparent change in substrate size distributions using visual comparison of downstream substrate in the UAV orthophotos among study years 4-6.

6.3 Environmental Stream Conditions

Temperature and hydrological inputs for Year 6 were atypical (see Appendix 3). The average source of annual reservoir inflows is 51% from snow and 49% from rainfall (BC Hydro 2007), but snowpack was low in 2016. The primary supply of inflows for 2016 was likely supplied by peaks in rainfall, which is registered in the high early season (April) and chaotic seasonal fluctuations in the 2016 mean water depth. These changes are consistent with a warming climate and significant declines in snow accumulations in BC, which is causing transition from snow to hybrid (nival / pluvial) or rain-dominated hydrological conditions (Kang *et al.* 2014). Higher than normal water levels in April-May also prevented field crews from the manual discharge measurements task at this time. The environmental differences noted for 2016 has the potential to affect stream ecology and fish migration through associated changes in water chemistry, flow rates, and associated hydrodynamics (Gunn & Keller 1984; Poff *et al.* 1997; Pringle 2003; Kang *et al.* 2014).

The rating curves and stage discharge tables were updated for both Six Mile and Ole Creeks based on the manual discharge measurements recorded across a variety of discharge levels in Year 6. A concern of the mitigation works is the potential to impact flow that would register in the discharge rating curve. The pre-construction rating curves for Six Mile and Ole Creek (Roscoe, Poupard & Arsenault 2014) are similar to the post-construction rating curves (see Appendix 3). There is greater potential utility for the rating curve in relation to the research management questions, as discharge is "a 'master variable' that limits the distribution and abundance of species and regulates the ecological integrity of flowing water systems" (Doyle *et al.* 2005, p.1). However, the discharge measurements have not been utilized as such in this study. Orth & Leonard (1990) demonstrate the use of discharge rating curves to obtain estimates of the amount of usable fish habitat.

6.4 Spawner Surveys

The observation of spawning activity in both Six Mile and Lamonti Creeks confirms that the timing of the surveys with the observed water temperatures was appropriate. Daily mean water temperatures that are consistently above 5°C are the initial indicator for the timing of the surveys. Daily maximum and minimum water temperatures were close to 7°C during the spawner surveys in Year 6 as recommended in last years report (MacInnis *et al.* 2016).

Spawning activity for bull trout occurs below a 9^0C threshold and generally occurs in mid-September to late-October and varies little with latitude (McPhail & Baxter 1996). Rainbow trout spawning migrations are triggered by temperatures above 5^0C and rising water levels, they spawn just before ice-out (late April to May), and deposit eggs when temperatures reach 8-15^0C (McPhail 2007). Kokanee spawn in the fall when water temperatures drop below 12^0C (McPhail 2007). While these environmental conditions coincide with the schedule and timing of the spawning surveys completed in this study (Appendix 3) it is important to note that spawning times can vary and even up to a month between inlet and outlet populations in the same lake (McPhail 2007), which could skew the results of this study as insufficient survey time was used to collect the data (discussed further in closing section of this report).

A technical error lead to a limited window of temperature data for Lamonti Creek is limited to a narrow time window (June 26 - July 26, 2015; see Appendix 3). The maximum temperature reached in this window was 14.0^{0}C, while the maximum temperature at Six Mile during the same time window was 11.4^{0}C, which is consistent with last year's inference from the timing of fry emergence and spawning observations that Lamonti Creek may be slightly warmer than Six Mile Creek (DWB and CBA 2015).

The lack of redd observations at Factor Ross and Ole Creeks is not considered evidence of an absence of spawning. Spawning has been confirmed in previous years by the identification of Rainbow Trout fry and juveniles in all four streams during the August field surveys (Roscoe, Poupard & Arsenault 2014). Additional length of survey time is required to comprehensively address questions concerning spawning and accessibility in these streams. Poor visibility is also limiting factor at Factor Ross Creek. The area of suitable spawning substrate identified at each study site is highly variable from year to year (Table 9) and may be due a combination of inter-observer subjective variation; one member of the field crew has remained, but the two-person team structure has changed.

6.5 Amphibians

Amphibian encounters and activity was low in Year 6 compared to study Years 4-5. The first May 15-16th survey time was cancelled and field crews returned May 24th, but amphibians were still relatively inactive as noted in the low detection rates. This contrasts sharply against Year 5 where more western toads were observed than could be processed and they were so densely spaced that observers also had to be careful not to step on them during the night-time surveys. Detection rates were too small in Year 6 to yield biologically meaningful results for either plots or transects established in the DDZ. The wetland at Six Mile and transects within the DDZ at all other sites were flooded by the time that the second amphibian field survey occurred (July 21-29). While field crews installed new transects along the shoreline where room was available the dynamic nature of the DDZ and timing of inundation is a key complicating factor in the research.

Seebacher *et al.* (2012) identified long-toed salamander eggs on May 11th, 2011 in one of the pools of the DDZ and western toads displaying courtship behaviours were observed on June 3-4th, 2015 in small inlets of the reservoir that finger into the DDZ (MacInnis *et al.* 2016). In other studies in surrounding areas of the Williston Reservoir, MacInnis, Prigmore & Carson (2016) report long-toed salamander eggs on May 7-8th 2015, tadpoles were reported June 12th, 2012 (MacInnis *et al.* 2013), egg masses May 11-12th, 2014 (MacInnis, Prigmore & Carson 2015), and eggs and tadpoles were observed from May 12 – June 16th, 2013 (MacInnis, Prigmore & Carson 2015). Hence, there is a two-month period from early May until late-June where breeding amphibians become active around the Williston Reservoir, but it is difficult to gauge when breeding will be site-specifically or annually active within this window. Consistent warm temperatures are important, but the influence of weather and even the lunar cycle on the timing of spring-time emergence and behaviour of amphibians is rather complex in amphibians (Green, Das & Green 2016). It is suspected that activity was reduced in 2016 due to more dynamic fluctuations in daily air temperatures, which were sustained well above 5^{0}C in 2015 at Six Mile and Ole Creek (Figure 12), but did not reach the same steady daily high temperatures until the middle of June (see Appendix 3).

The detection of salamander eggs in stranded pools of the DDZ in study Year 1 (Seebacher, Poupard & Arsenault 2012) is important for several reasons. First, it is not known if the larvae will have sufficient time to develop and mature prior to flooding by the reservoir. This seems unlikely unless the sites are situated high in the flood zone as long-toed salamanders metamorphose late in the summer season to early fall (M. Thompson, personnel observation). Second, the mitigation works may have reduced the amount of flooding and saturation into the DDZ at Six Mile Creek, which would reduce available water supplies; the flooded area was digitized in GIS for some years and visual inspection of the orthophotos leads us to conclude that the area of saturation is reduced post-construction. The digitized area of saturation is not quantified or shown, because the boundaries of saturation is not sufficiently clear for precise demarcation. However, it is clear that the DDZ drains more readily at Six Mile without the braided channels that are illustrated in Figure 3. Small pools of water continue to exist within the DDZ at Six Mile and these were surveyed each season, but it is not known how the hydrodynamics of these pools might have been affected by the mitigation works. The discovery of long-toed salamander burrows within hard pieces of birch logs (Thompson & McDermot-Fouts 2016) is an important discovery for upland habitat. This discovery leads to a new understanding of habitat use and may serve to increase detection rates for this elusive species in forested plot areas. This natural-history information can also be used to address questions on their relative detectability or occupancy in wooded areas according on the type of woody debris that is present.

CPUE data was reported in previous reports in relation to the amphibian surveys (Roscoe, Poupard & Arsenault 2013, 2014, MacInnis *et al.* 2015, 2016), but there are fundamental flaws with the CPUE approach, which is why it is not reported for this study year. Durso & Seigel (2015) note that the CPUE approach "is not suitable for accurate long-term monitoring" (p. 503). Rodda *et al.* (2015) cite similar concerns and review the problems of wasted effort due to issues associated with detectability and study design. Relative abundance is also problematic as potential test measure in the BACI approach. Further recommendations in relation to CPUE and the BACI study design limitations are provided in the closing section of this report.

Management question #5 includes a question about effects of the enhancement on diversity of amphibians. However, there are multiple meanings behind the term "diversity" (Anderson *et al.* 2011) and species richness is unlikely to be impacted or detected (i.e., low effect size) with so few amphibian species in the region. Multiple authors have recognized biomass is encompassed as an index of diversity (McIntosh 1967; Whittaker 1972; Anderson *et al.* 2011). As such, body size and biomass became a focus of the investigation in Years 4-5 in an attempt to increase effect size and address the research question; these indices have proven effective in other studies (Wright & Zamudio 2002; Băncilă *et al.* 2010; Powell & Babbitt 2015). Body size or biomass data is not analyzed in this year's report, because sample sizes were too small and the sampling design requires attention as discussed further in the closing section of this report. However, if the PIM measurement approach is adopted in future investigation, then disagreement between field measurement needs to be understood. The directional t-test results (Appendix 16) may indicate that the person doing the measurement is consistently doing a different kind of measurement in the field versus in the office and may be resolved through training.

Amphibians can migrate incredible distances to find breeding partners. Denton, Greenwald & Gibbs (2016) report on distances approaching 15-km for Ambystomatid salamanders and western toads are known to have home range sizes in excess of 2 km^2 and up to 7 km^2 (COSEWIC 2012). Hence, the sampling design that would be required to answer questions about relative amphibian abundance and treatment effects (i.e., $H_0 4$ and $H_0 5$) at the scale of individual stream basins requires sampling beyond the DDZ. Amphibians migrate through and are affected by different parts of a landscape in relation to their complex life history (Trenham & Shaffer 2005). Hence, the upland plot survey method adopted in Years 4-5 was continued in Year 6, but only plots where detections were previously made were revisited to reduce on the amount of effort until sampling design problems could be resolved and to concentrate effort on night-time transects within the DDZ; the reasoning behind this is discussed further in the closing section of this report.

Density measures within transects is an effective and proven method to measure of relative abundance (Buckland *et al.* 2005), in accordance with research management question #4; density and abundance are used interchangeably in the literature (e.g., McIntosh 1967). The advantage of line transects is that it can provide an unbiased estimator of density by fitting a detection function (Buckland *et al.* 2005; Krebs 2014) and the DDZ provides an open habitat to execute this technique. The decision to establish night-time transects in the drawdown zone was made after an initial trial was completed in Year 5 when encounters were common. They were completed at nigh when the western toad activity peaks. However, insufficient captures were made in Year 6 and more intensive sampling would be required to account for seasonal fluctuations of activity. Either the sampling time for amphibians did not coincide with seasonal activity in the DDZ in Year 6, or activity was attenuated throughout the season and amphibians did not aggregate into densities that were qualitatively witnessed in Year 5.

It is possible that the mitigation works within the DDZ had an impact on the amphibian populations in the area through the removal of debris, through roadway construction, and by machinery compaction in areas that may otherwise provide important food supply and cover. The recapture of the single western toad within close proximity to its initial capture point in the DDZ (Appendix 15, Amphibian Map 2) indicates that these individuals remain local through most of the season. More recaptures providing replicates on this inference would increase confidence in this inference and to sort out the important distinctions between habitat use, habitat selection, and performance (Gaillard *et al.* 2010; Boyce *et al.* 2016). However, this individual gained weight through a summer season (in between capture times) and provides direct evidence of an increase in biomass within the DDZ of a treatment area, Ole Creek. Therefore, we can conclude that the research management question has been partially answered through a record of increased abundance in terms of biomass. The mitigated DDZ area provides suitable feeding habitat for western toads. Additional replicate recapture data is needed to increase confidence in this conclusion, because results from the single western toad may not represent the population as a whole.

Understanding upland habitat connection is a critical part of the amphibian study. Western toads tend to forage at night in treeless habitat within 15-m of refugia that can provide a suitable microclimate with relative humidity elevated relative to the surrounding habitat (Long & Prepas 2012). However, western toads must return into upland areas to overwinter (Browne & Paszkowski 2010). Western toad adults have been detected in adjacent upland plots, but their migratory movements in relation to the DDZ are unclear. Extension of the effective survey area into the upland habitat surrounding the DDZ is necessary to address the research management questions, because surrounding metapopulation structure within the landscape is very likely having an effect on local abundance in the DDZ. Hawkes, McKinnon & Wood (2017) used telemetry to monitor garter snakes moving seasonally out of the reservoir into upland habitats and there is strong evidence to suggest that western toads "use a portion of the drawdown zone during some or most of their active season (breeding period for toads in the spring, foraging or basking sites for snakes, which coincides with spring and summer) and subsequently move into upland habitat later in the summer or early fall for overwintering" (p. 61). Likewise, we observe that all species occur in the DDZ and adjacent upland habitat, but the extent or level of migration between these habitats has yet to determined. Amphibians using the DDZ in the spring must migrate into the adjacent upland forests as the area becomes flooded and inundated. Metamorphs and adults emigrating from upland breeding habitats may also move into the DDZ to forage and later return into upland habitats to overwinter.

The maps that have been generated from this study provide a first glimpse into the spatial configuration of the different species (Appendix 15). For example, wood frogs tend to be located within the organic veneer of the DDZ, whereas western toads are more widely distributed and seem to make effective use of the entire DDZ. Hawkes, McKinnon & Wood (2017) conclude that western toads and frogs use "the DDZ to fulfill most of their life history stages (e.g., breeding, foraging and, in the case of turtles and possibly frogs, overwintering), while other species (e.g., Long-toed Salamander, garter snakes) appear to use the DDZ to fulfill specific life stages" (p. 61). A similar pattern (except turtles) may occur within the Williston Reservoir. However, while Hawkes, McKinnon & Wood (2017) conclude "that all life stages of all expected species of amphibians […] use habitats in the drawdown zone" (p. 72), we question if overwintering of western toads is feasible in these environments as the structure of their brumation sites requires cavities, crevices, decayed root channels, or abandoned beaver lodges above the water table (Browne & Paszkowski 2010). Nonetheless, habitats in the DDZ are very important for amphibian abundance and persistence along the Williston Reservoir. Further, the uniqueness of the DDZ and suspected high abundance of amphibians using the area creates a unique set of ecological conditions in the transition from upland forested habitat as animals migrate in and out of the DDZ.

6.6 Vegetation

Mackenzie and Moran (2003) describe naturally recurring wetlands within British Columbia that are relatively stable in terms of their hydrologic cycle and plant species composition and have established over long periods of time. The plant species assemblages identified in this project are in constant transition to a stable state due to variability of flood events in the DDZ from dam operations. We infer no biologically significant changes in the abundance and diversity of habitat and enhancement class polygons in comparison to the previous year and this is based on our qualitative assessment of the terrestrial habitat mapping in Year 6. Thus, mapping completed in Year 5 provides an accurate representation of enhancement and habitat classes present at the sites in Year 6.

A total of nine habitat classes and one non-vegetated (open water) habitat class were identified at the four sites. With the exception of three wetland habitat classes identified at Six Mile Creek and one habitat class absent at Ole Creek, the vegetation communities documented at the enhancement and reference sites were very similar and their distribution throughout the DDZ followed a similar pattern. The general pattern, beginning at the forest edge and moving down the DDZ in bands relatively parallel to the shoreline, begins with willows and grasses, followed by a moderate to high cover of coarse woody debris, transitioning into sparsely vegetated organic and coarse mineral soil surfaces and ending on non-vegetated silt flats that meet the reservoir body at low pool.

Terrestrial plants species identified during Year 6 ground sampling are known to be tolerant to flooding events or adapted to wet soils for a portion of or the entire growing season (e.g., dwarf scouring-rush, lady's thumb, common and swamp horsetail, bluejoint and water sedge). Many of these species have also been observed in other areas of the Williston reservoir (e.g., GMSMON 15 Airport Lagoon and Beaver Pond sites; (MacInnis, Prigmore & Carson 2016). Nine vegetation enhancement classes were mapped for Six Mile and Ole Creek. Enhancement structures at the two sites were for the most part similar and were concentrated along the edge of the main stream channels. During Year 5 ground sampling, some shrub and herbaceous vegetation had established on the enhancement structures, including willow stem cuttings, annual ryegrass and a few native herbs. The high mortality in willow stakes is likely due to the nature in which the cuttings were planted (e.g., shallow depth, damaged tissue from pounding into hard ground).

With the exception of the undisturbed forest cover at shoreline, the habitat classes observed at the four sites have developed in response to the annual flooding regime from reservoir operations. As the timing of reservoir filling and the maximum elevation reached varies from year to year the species present in each of the habitat classes is expected to be variable, particularly in higher elevation habitat classes that may not be flooded every year. This is evident in the cross-year comparison at the control sites. For example, there is decline in herb cover at the Lamonti control sites: 0.6% cover in herb, forb, and graminoid species in transect LC4 in 2016 (Appendix Table 13-1), 35.3% in 2014 (MacInnis, Prigmore & Carson 2015), and 7% in 2015 (MacInnis *et al.* 2016). Variation is not as great in percentage cover across years at the Factor Ross site (*c.f.*, Appendix 12 in MacInnis *et al.* 2015; Appendix 14 in MacInnis *et al.* 2016). Species that are less tolerant to flooding may colonize the DDZ during the following growing season in a year where the reservoir level does not reach full pool (e.g., MacInnis *et al.* 2015, 2016a). In comparison, species that are less tolerant to flooding are for the most part absent during a year where full pool is reached.

Vegetative cover across the three transects on the berm structures at Six Mile Creek increases with increasing distance and elevation from the reservoir flood zone (Table 13; Appendix 9, Vegetation Map 1). However, there is more herbs cover in the middle transect SC-2 (Table 12). Cover in the upper transect (SC-3) is represented by graminoid species (dead and alive) that were seeded as part of the reclamation effort. Herb cover (dwarf scouring-rush; Appendix Table 13-1) is identified in the middle transect. Dwarf scouring-rush is known to occur on naturally hygric sites where the water table rises above the ground surface in the spring or on fluvial benches (Delong 2004).

Dwarf scouring-rush has naturally colonized the substrate along the earth berms at Six Mile to replace the graminoids that were seeded post-construction. The grasses died at lower transects due to flooding at greater depth and for longer time than experienced at the upper transect sites where some survival is noted. This finding highlights that flood tolerant vegetation can colonize and survive on the mitigation earth berm structures. However, the level and scale of flooding is an important factor, because dwarf scouring-rush was only detected in the lower transect (SC-1) in the first year of post-construction investigation (see Appendix 14 in MacInnis, Prigmore & Carson 2015). Moreover, additional site specific factors, such as season, substrate, and topography are likely relevant and further investigation would be needed to understand the colonization process as the berm structures at Ole Creek were not colonized as such.

6.7 Songbirds and Waterbirds

Birding survey points were located within the DDZ, along streams near the enhancement works. Habitat diversity is extremely limited with little to no established vegetation within the 75 m radii. This is likely the primary limiting factor in relation to both species richness and abundance. There were no unusual songbird, waterfowl or shorebird detections at any of the study sites. Waterbird and shorebird surveys were first completed in Year 4. Though slightly higher than the previous year, abundance and diversity remained low during the Year 5 surveys.

Higher than average water levels in Year 5 required survey points to be moved to higher elevations at both Lamonti Creek and Factor Ross Creek. The reservoir level also decreased the amount of available terrestrial habitat within the survey radii. Water noise levels at Six Mile Creek made it challenging to complete point count surveys at that site.

Terrestrial habitat diversity, quality and quantity increases with distance from the DDZ. Incidental observations for birds outside of the 75-m range were higher than the number of detections within the survey plots in most cases. Pre-construction surveys detected a total of 70 species at these sites (Golder 2012). However, those surveys included more points and covered a wider variety of habitats at each of the sites. Re-vegetation efforts formed part of the enhancement works at Ole and Six Mile Creeks. This has the potential to improve habitat availability and may result in increased avian use in the coming years.

7 CONCLUSIONS AND RECOMMENDATIONS

This report provides a comprehensive summary of data and results from the sixth year of a ten-year monitoring program along four select tributaries of the Williston Reservoir. The focus of field activities in Year 6 was to continue data collection at each site following the previously established methods for fish, vegetation, amphibians, songbirds, and waterbirds. The research management questions remain largely unanswered. The goal was to provide a robust BACI experimental design (e.g., Smith 2006) that was coupled with a qualitative assessment of the data. However, the end result is a descriptive study despite several attempts to establish and adjust the experimental design. This closing section provides a review of the methods and study design that was implemented and discusses this in relation to the conclusions. Recommendations are provided to improve on the monitoring program per the cited TOR (BC Hydro 2008). A summary of the progress towards addressing the management questions and hypotheses is provided in Table 19.

Table 19. The status of the GMSMON-17 management questions and hypotheses following completion of Year 6 of the monitoring program.

Management Question	Management Hypothesis (Null)[1]	Year 6 (2016) Status
Does access for spring spawners (i.e., Rainbow Trout and/or Arctic Grayling) improve as a result of enhancement?	H_{01}: Access to spawning habitat in the spring period – as measured by the proportion of modified channel with sufficient depth for target fish passage – does not increase following enhancements to tributaries.	Fish, redds, and spawning activity are detected in areas above the mitigation construction areas. Passage through the modified channel occurs, but some species (e.g., AG at Factor) may be partly to wholly inhibited by flow rates through extended riffle-run channel at Six Mile. A new remote sensing CGU method was developed to assist with this question. Applicable data on channel depth is not collected to comprehensively model conditions and address the hypotheses as framed.
Is the area and quality of fish habitat created by the tributary enhancement maintained over time?	H_{02}: Total rearing area for fish does not increase following enhancement to tributaries.	A new remote sensing CGU method was developed to address this question. The channel area is maintained over time in the DDZ. Methods adopted for measuring rearing area are too imprecise to address the hypothesis.
Does riparian vegetation along tributaries increase in abundance and diversity as a result of enhancement?	H_{03}: Riparian vegetation abundance and diversity along the tributaries does not increase following enhancement to tributaries.	No major changes in riparian vegetation have been detected in post-construction monitoring. Herbs have colonized earth berm structures at Six Mile. Additional monitoring will be required for the testing of this hypothesis.
Does amphibian abundance and diversity in tributaries change as a result of enhancement?	H_{04}: Amphibian abundance and diversity in and near tributaries does not change following tributary enhancement.	Sampling effort and design must be modified to address the research management question. Proper study design is required for statistical independence of response to other potential factors (e.g., natural demographic fluctuations over time, weather, predation, etc.).
Does tributary enhancement change the area and quality of amphibian breeding habitat over time? If so, is the area and quality maintained over time?	H_{05}: Total amphibian breeding area does not change following enhancement.	The beaver breeding pond at Six Mile Creek flooded in Years 5-6. The earth berm does not prevent flooding at this site. Quality at this breeding location is not maintained over time, but it is not changed as flooding also occurred prior to construction. Reduced flooding and saturation in the DDZ at Six Mile Creek may have altered the hydrodynamics of stranded ponds in the DDZ where long-toed salamanders deposited eggs previous to construction. No breeding areas were identified in the immediate vicinity of the Ole Creek DDZ throughout the study period.
Does abundance and diversity of song birds (passerines) around tributaries change as a result of enhancement?	H_{06}: Song bird abundance and diversity near tributaries does not increase following tributary enhancement.	The research question cannot be addressed by the level of sampling effort, design, and methods. It is likely that the areas where habitat changes have occurred are so small that a response by birds would be biologically insignificant. An annual inventory of avifauna in the study area is complete.
Does abundance and diversity of waterfowl and shorebirds around tributaries change as a result of enhancement?	H_{07}: Waterfowl and shorebird abundance and diversity near tributaries does not change following tributary enhancement.	The research question cannot be addressed by the level of sampling effort, design, and methods. An annual inventory of avifauna in the study area is complete.

[1]H_{01}-H_{03} are directional, whereas H_{04}-H_{07} are framed in the traditional null-format.

7.1 Remote Sensing and CGU Classification

The BC RISC standards for Aerial Photography and Videography Standards (Ham 1996) discuss digitizing in GIS, but no specific RISC guidelines are provided for CGU classification for field surveys or via aerial imagery. Hence, new methods had to be developed to interpret the remote sensing data using a GIS to map stream habitat. Applicable guidebooks for BC (BC Ministry of Forests & BC Ministry of Environment 1998; BC Fisheries Information Services Branch 2001) refer to CGUs, provide illustrations, and discuss their utility for defining reach survey length, but explicit definitions are not provided. Guidelines are needed to match the growing use of remote sensing technology and methods developed in this report may be of value in this respect. An initial guide to the process of digitizing and interpreting CGU's is developed in this report. The interpretation and categorization of CGU's stems from field based procedures. The approach may be of value for future investigations in the DDZ.

Tamminga *et al.* (2015) note that UAV is "ideally suited to river research and management" (p. 379) in terms of low cost, high efficiency, resolution, and accuracy. A great strength of the remote sensing CGU approach is that it can be used for a spatially-explicit sampling design to monitor fish abundance or to measure depth and flow according to each CGU category. Each CGU could be used to stratify the environment for refinement of experimental design, which was a key limitation of the fish mark-recapture approach that was adopted in study years 1-4. However, there is a key limitation to the remote sensing CGU approach. While the full stream channel can be viewed in the DDZ the channel is largely obscured by canopy and shadows in the upland areas where spawning and rearing occurs. Lower scale drone video along the stream channel and below the canopy coupled with LiDAR delimitation of the channel may be a potential consideration to compare and check the precision of field based determinations. Another approach may include use of a UAV boat drone that could gather extensive data on water depth and velocity. Methods would have to be developed to translate this kind of information into the CGU classification scheme.

The UAV orthophotos, DEMs, and LiDAR utilized in this study do not cover the full suite of remote sensing analytical capabilities, such as estimating biomass (e.g., Wilkes *et al.* 2016), mapping snags and debris for habitat suitability (Martinuzzi *et al.* 2009), and fish stream habitat suitability mapping (Tamminga *et al.* 2015). Extents of stream substrate, including boulders and classification of cobbles, gravels and fine materials are visible at the resolution of the UAV orthophotos from 2014-2016 and could be used in habitat suitability modelling (e.g., Koljonen *et al.* 2013); water clarity was also sufficient at the study locations for this type of exercise. However, bed material was not classified into GIS layers for spatial analysis in this study as additional data on depth and flow would be required for development of an applicable HSI. Nonetheless, there is no apparent change in substrate size distributions using visual comparison of downstream substrate in the UAV orthophotos among study years 4-6.

The habitat mapping exercise provides a useful guide to modified stream channel conditions within the DDZ pre- and post-construction of the earth berm. Remote sensing data is best coupled with an effective sampling design, data collection in the field, and modelling in a GIS with applicable software, such as River2D (Steffler & Blackburn 2002; Tamminga *et al.* 2015). Integration of the River2D software (or other types of flow to habitat modelling) would require measuring depths at multiple cross sections coupled with velocity measurement (Orth & Leonard 1990; Tamminga *et al.* 2015) to develop a habitat suitability model; a high-quality habitat would correspondingly have a high Habitat Suitability Index (HSI) score.

7.2 Channel Depth and Velocity

Channel depth was not measured consistently after the mitigation treatment. Pre-construction channel base survey data for Six Mile Creek comes from 2009 Lidar data covering most of the constructed channel area; the survey transitions to May 2014 survey data at 0+410 m (Kerr Wood Leidal and Associates Ltd 2011, 2014). The May 2014 pre-construction survey data for Ole Creek transitions at 0+143 m (Kerr Wood Leidal and Associates Ltd 2014) and covers most of the constructed channel area, but this information gives a limited overview on stream channel depth over the length and time during critical periods of fish passage.

Stream depth and velocity values measured at the single cross section for discharge at Six Mile Creek align with a precipitous drop in HSI curves for young-of-the-year rainbow trout, but match a HSI value of 1.0 for mean depth and velocity requirements for juveniles and adults (Laliberte, Post & Rosenfeld 2014). Furthermore, detection of redds and spawning activity (Appendix 8) indicate that fish are passing through the new stream channel, but low detection of burbot, sculpins, and kokanee (Table 8) may suggest that sustained speeds required to pass through the >200 m of a riffle-run channel morphology (Figure 3) are insufficient for passage due to an absence of pools and cover. These species tend to select habitat with slower velocities and greater depth (McPhail 2007; Eick 2013). Data on swimming capabilities are available for some fish species that occurred in this study (e.g., Taylor & Foote 1991; Parker 2000), but more detailed analysis would be required to relate swimming capabilities to field conditions (e.g., Froude number or nose velocity) or to model passage in terms of HSI.

7.3 Study Design Limitations

The CPUE approach is not recommended for terrestrial or aquatic comparative estimates of relative abundance without proper accounting for imperfect detection (Rodda *et al.* 2015; Gwinn *et al.* 2016). Proper accounting for imperfect detection must be coupled to a robust sampling design (Raabe, Gardner & Hightower 2013; Rodda *et al.* 2015; Gwinn *et al.* 2016; Muñoz *et al.* 2016). Fish surveys could be potentially simplified by scheduling and stratifying consistent presence / absence surveys along the stream channels (e.g., Hankin & Reeves 1988). However, visual surveys significantly underestimates cryptic fish densities, but is more efficient at measuring densities and biomasses of other species, such as salmonids (Macnaughton *et al.* 2015). Hence, sampling method will give different results according to the type of species that is being investigated and must be factored into the initial design. It is recommended that future studies of this type couple presence / absence visual fish surveys with other techniques, such as electrofishing or the establishment of PIT tagging stations at specified CGUs.

The key limitation of this study and its overarching design is that there was insufficient sampling time and effort to address the research management questions pertaining to fish and wildlife. Accounting for probability of detection and appropriate sampling design are required for these kinds of investigations (Royle & Nichols 2003; Bailey *et al.* 2007; Raabe, Gardner & Hightower 2013; O'Donnell & Semlitsch 2015; Muñoz *et al.* 2016). If occupancy is low, then a large number of visits per site (up to 49 with $p \leq 0.3$) is recommended. Some species, such as long-toed salamanders, might be deceptively abundant, but detectability is low due to their ability to dig and evade capture. Specht *et al.* (2017) recommend conditional deletion of sites for rare or hard to detect species to reduce on effort wasted searching in locations where they are less likely to occur. This method involves removal of plots where no detections are made in a first round of surveys to concentrate effort on and around sites where detections have occurred. Similarly, Andrusak, Andrusak & Langston (2012) review some of the limitations of Redd count surveys along the Williston Reservoir, including recommendations for replicate counts that were not employed in this study; these counts also need to be coupled to an independent estimator of population size.

This study also suffered from concerns related to statistical effect size. This concern is particularly relevant to the avifaunal component of the study, but the fish and amphibian study components were similarly compromised. While monitoring diverse taxa is recommended for impact studies, the site-specific scale of the impact is unlikely to be detected in birds (Bro *et al.* 2004; Dickson *et al.* 2009). The footprints of the mitigation structure relative to the scale of avian home range sizes are unlikely to have a significant impact on local avifaunal demographics to any measurable degree greater than experienced in upland areas where land-use changes are noted in the surrounding landscape (e.g., logging).

The avifaunal research management questions were ill-designed and would require extensive effort into the surrounding landscape, but even this would have little chance of success due to the scale of the problem in relation to avian migration. Establishment of woody vegetation is the key factor that could potentially influence avian habitat, use, or demographics in the mitigation areas and there was no appreciable growth or change in this regard. Several attempts were made to adjust the methods across study years to address concerns related to effect size generally. For example, the fish mark-recapture study was dropped in Year 5 to refocus efforts on habitat analysis. For amphibians, survey efforts were concentrated in Year 6 to plots where individuals were previously detected (a conditional deletion approach, Specht *et al.* 2017), which allowed re-allocation of effort onto night transects. However, the amount of survey sites and length of time allocated was still insufficient to understand the ecology of the organisms under investigation to draw an inference in relation to the research management questions.

In terms of the scale of the study, it is likely that amphibians that breed in wetlands in adjacent upland areas migrate or disperse into the DDZ to hunt or carry out other aspects of their life history as these locations exist within the natural range of movement distance documented for amphibians. As such, the study area cannot be restricted to the treatment area alone (i.e., DDZ), because an understanding of the minimal demographic unit for monitoring purposes is needed to ensure "statistical independence of population responses to environmental stressors" (Petranka, Smith & Floyd Scott 2004). Individuals migrating from different parts of an interconnected landscape will contribute to local abundance and diversity measures when detected. If sampling for relative abundance is restricted to a small area relative to the full-extent of the population unit, then the data will only give information on relative activity.

The concern of spatial autocorrelation ("i.e. locations close to each other exhibit more similar values than those further apart", Dormann *et al.* 2007, p. 609) also applies to the fish populations that share a common connection to the reservoir. This issue may be especially pronounced at Six Mile and Lamonti Creek as these sites are situated in geographic proximity and essentially join at the reservoir and in the DDZ. Treatment effects cannot be tested without independence, replication, and accounting for imperfect detection. Otherwise the research becomes descriptive, *ad hoc*, and costly. These and other concerns that must be considered for the improvement of BACI study design are comprehensively reviewed in Smith, Orvos & Cairns Jr. (1993), Underwood (1994), and Beyers (1998).

7.4 Vegetation

For terrestrial vegetation, the baseline data collected in Year 6 provides further characterization of the vegetation types that are present at the four study sites in comparison to vegetation data collected in previous years of the study. The proposed tributary enhancements are likely to increase vegetation establishment along the stream channels within the DDZ over time; however, the abundance and diversity of vegetation in these areas is still expected to be primarily influenced by variation in annual reservoir influx and elevations.

Changes in vegetation communities as a result of the tributary enhancements is most likely to be observed on the enhancement structures themselves and on areas adjacent to the structures where the ground has been disturbed as a result of construction activities. Vegetation establishment will be the most important factor for determining if the mitigation works had any effect on local avifauna, such as establishing nesting sites in willows. However, insufficient time has elapsed to fully understand how the vegetation communities will mature at the study sites. Vegetation cover is expected to increase on the enhancement structures as more time allows and community structure that is tolerant of the flooding matures.

7.5 Recommendations

Timing of survey is critical in these environments as the seasonal windows are brief and dynamic. It is important to capture early season breeding migration activity within the DDZ before it becomes flooded. Fish and wildlife are most densely concentrated during the breeding season, which provides an opportunity for increasing detection levels, monitoring breeding behaviour, and habitat use can be more readily surveyed at this time. However, activity later in the season that may be linked to population presence, density, abundance, or varied spatial distribution in different age related cohorts in subsequent periods (Marra *et al.* 2015). A landscape level investigation is required to understand migratory influence on pattern and landscape influence on local richness and demographics (Mazerolle & Villard 1999; Houlahan & Findlay 2003; Petranka, Smith & Floyd Scott 2004; Van Buskirk 2005; Trenham & Shaffer 2005; Brodman 2009; Jackson & Fahrig 2014; Burgett & Chase 2015).

Lessons were learned in this program and the importance of research design is key among them. Good experimental design is needed to understand how development is impacting fish, wildlife, and vegetation along the Williston Reservoir and inform on management practice. Remote sense data is available to establish an effective study design (e.g., randomized, adaptive random sampling, stratified, structured - Thompson 2012) to ensure that the right kind of information is gathered, sufficient replicates are included, controls are set, and the right kinds of spatial ecology statistics (e.g., Wagner & Fortin 2005; Fortin *et al.* 2012) are comprehensively included to discern environmental covariates from treatment effects.

The window of opportunity has passed for this project to provide an effective test of potential impacts associated with the mitigation works at the study sites. However, data collected from this project can be used to provide a solid foundation to establish new research within the areas that were investigated and improve understanding of land management effects on fish, wildlife, and vegetation along the Williston Reservoir more generally. Data collected in this study can be used in future study design plans and could potentially be analyzed in other ways to make use of what has been collected. It is recommended that all future projects are established with sufficient effort allocated to planning and coordinating a study design that includes field reconnaissance or pilot study, power analysis, use of remote sense data to assist with the sampling plan, and establishing a sampling plan prior to commencement of the field work.

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