Peace Project Water Use Plan

Dinosaur Tributary Inventory and Feasibility

GMSWORKS #9

Recommendations for Improving Access or Enhancing Habitat on Dinosaur Reservoir Tributaries

Study Period: June 2009 to November 2009

Mark LeRuez
Triton Environmental Consultants Ltd.
Prince George, BC

November 26, 2009

4179/WP#P-2110

GMSWORKS#9 - DINOSAUR TRIBUTARY INVENTORY AND FEASIBILITY

RECOMMENDATIONS FOR IMPROVING ACCESS OR ENHANCING HABITAT ON DINOSAUR RESERVOIR TRIBUTARIES

Prepared for:

BC Hydro
GMS Generating Station
Box 359
Hudson's Hope, BC
V0C 1V0

Prepared by:

TRITON ENVIRONMENTAL CONSULTANTS LTD.

Unit 201, 1157 – 5th Avenue, Prince George, BC V2L 3L1

November 2009

This page is intentionally blank.

Executive Summary

The steep bottom topography and short water retention period within the Dinosaur Reservoir has resulted in low fish productivity. The lack of quality rearing and spawning habitats within the Reservoir make the limited available tributary habitat particularly important for maintaining a naturally sustainable sport fishery.

This Peace Water Use Plan (WUP) project was prompted by concerns about potential fish access restrictions to tributary habitat caused by reservoir operations and woody debris accumulations at tributary confluences. The primary objectives were to:

1. Evaluate the number and extent of tributaries affected by reservoir operations and/or woody debris fields; and
2. Complete a feasibility study to determine whether access restoration or other tributary enhancement opportunities exist based on a priority ranking approach (*i.e.* biological benefit relative to mitigation costs and potential for success) and identify two 'demonstration' streams where works could occur.

This was achieved by completing a pre-field scoping exercise to identify streams with the highest potential to offer any fish habitat, followed by a field validation component. Field investigations revealed that ten tributaries offer some level of reservoir-accessible habitat, amounting to a combined area of 51,326 m^2 (80% of which is split between Johnson Creek and Gething Creek).

Concerns that woody debris accumulations from upstream logging are restricting fish access to tributaries was not validated during any step of this project (*i.e.* literature review, orthophoto review, and field investigations). In fact, wood within the Reservoir was very sparse and primarily limited to habitat features installed into several bays for rearing habitat enhancement.

A combination of reservoir operations and high bedload movement are causing access restrictions to five tributaries with reservoir-accessible habitat. Dredging to remove aggregated bedload at stream confluences may be viable, but would require an ongoing maintenance commitment. If this concept were pursued, Starfish Creek and unnamed creek (230-804398) are the best two candidates since they have the highest quality habitat with the most available area, and they are located next to each other.

Other enhancement options not related to access restrictions were considered to increase tributary rearing and spawning including: removing barriers; habitat complexing on tributaries; creating new tributary habitat; augmenting flow to existing reservoir-accessible tributaries by diverting non-fish bearing tributaries; habitat complexing within the reservoir; and diverting non-reservoir tributaries into the reservoir.

No viable barrier removal opportunities were identified. The lower end of Johnson Creek is the best candidate location for new side channel creation, but partitioning flows from the existing channel may not result in net gains in productive habitat capacity. No viable opportunities exist for augmenting flows in accessible streams.

Most accessible tributaries are not considered suitable candidates for habitat complexing initiatives due to chronic bedload movement and unstable canyon conditions. Accessible tributary habitats on stable streams are considered functional and provide limited opportunities for habitat complexing enhancements. Converting high value rearing habitat into spawning habitat on Moosebar Creek, and offsetting that alteration by habitat complexing the inlet bay for rearing may achieve an overall net gain to the productive capacity for rainbow trout, but results would have a significant level of uncertainty. This is partly because there is no guarantee relocating an equivalent or greater amount of stream rearing habitat into the reservoir will afford juveniles similar or better success. Although the lower 364 m of Moosebar Creek contains rainbow trout and is considered reservoir-accessible habitat, removing two small falls (1.2 m and 1.4 m) from the lower 60 m should precede any enhancement works upstream to maximize the benefit.

The best tributary-related opportunity for enhancing the productive capacity of the Dinosaur Reservoir fishery is to divert Portage Creek and Bullrun Creek into the Reservoir. Currently both creeks flow into the Peace River just downstream of the Peace Canyon Dam, and have impassable barriers located at their confluences. In total, an estimated 21.5 km of new stream habitat could become accessible to reservoir fish through this initiative. The greatest benefit of this newly accessible habitat would be for rearing, although an effort should also be made to augment spawning habitat within the 1,850 m long new channel section.

Continuing to add woody debris to reservoir bays is another proven strategy to increase rearing habitat quality in a low-risk, economical manner.

BC Hydro will utilize the information provided in this report in its implementation of the follow-up Peace WUP project GMSWORKS#8 – Dinosaur Reservoir Demonstration Tributary, which is designed to consider the potential fish habitat and/or access restoration in more detail and undertake the required remedial works and maintenance over the five year life of the project. A related Peace WUP project GMSMON#14 – Dinosaur Tributary Habitat, would facilitate baseline and post-construction monitoring to evaluate three key management questions:

1. Is the tributary enhancement work effective at increasing usable habitat?
2. Is the area and quality of fish habitat created by the tributary enhancement work sufficient to noticeably increase spawning and rearing opportunities in the reservoir?
3. Is the area and quality of fish habitat created by the tributary enhancement maintained over time?

Acknowledgements

Many thanks to Kim Hawkins (BC Hydro) for administering the project and for the time she contributed to review the initial draft. Triton Environmental Consultants Ltd. (Triton) would also like to thank Arne Langston (Peace/Williston Fish and Wildlife Compensation Program), and Mike McArthur (Environmental Resources group) for their insightful reviews, which improved the quality of this document.

Triton staff who contributed to the project included:

- Mark LeRuez Lead Biologist and Author
- Jim Trask Senior Biologist and Report Reviewer
- Tristan Siemens Biologist

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1.0 Introduction

1.1 Background

The Dinosaur Reservoir is a run-of-the-river design that has 15 sport and non-sport fish species documented (Langston and Murphy 2008). Pattenden and Ash (1993b) identified reservoir food supply, fish entrainment over the Peace Canyon Dam, and rearing and spawning habitat as the primary factors limiting fish productivity within the Dinosaur Reservoir. This is largely due to the small littoral area associated with the Reservoir's steep bottom topography, and the short water retention period of only three days (Pattenden and Ash 1993b). As such, the rearing and spawning habitat opportunities available in tributaries is critical for supporting a viable sport fishery in the Reservoir.

According to Murphy and Blackman (2004), Gething Creek and Johnson Creek are the only tributaries with significant rearing and spawning areas for Dinosaur Reservoir fish, and this habitat is limited to 600 m and 500 m respectively due to barriers. Other smaller tributaries are ephemeral or have very limited habitat that is accessible due to the presence of barriers (Murphy and Blackman 2004).

Creel surveys have been routinely completed since 1984 and rainbow trout (*Oncorhychus mykiss*) have consistently been identified as the most abundant sport fish captured (Pattenden and Ash 1993a, Joslin 2001a, Joslin 2001b, Cowie 2004, and Stiemer 2006). The importance of rainbow trout as a sport fish is further supported by the history of a stocking program within the Reservoir (Langston and Murphy 2008).

Low densities of bull trout (*Salvelinus confluentus)* are also present in the Reservoir, and considerable effort has been expended over the years to maintain or increase their numbers (Euchner 2006). Although bull trout sporadically occur in Johnson Creek, Gething Creek is the primary tributary utilized. Adult transplants upstream of the lower barriers on Gething Creek have reportedly been unsuccessful at establishing a sustainable resident population (Langston 2008).

Lake trout (*S. namaycush*), another important sport fish in the Reservoir, have appeared relatively recently (Euchner 2006). Although they account for a small proportion of the annual angling catch, creel survey results suggest their numbers are increasing. A telemetry study determined that lake trout distribution in the Reservoir is largely restricted to the upper 9 km, with inferred spawning occurring near the Gething Creek delta, the spillway scour hole, and the rock ledge area near the decommissioned WAC Bennett Dam diversion tunnels (Euchner 2006).

Although the Reservoir's limited water storage capacity minimizes littoral zone habitat effects associated with water fluctuations during normal operation, habitat in shallow bays is temporarily reduced during low periods and free access to tributaries is sometimes restricted (BC Hydro 2008). Another concern is that large volumes of woody debris associated with upstream logging activity enter the Reservoir and reportedly create debris jams at tributary confluences (BC Hydro 2008).

1.2 Study Objective

To address concerns related to tributary access restrictions, the Peace Water Use Planning Committee endorsed an initiative to:

1. Evaluate the number and extent of tributaries affected by reservoir operations and/or debris fields;
2. Complete a feasibility study to determine whether access restoration or other tributary enhancement opportunities exist based on a priority ranking approach (*i.e.* biological benefit relative to mitigation costs and potential for success) and identify two 'demonstration' streams where works could occur; and
3. Design and implement enhancement recommendations from the feasibility study, and monitor results over a five year period.

The present study fulfills the GMSWORKS#9 component of this Peace Water Use Plan initiative (*i.e.* the tributary inventory and feasibility elements), while the GMSWORKS#8 component (*i.e.* the design, implementation, and monitoring elements) will be completed through a subsequent project (BC Hydro 2008). Since stream treatment strategies were the focus of this project, opportunities to address rearing and spawning deficiencies were considered most relevant. As such, mitigation opportunities for other limiting factors to the Reservoir fishery such as food deficiencies and entrainment concerns were not directly considered.

The study approach included a pre-field scoping exercise to identify streams with the highest potential to offer any fish habitat, followed by a field validation component. Data collected during the field program contributed to recommendations for habitat enhancement activities. Enhancement recommendations were primarily targeted toward rainbow trout since this species is the dominant sportfish in the Reservoir, and is most likely to utilize any stream enhancement initiatives that are completed; bull trout predominately use Gething Creek with sporadic occurrences in Johnson Creek, and lake trout are typically limited to lacustrine habitats or large rivers.

2.0 Methods

2.1 Literature Review and Data Consolidation

Historical information was collected that primarily focused on references about the quality and extent of reservoir-accessible tributary habitat and fish species utilizing those habitats (*e.g.* fish sampling results and documented barrier locations). In addition, consideration was given to literature for other projects where similar works were completed to help refine the methodology for this project. Online sources that were consulted included:

- Cross-linked Information Resources (CLIR) search engine. CLIR's umbrella search application allows users to search multiple sources of environmental and natural resource information in:
  - EcoCat - Ecological Reports Catalogue
  - BCSEE - BC Species and Ecosystems Explorer
  - EIRS BD - Biodiversity / Environmental Information Resources e-library
  - EIRS EP - Environmental Protection Information Resources e-library
  - SIWE - Species Inventory Web Explorer, a component of the Species Inventory Data System (SPI)
  - B.C. Ministry of Forests and Range library
- Fisheries Information Data Queries (FDIQ) search tool
- HabitatWizard search tool
- Peace/Williston Fish and Wildlife Compensation Program (PWFWCP) online reports

Applicable data was consolidated onto a digital base map using ArcView geographic information system (GIS) software. One of the most relevant resources was a Reconnaissance (1:20,000) Fish and Fish Habitat Inventory completed on Johnson Creek and other tributaries to the southern side of Dinosaur Reservoir for Canfor (Aquatic Resources Ltd. 1999b). While this study provided reach breaks for many tributaries and included useful channel characteristics at sample sites (*e.g.* average channel width, gradient), limited insight was gained about reservoir-accessible habitat since fish sampling was rarely done and barriers near the Reservoir were not identified.

A selection of other relevant documents are summarized in Table 2-1. Other than inferences to woody debris accumulations at tributary confluences in the terms of reference (TOR) for this project (BC Hydro 2008), no other reference to this issue was identified in the literature. In fact, the PWFWCP has added woody debris to several shallow bays in the Reservoir as a habitat enhancement initiative.

Table 2-1. Selected summary of documents reviewed in association with this project and relevant findings.

Reference	Summary of Relevant Content
Pattenden and Ash (1993b)	• poor habitat quality and variable flow regimes in Johnson Creek and Gething Creek results in low sportfish recruitment, which translates into restricted fish abundance • rainbow trout is the dominant sportfish, with the population supplemented by a hatchery program since spawning success and survival are low • Johnson Creek is the primary spawning location for rainbow trout, while bull trout primarily utilize Gething Creek • techniques for reservoir habitat enhancements are covered including strategies for reducing entrainment, and rearing and spawning habitat improvements
Harvey (1995)	• electrofishing at sites on Gething Creek and Gaylard Creek suggested adult bull trout transplants in 1994 were very successful on Gething Creek and not very successful on Gaylard Creek in terms of juvenile recruitment
Agra Earth and Environmental Limited (1996)	• Level 1 watershed assessment on Johnson Creek that identified surface erosion and mass wasting as significant impacts within the watershed (61 landslides and 20 channel bank failures were noted)
Peace Country Materials Testing Ltd. (1997)	• the report provides a risk assessment and estimated remediation cost for two road washout sites and a hillslope failure on Burnt Trail Creek (tributary to Johnson Creek)
Aquatic Resources Ltd. (1998)	• rainbow trout were captured on Gaylard Creek
Langston and Zemlak (1998)	• a bull trout transplant in Gaylard Creek is feasible • a rainbow trout population established during a stocking effort in 1983 exists in Gaylard Creek upstream of barriers in the lower 2 km • constructing fish passage structures around the barriers is not feasible
Hatfield Consultants Ltd. (2000)	• no fish captured in Moosecall Lake (part of the Johnson Creek system) using one floating gill net (overnight set) • maximum depth of Moosecall Lake is 2.1 m and mean depth is 1.14 m
Blackman *et al.* (2004)	• a statistically significant difference between treated and untreated conditions was not detected, potentially because the boat shocking method was less effective after the woody habitat features were installed
Murphy *et al.* (2004)	• this report summarizes baseline sampling efforts in the reservoir prior to implementing habitat enhancement activities • rainbow trout were the dominant species captured (41%), followed by mountain whitefish (19%), peamouth chub (12%), longnose sucker (10%), bull trout (6%), lake whitefish (5%), kokanee (5%), and lake trout (2%)
Blackman and Cowie (2005)	• instead of boat shocking which was inefficient during the 2003 study, the 2004 program applied trap nets, minnow traps and angling to evaluate woody debris effectiveness for improving rearing habitat • five times more fish were captured at enhanced sites than control sites
Newsholme and Euchner (2006)	• report details a fish fence initiative on Johnson Creek that was operated in 2006 to evaluate spawning movements and the adult population structure of rainbow trout
Langston and Murphy (2008)	• summarized the history of fish stocking within the PWFWCP area including the Dinosaur Reservoir and its tributaries up to 2005 • stocking occurred in: Burnt Trail Creek (RB in 1984), Dinosaur Reservoir (RB in 1983, 1985-1997, 1999-2003), Dowling Creek (BT in 1985), Gaylard Creek (RB in 1983; BT in 1994), Gething Creek (RB in 1983; BT in 1993, 1997, 1999), Johnson Creek (RB in 1982, 1984), Pete Lake (RB in 1994-1997, 1999-2005), and Wright Lake (RB in 1991-1994, 1996, 1998-2005)
Langston (2008)	• summarized bull trout translocation efforts and in Gething Creek upstream of the

Reference	Summary of Relevant Content
	impassable falls on Gething Creek and Gaylard Creek. • concluded that a stream-resident dwarf population in the upper watershed was not established; by age 3 or 4 bull trout migrate downstream to the Reservoir since the upper watershed streams are too small to support them • a small population in Wright Lake could potentially become self sustainable in the future

RB = rainbow trout; BT = bull trout

2.2 Map and Air Photo Analysis

Digital TRIM 1 maps and air photos were reviewed to identify potential barrier locations and estimate the amount of useable habitat that might currently exist above and below. As such, the following conservative assumptions were applied during this office-based exercise:

- >20% gradient based on TRIM interpretation over at least 100 m is a barrier;
- the top 1 km of each stream provides insufficient drainage length to provide significant spawning or rearing habitat for any fish species; and
- insufficient habitat exists upstream of a barrier to provide moderate quality or better rearing and/or spawning opportunities, as defined in Section 2.3.1.2, if no accessible lakes exist or if <5 km of stream drainage exists (including tributary contributions).

Using the first two assumptions, a realistic summary of reservoir-accessible tributaries with any fish habitat potential was achieved by: interpreting lower barrier locations, excluding tributaries with steep gradient throughout the majority of their mapped lengths, and excluding short, first order tributaries that would likely have insufficient headwater to scour a continuously defined channel. The following nine tributaries were identified as having potential reservoir-accessible habitat, and are described in more detail in Tables 3-1 and 3-2:

- unnamed creek (230-816500)
- Gething Creek
- Mogul Creek
- Moosebar Creek
- Johnson Creek
- unnamed creek (230-807100)
- unnamed creek (230-806200)
- Starfish Creek
- unnamed creek (230-804398)

All of these tributaries were prioritized for a detailed field visit to confirm available habitat quantity and quality, although the other mapped drainages were also observed to confirm no useable habitat existed. These other drainages were all first or second order, and most had long sections of steep gradient immediately upstream of their confluences with the Reservoir.

In addition, Bullrun Creek and Portage Creek were screened in for field inspection since the PWFWCP had considered diverting them into Dinosaur Reservoir. Currently they flow into the Peace River just downstream of the Peace Canyon Dam, and have impassable barriers located at their confluences. Rainbow trout and longnose sucker (*Catostomas catostomas*) have been documented in Portage Creek, which is likely the result of illegal introductions by residents (Langston and Murphy 2008).

The third assumption was included to focus potential barrier removal opportunities on streams with meaningful habitat value. A minimum amount of upstream drainage is required to scour a continuously defined stream channel, as recognized by the second assumption, and this channel would likely only provide poor or low value habitat at that point. Therefore, five kilometres of mapped stream drainage at the headwater would not translate into five kilometres of useable habitat. Although available habitat estimated upstream of the first full obstruction was considered in the overall decision-making framework for barrier removals outlined in Section 4.1, it did not solely result in the exclusion of any streams as potential candidates. All reservoir tributaries were observed in the field to validate pre-field assumptions that were made, and identify any anomalies.

To further the investigation about woody debris field accumulations described in the TOR, this possibility was explored using Google Earth to scan the entire perimeter of the lake. Resolution of the Google Earth images was sufficient to identify the occasional log that was present (including wood that had been installed into some of the bays for habitat enhancement), however, no evidence of chronic debris accumulations was detected during this preliminary exercise.

2.3 Field Assessment

The protocol developed by ARL (2002) for the Williston Reservoir was considered for this study, although that protocol was partly intended to priority rank the large number of streams with potential fisheries value such that tributaries with the highest value were targeted for field investigation. Since the Dinosaur Reservoir is much smaller it was possible to complete a comprehensive field assessment to identify all tributaries with any fisheries potential. This primarily involved visiting each of the nine tributaries identified during the pre-field screening process, along with validating inferences about each of the other streams where no habitat was expected. This was achieved by cruising the entire shoreline over a four day period between July 21 to 24, 2009 using a boat for access.

2.3.1 Site Data Collection

For streams where reservoir-accessible habitat was identified, surveys were completed to establish the length and relative quality of the habitat above the highwater mark of the Reservoir. Site data were recorded on reconnaissance inventory standard Site Cards (Province of British Columbia 2001), confluences and relevant features were georeferenced, and photographs were taken. The typical range of photographs taken at sites with accessible habitat include: view of the confluence from the Reservoir; view of the barrier(s); representative upstream and downstream views; and any other notable features.

Streams without reservoir-accessible habitat were georeferenced at their confluences, photographed, and a comment was recorded in a field notebook describing why no significant habitat was available.

2.3.1.1 Barrier Assessment

Access barriers to reservoir fish were evaluated according to gradient, instream obstacle, hydraulic conditions, and approach conditions.

Gradient

The gradient of the access barrier was measured using an Abney Level and compared to thresholds for the species of interest.

Instream Obstacle

The drop, plunge pool depth, geometry, extent and permanence (*e.g.* bedrock control versus embedded log) of the feature was documented. Reference photographs were taken with a scale item in view.

Hydraulic Conditions

Where applicable, the hydraulic conditions around access barriers were described in terms of depth (maximum, minimum and average along the potential barrier), velocity (maximum, minimum and average along the potential barrier).

Approach Conditions

Approach conditions were carefully documented for potential barriers with an apparent inadequate staging area. Measured parameters included an accurate description of the plunge pool or approach habitat (area, maximum/average/minimum depth and velocities), drop height or gradient, and length that must be passed by fish to gain access to upstream habitats. Cover in the staging area or potential resting area above the barrier were also described and quantified.

2.3.1.2 Fish Habitat Description

The assessment of fish habitat values was based on criteria developed by Triton, which include physical habitat parameters, flow parameters and fish abundance. It is important to note that the following is only a guide and that not all criteria identified with each bullet must be met. It is also important to note that any given reach may contain high rearing habitat values but not contain any suitable spawning habitat.

High value fish habitat is typically characterized by:

- the presence of significant (at least 5% of the total habitat area) suitable salmonid spawning habitat; suitable conditions that must exist at the time of spawning include minimum water depths of 15 cm, velocities between 0.3 m/s and 1.0 m/s, gravel patches >0.1 m^2, and particle sizes between 10 mm and 75 mm (Johnston and Slaney 1996)

- abundant cover, perennial flows, coarse substrates, moderate gradient (1-5% for rainbow trout)
- significant representation (>10% of the total habitat area) of both pool (>25 cm deep) and riffle habitats for rainbow trout
- an abundance of fish (at least 10 per 100 electrofishing seconds).

<u>Medium or Moderate value fish habitat is typically characterized by:</u>

- moderate to abundant cover, predominantly coarse substrates, moderate gradient (0.5-10% for rainbow trout)
- perennial or occasionally ephemeral flows
- some representation of riffle and pool habitats (5-10% riffle and >10% pool) for rainbow trout (note that side channels that provide high value habitat may increase habitat values from low in the mainstem to moderate overall)
- low to moderate numbers of fish (note that fewer or perhaps no fish would likely be captured at low flows).

<u>Low value fish habitat is typically characterized by:</u>

- low cover, low habitat complexity (homogenous shallow glide-pool or riffle habitat), low discharge volume, shallow (<10 cm) average water depth, infrequent pools >15 cm deep, ephemeral flows, predominantly fine substrates
- wetland reaches with seasonal rearing habitat (usually means there is visible flow and occasionally gravels)
- none, few or moderate numbers of fish at optimal flows.

<u>Poor value fish habitat is characterized by:</u>

- ephemeral flows, poor channel definition, vascular plant growth within the channel, low proportion (or no) of coarse substrates, low (0-1%) or high (>15% in small and >20% in larger streams) gradient, infrequent or no pools >15 cm deep, shallow (<5 cm deep) average water depth
- wetland reaches (may support coarse fish species but not suitable for salmonids)
- no fish captured or observed, low likelihood of use.

<u>No suitable fish habitat is typically characterized by:</u>

- high average gradients (>15-20% in streams <1.5m wide, >20% in streams >1.5 m wide), strongly ephemeral flows (may only flow during snow melt and/or prolonged heavy rains), shallow average water depth (<5 cm) with infrequent or no pools >10 cm deep
- intermittent or poorly defined channels
- no fish captured or observed, insignificant possibility of use by game fish.

<u>Suitable overwintering habitat varies with stream size as follows:</u>

- Streams: pools of at least 50 cm in depth
- Ponds: at least 0.25 ha with a maximum depth of at least 2 m.

2.4 Refinement of Useable Habitat Calculations

Following the field program the original estimates of reservoir-accessible habitat derived during the pre-field screening phase were refined.

3.0 Field Assessment Results

Of the nine tributaries identified during the pre-field phase as having potential reservoir-accessible habitat, accessible habitat was confirmed at seven locations while two tributaries had firm barriers identified at their reservoir confluences (Table 3-1). In addition, three streams were found to have some reservoir-accessible habitat available when none was expected. In total, 48 mapped drainages to the Dinosaur Reservoir were documented, georeferenced, and photographed, along with Bullrun Creek and Portage Creek. Of those, the majority were either ephemeral or exhibited non-classified drainage conditions (*i.e.* less than 100 m of continuously defined channel bed; therefore not a stream).

As previously documented in the literature, Johnson Creek and Gething Creek are the best streams available to reservoir fish both in terms of rearing and spawning habitat quality and quantity (Table 3-2). Both streams were found to have similar amounts of habitat area, which is an order of magnitude greater than the next best stream. Of note, the length of habitat available on each stream was found to be greater than previously documented (1,066 m for Johnson and 675 m for Gething were identified compared to 500 m and 600 m originally reported respectively). This may partly be the result of extreme bedload depositions at the reservoir confluences that have essentially created new channel bed in what used to be reservoir habitat.

The next best streams in terms of available habitat area were Starfish Creek and unnamed creek (230-804398) located immediately to the east, both of which drain into the same bay. Although both streams offer moderate quality rearing and low to moderate quality spawning habitat, they are prone to dewatering in the lower 100 m to 200 m during daily reservoir fluctuations. This trend was observed within a period of several hours, and some fish mortalities were observed due to stranding in dewatered sections. Both streams also show evidence of extreme bedload movement, and the aggrading conditions that have resulted at their confluences may be contributing to the dewatering problem. Fish sampling with a backpack electrofisher on Starfish Creek resulted in the capture of longnose sucker and slimy sculpin (*Cottus cognatus*) at the unconfined lower end where limited cover existed. Upstream in the more confined habitat, rainbow trout and longnose sucker were captured within the coarse substrate material. Given its close proximity to Starfish Creek and its similar channel characteristics, similar capture results would be expected on unnamed creek (230-804398).

The other notable stream was Moosebar Creek, which had high quality rearing and spawning habitat available within a relatively stable channel environment. Although 1.2 m and 1.4 m high falls were identified 50 m and 60 m upstream respectively (Table 3-3), rainbow trout were captured upstream of both.

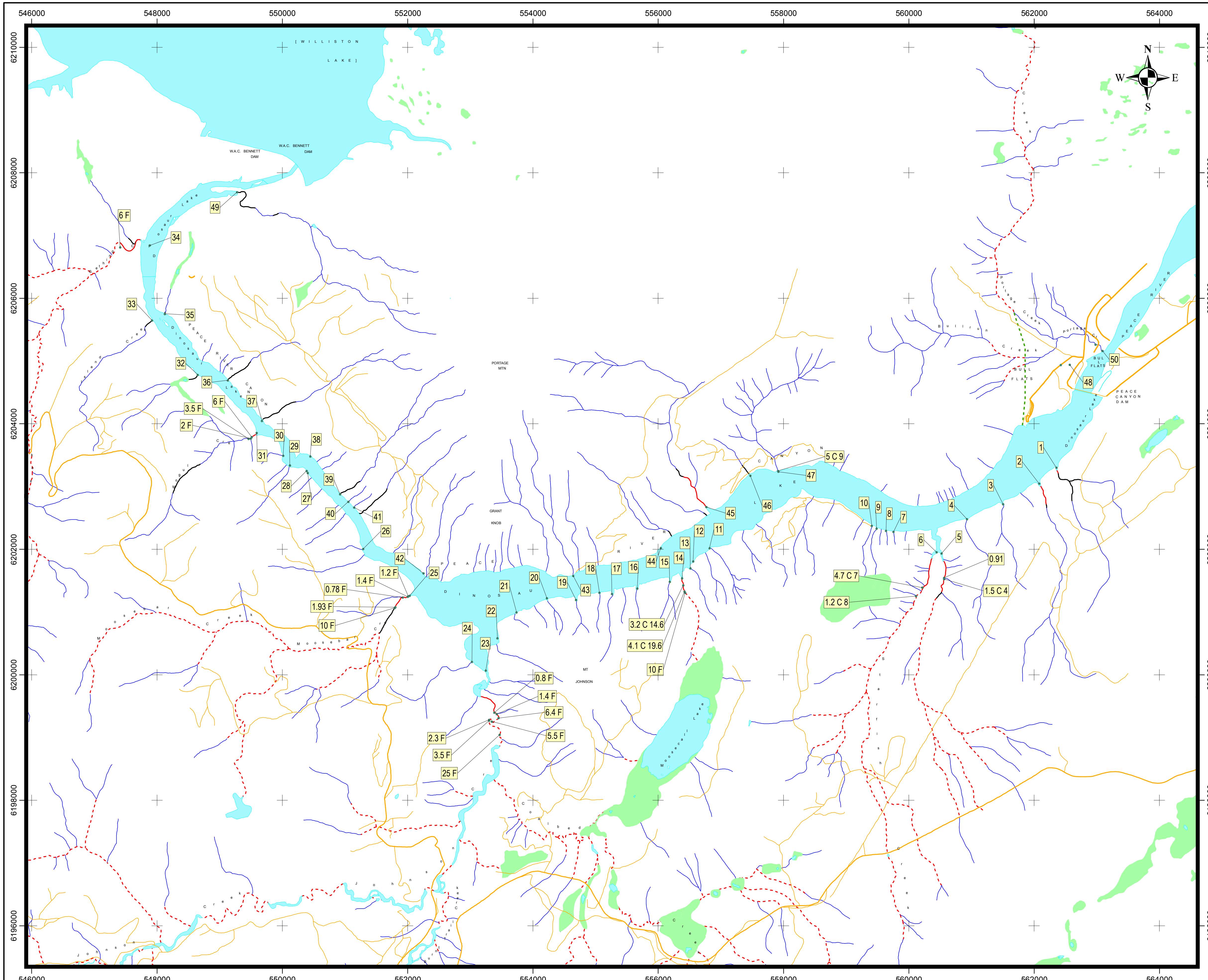
All of the other five streams with reservoir-accessible habitat had less than 1000 m^2 available. Although its average channel width was less than 1 m wide, unnamed creek (230-807600) had high quality rearing habitat. This channel appeared relatively stable, and likely receives some headwater flow from Moosecall Lake. Mogul Creek had low quality habitat due to a lack of cover, but an abundance of suitable sized gravels provided moderate spawning potential. Similar to Starfish Creek, this stream appears to be aggrading at the reservoir confluence, as evidenced by the large gravel bar that was dewatered in the lower 30 m.

Unnamed creek (230-803000), unnamed creek (230-803200), and unnamed creek (230-807100) all have poor to low value rearing habitat and limited to no spawning habitat available. The former two streams are prone to extreme bedload movement, while the latter stream is more stable but intermittent. All three dewater near their confluence with the reservoir, although connectivity is expected when water levels are higher.

Although only a small portion of Portage Creek was surveyed relative to the potential habitat that is available, high value rearing habitat for salmonids was observed within the 3 m wide average channel. Abundant cover was available from large woody debris (LWD) and pools, along with some undercut banks, coarse substrate, small woody debris, and overhanging vegetation. Isolated pockets of suitable substrate offer low value spawning habitat, and overwintering is evidently possible given that introduced rainbow trout and longnose sucker populations persist according to Langston and Murphy (2008).

Bullrun Creek had an average channel width of 1.2 m within the lower 300 m, with moderate value rearing potential. There are sections with extensive beaver activity which has produced some deep, stagnant channel areas that run through thick overhanging vegetation. Areas not influenced by beavers had a dominance of undercut bank for cover. Spawning potential was poor since the occasional pockets of suitable gravels were typically mixed with fines. No suitable overwintering habitat was observed.

With regard to woody debris accumulations in the Reservoir restricting fish access at tributary confluences, no evidence was found to validate these concerns. Identified barriers were either topography based (*i.e.* steep gradient) or bedrock controlled features (*i.e.* falls or cascades). In fact, wood within the Reservoir was very sparse and primarily limited to habitat features installed into several bays for rearing habitat enhancement. Tributaries impacted by reservoir operations (*i.e.* prone to dewater at their confluences) are identified in Table 3-2.



GMSWORKS#9 - Dinosaur Tributary Inventory and Feasibility Study

Figure 3-1. Overview map of tributaries to the Dinosaur Reservoir that were surveyed

Legend

- Potential Diversion Route
- Lakes
- Wetlands

TRIM Streams

- Reservoir-accessible Habitat
- Potential Habitat Upstream of a Barrier
- Gradient Barrier
- Not Useable Habitat
- Unclassified Stream

Location Map

NOTE: Potential habitat upstream of a barrier is based on map interpretation and likely overestimates the actual amount of habitat available.

0 250 500 1,000 1,500 2,000 2,500 3,000 Meters

Scale: 1:60,000

NO.	DATE (yyyy/mm/dd)	REVISION	BY
1	2009/10/15	Initial Draft	ML
2	2009/11/20	Final Draft	ML

Basemap Source: TRIM Data

Map Datum: UTM NAD 83 Zone 10

Project No: 4179

File No: Map#: 4179_Dinosaur\MXD\ Dinosaur_Figure3-1.mxd

Date: Nov. 20, 2009

TRITON ENVIRONMENTAL CONSULTANTS LTD.

Table 3-1. Tributaries with pre-field anticipated and/or field confirmed reservoir-accessible habitat ordered by watershed code.

WSC	Tributary Name	Fig. 3-1 Ref. #	Linear Amount of Reservoir Accessible Habitat (m)				1st Full Mainstem Barrier		Other Barriers Upstream? (Y/N [#])	Potential Available Habitat Upstream of 1st Barrier (m)		
			Drawdown Zone	Mainstem	Tributary	Total	Location[1] (m)	Type		Mainstem	Tributary	Total
230-801600	Portage	50	0	0	0	0	0	falls	N	18,301	1,974	20,275
230-801900	Bullrun	48	0	0	0	0	0	falls	N	803	447	1,250
230-803000	unnamed	1	40	56	0	96	96	gradient	N	0	0	0
230-803200	unnamed	2	45	305	0	350	350	gradient	N	0	0	0
230-804398	unnamed	5	124	523	0	647	647	gradient	N	3,430	4,142	7,572
230-804400	Starfish	6	133	535	0	668	668	cascade	Y [1]	6,194	5,359	11,553
230-806200	unnamed	47	0	0	0	0	0	cascade	N	0	0	0
230-807100	unnamed	45	10	656	0	666	666	gradient	N	0	0	0
230-807600	unnamed	14	0	246	0	246	246	falls	N	1,760	0	1,760
230-809800	Johnson	23	225	841	0	1066	1066	falls	Y [4]	28,640	158,054	186,694
230-810500	Moosebar	25	30	334	0	364	364	falls	Y [1]	6,167	6,224	12,391
230-813000	Mogul	31	40	81	0	121	121	falls	Y [3]	0	0	0
230-815600	Gething	34	180	495	0	675	675	falls	Y	27,603	?	?
230-816500	unnamed	49	0	0	0	0	0	gradient	Y [1]	0	0	0

[1]Upstream location from reservoir confluence

Note 1: Portage Creek and Bullrun Creek currently have no reservoir-accessible habitat since they discharge downstream of the Peace Canyon Dam into the Peace River, but PWFWCP has considered diverting their flows into Dinosaur Reservoir as a fish habitat enhancement initiative.

Note 2: Potential habitat upstream of the first barrier is based on map and air photo interpretation and likely overestimates the actual amount of habitat available.

Table 3-2. Summary of reservoir-accessible tributary habitat quality and quantity ordered from greatest to least area.

WSC	Tributary Name	Figure 3-1 Ref. #	Rearing Habitat Quality	Spawning Habitat Quality	Linear Habitat (m)	Average Channel Width (m)	Estimated Area (m^2)
230-809800	Johnson	23	high	high	1,066	20	21,320
230-815600	Gething	34	high	high	675	30	20,250
230-804400	**Starfish**	**6**	**moderate**	**low/moderate**	**668**	**5.84**	**3,901**
230-804398	**unnamed**	**5**	**moderate**	**low**	**647**	**3.90**	**2,523**
230-810500	Moosebar	25	high	high	364	4.93	1,795
230-813000	**Mogul**	**31**	**low**	**moderate**	**121**	**6**	**726**
230-807100	unnamed	45	poor	none	666	0.50	333
230-807600	unnamed	14	high	low	246	0.94	231
230-803200	**unnamed**	**2**	**poor**	**poor**	**350**	**0.50**	**175**
230-803000	**unnamed**	**1**	**low**	**low**	**96**	**0.75**	**72**
Total							**51,326**

Note: Bold text denotes tributaries with periodic fish access restrictions due to a combination of reservoir operations and high bedload movement resulting in aggraded conditions at their confluences.

Table 3-3. Summary of features identified on tributaries with reservoir-accessible habitat ordered by watershed code.

WSC	Tributary Name	Figure 3-1 Reference #	Barrier			
			Location[1] (m)	Type	Dimensions	Full / Partial
230-801600	**Portage**	**50**	**0**	**falls**	**20 m high**	**full**
230-801900	**Bullrun**	**48**	**0**	**falls**	**~30 m high**	**full**
230-803000	**unnamed**	**1**	**96**	**gradient**	**24% over 575 m**	**full**
230-803200	**unnamed**	**2**	**350**	**gradient**	**167% over 48 m**	**full**
230-804398	unnamed	5	405	falls	0.91 m	partial
230-804398	unnamed	5	425	cascade	1.5 m high, 4 m long	partial
230-804398	**unnamed**	**5**	**647**	**gradient**	**29% over 140 m**	**full**
230-804400	**Starfish**	**6**	**668**	**cascade**	**4.7 m high, 7 m long**	**full**
230-804400	Starfish	6	675	chute	1.2 m high, 8 m long	full
230-804400	Starfish	6	844	log jam	35% over 27 m	full (temporary)
230-806200	**unnamed**	**47**	**0**	**cascade**	**5 m high, 9 m long**	**full**
230-807100	**unnamed**	**45**	**666**	**gradient**	**23% over 100 m**	**full**
230-807600	unnamed	14	119	cascade	3.2 m high, 14.6 m long	partial
230-807600	unnamed	14	223	cascade	4.1 m high, 19.6 m long	partial
230-807600	**unnamed**	**14**	**246**	**falls**	**10 m high**	**full**
230-809800	Johnson	23	922	falls	0.8 m high	partial
230-809800	Johnson	23	968	falls	1.4 m high	partial
230-809800	**Johnson**	**23**	**1043**	**falls**	**6.4 m high**	**full**
230-809800	Johnson	23	1180	falls	5.5 m high	full
230-809800	Johnson	23	1247	falls	2.3 m high	full
230-809800	Johnson	23	1258	falls	3.5 m high	full
230-809800	Johnson	23	1598	falls	25 m high	full
230-810500	Moosebar	25	50	falls	1.2 m high	partial
230-810500	Moosebar	25	60	falls	1.4 m high	partial
230-810500	Moosebar	25	145	falls	0.78 m high	partial
230-810500	**Moosebar**	**25**	**349**	**falls**	**1.93 m high**	**full**
230-810500	Moosebar	25	360	falls	10 m high	full
230-810500	Moosebar	25	360	gradient	22% over 472 m	full
230-813000	**Mogul**	**31**	**81**	**falls**	**6 m high**	**full**
230-813000	Mogul	31	106	falls	2 m high	full
230-813000	Mogul	31	137	falls	3.5 m high	full
230-813000	Mogul	31	1,152	gradient	27% over 670 m	full
230-815600	**Gething**	**34**	**675**	**falls**	**6 m high**	**full**
230-816500	**unnamed**	**49**	**0**	**gradient**	**20% over 600 m**	**full**
230-816500	unnamed	49	972	gradient	>20% over 92 m	full

Note 1: Bold items represent the feature defining the upstream limit of accessible habitat for reservoir fish. Streams 47 and 49 were scoped in during the pre-field phase as having potential reservoir-accessible habitat but firm barriers were identified at their reservoir confluences during field investigations.

Note 2: Portage Creek and Bullrun Creek currently have no reservoir-accessible habitat since they discharge downstream of the Peace Canyon Dam into the Peace River, but PWFWCP has considered diverting their flows into Dinosaur Reservoir as a fish habitat enhancement initiative.

4.0 Habitat Enhancement Options

The range of potential opportunities for improving tributary access or enhancing habitat to directly benefit reservoir fish includes:

- removing barriers on tributaries;
- habitat complexing on tributaries;
- creating new tributary habitat;
- dredging bedload material from tributary confluences with the reservoir where dewatering is an issue;
- augmenting flow to existing reservoir-accessible tributaries by diverting non-fish bearing tributaries;
- habitat complexing within the reservoir; and
- diverting non-reservoir tributaries into the reservoir.

4.1 Barrier Removals

Barrier removal opportunities were carefully considered for all tributaries to the Dinosaur Reservoir, but no viable scenarios were identified. For the tributaries included in Table 3-2 the reasons included: insufficient habitat upstream to justify the effort (*i.e.* the minimum habitat criteria of moderate quality or better was not met as specified during the pre-field phase); features are too significant to feasibly remove (*i.e.* due to excessive height and/or length); conditions are too dangerous to work in (*e.g.* high, overhanging canyon walls); or additional barriers exist upstream within close proximity to the first. Any one of these reasons would be sufficient rationale for avoiding a barrier removal initiative, however, in all but one instance, two or more of these factors exist (Table 4-1). These rationales also extended to the other tributaries where no reservoir-accessible habitat exists.

Table 4-1. Logistical considerations associated with removing the lower barrier on tributaries to the Dinosaur Reservoir.

WSC	Tributary Name	Fig. 3-1 Ref. #	Type	Dimensions	Feasibility	Sufficient Upstream Habitat?	Additional Barriers Upstream?	Safety Risk
230-803000	unnamed	1	gradient	24% over 575 m	low	no	no	high
230-803200	unnamed	2	gradient	167% over 48 m	low	no	no	high
230-804398	unnamed	5	gradient	29% over 140 m	low	yes	no	high
230-804400	Starfish	6	cascade	4.7 m high, 7 m long	moderate	yes	yes	high
230-806200	unnamed	47	cascade	5 m high, 9 m long	moderate	no	no	low
230-807100	unnamed	45	gradient	23% over 100 m	low	no	no	low
230-807600	unnamed	14	falls	10 m high	low	yes	no	high
230-809800	Johnson	23	falls	6.4 m high	low	yes	yes	high
230-810500	Moosebar	25	falls	1.93 m high	moderate	yes	yes	high
230-813000	Mogul	31	falls	6 m high	low	no	yes	moderate
230-815600	Gething	34	falls	6 m high	low	yes	yes	high
230-816500	unnamed	49	gradient	20% over 600 m	low	no	yes	moderate

4.2 Habitat Complexing on Tributaries

No instream works are recommended on unnamed creek (230-803000), unnamed creek (230-803200), unnamed creek (230-804398), or Starfish Creek due to evidence of extreme bedload movement which would translate into a high likelihood of failure.

Although less extreme than the first group, high bedload movement within Mogul Creek, Johnson Creek, and Gething Creek would also present a significant risk of failure if instream works were implemented. Pattenden and Ash (1993b) supported this notion for Johnson Creek and Gething Creek, and indicated that restoring upstream habitat (presumably to stabilize significant sediment sources) should be completed before attempting to enhance reservoir-accessible habitat. Given that Agra (1996) identified 61 landslides and 20 channel bank failures on Johnston Creek alone, addressing even a fraction of these issues would be a very costly endeavour.

For unnamed creek (230-807100), habitat complexing is not considered worthwhile since this stream has an intermittent channel with poor rearing habitat quality and no spawning potential observed.

Unnamed creek (230-807600) and Moosebar Creek appear to be more stable systems where habitat complexing opportunities could be viable. However, both of these streams already have relatively high value rearing habitat, so attempting to further enhance this habitat would likely yield a limited return on investment in terms of increased productive capacity in the Reservoir.

Another consideration might be a 'redistribution concept' that would involve converting rearing habitat to spawning habitat in unnamed creek (230-807600) and Moosebar Creek, and then offsetting that alteration by adding LWD and other habitat complexes to the inlet bays for rearing to achieve an overall net gain to the productive capacity for rainbow trout. This is not a strong option for unnamed creek (230-807600) due to the small average channel width (0.94 m) that would provide limited staging area for many fish pairs, and the relatively steep average gradient (12% to 13%) is far from ideal.

Although the lower 364 m of Moosebar Creek contains rainbow trout and is considered reservoir-accessible habitat, removing two small falls (1.2 m and 1.4 m) from the lower 60 m should precede any enhancement works upstream to maximize the benefit. Since high value spawning and rearing habitats are currently present, further consideration of the redistribution concept should commence with a detailed habitat survey following the fish habitat assessment procedure (FHAP), to fully evaluate the existing conditions. A site prescription would be necessary to formalize the construction design plans for the instream spawning enhancement works, and the FHAP results would allow the amount of displaced rearing habitat to be quantified. A site prescription would also be required for the rearing enhancement activities in the reservoir, which should be equivalent to or greater than the amount of rearing habitat that was displaced from the stream.

It should be noted that a significant level of uncertainty would be associated with any proposed works on Moosebar Creek with regard to whether the project objectives would be met (*i.e.*

achieving a net gain in productive capacity for rainbow trout). This is largely because a functional system currently exists, which includes high value rearing and spawning habitat. As such, there is no guarantee relocating an equivalent or greater amount of stream rearing habitat into the reservoir will afford juveniles similar or better success, especially when the limited reservoir food supply identified by Pattenden and Ash (1993b) is considered. To validate this strategy, the baseline sampling program should include spawning (*i.e.* enumeration of adult spawners and/or a fry emergence program) and juvenile rearing utilization components. At least one year would be needed but ideally a multi-year approach would be taken to identify natural variability. Over a five year monitoring program, it is suggested that two years occur pre-construction, and three years occur post-construction.

4.3 Creating New Tributary Habitat

Due to the steep topography associated with the reservoir and its tributaries, there are limited opportunities to create new habitat in the form of side channels. The best option exists in a wide section at the lower end of Johnson Creek, however, this system currently has some of the best quality rearing and spawning habitat in the reservoir (comparable only to Gething Creek). As such, it is questionable whether a net gain in productive habitat capacity would result since partitioning flows into a new side channel would detract from the existing habitat capacity.

4.4 Dredging

To address dewatering conditions at the lower end of several streams, which is jointly caused by high bedload movement and reservoir operations, dredging may be a viable solution to treat the problem. This strategy would require use of a barge to facilitate excavator access. Of the five tributaries that might benefit from a dredging program, Starfish Creek and unnamed creek (230-804398) are the best two candidates since they have the highest quality habitat with the most available area, and they are located next to each other (Table 4-2).

The major drawback to this concept is that an ongoing commitment (likely annual) would be required to maintain desired conditions at each tributary confluence with the reservoir. However, the five year maintenance period associated with the implementation phase of this Peace Water Use Plan project (*i.e.* GMSWORKS#8) would provide an evaluation period do determine whether dredging is a practical long-term option.

Another point for consideration is that dredging may help to restore free fish access to existing habitat that is currently being utilized, but no new habitat would be created or become accessible because of that initiative. It is therefore questionable whether dredging would result in a measureable increase to the productive capacity of the Reservoir, since migration between the Reservoir and relevant streams does periodically occur as often as daily. A related Peace WUP project (*i.e.* GMSMON#14), would address this concern through baseline and post-construction monitoring.

Table 4-2. Priority ranking of tributaries affected by reservoir operations that might benefit from a dredging program.

Priority Rank	WSC	Tributary Name	Figure 3-1 Reference #	Reservoir-Accessible Habitat (m^2)	Rearing Habitat Quality	Spawning Habitat Quality
1	230-804400	Starfish Creek	6	3,901	moderate	low/moderate
2	230-804398	unnamed creek	5	2,523	moderate	low
3	230-813000	Mogul Creek	31	726	low	moderate
4	230-803000	unnamed creek	1	72	low	low
5	230-803200	unnamed creek	2	175	poor	poor

4.5 Augmenting Tributary Flows

To enhance the potential habitat capacity for reservoir-accessible streams, opportunities were considered whereby flow from non-fish bearing drainages could be diverted. With the additional flow, the recipient stream(s) could potentially be widened to create new habitat. However, no viable opportunities exist.

4.6 Habitat Complexing within the Reservoir

Although the primary objective of this project was to identify habitat enhancement opportunities on tributaries to the reservoir, the limited range of viable options naturally directs further consideration toward treatments within the reservoir. To date, woody debris complexes installed in several bays have proven effective at increasing fish use in treated areas, and it is believed that furthering this initiative by adding more wood to more bays would be a sound strategy for augmenting rearing habitat.

4.7 Diverting Portage Creek and Bullrun Creek into the Reservoir

The concept of diverting Portage Creek and Bullrun Creek into the Reservoir was originally put forward by a local BC Hydro employee in response to BC Hydro's "Resource Smart" initiative in 1989 to increase power production at the Peace Canyon Dam. Pattenden and Ash (1993b) built on the idea by suggesting a fish habitat benefit could be incorporated in addition to power production. PWFWCP staff explored the concept further with preliminary field studies, and presented the idea during the initial WUP meeting for the Peace (Langston, pers. comm.).

Currently both creeks flow into the Peace River just downstream of the Peace Canyon Dam, and have impassable barriers located at their confluences. The rainbow trout and longnose sucker populations in Portage Creek are likely the result of illegal introductions by residents (Langston and Murphy 2008). Evidently, sufficient habitat to support overwintering exists since both species have continued to persist after the introductions.

As depicted in Figure 3-1, Portage Creek would represent the most significant habitat gain, with approximately 18 km of mainstem habitat and 2 km of tributary habitat to be made accessible. Bullrun Creek could represent an additional 800 m of mainstem habitat and 450 m of tributary habitat. In total, an estimated 21.5 km of new stream habitat could become accessible to reservoir fish.

With respect to feasibility, commencing realignment from a point on Portage Creek approximately 1,800 m upstream of the Peace River would be recommended in order to maintain a favourable average gradient (2%), minimize alteration of existing habitats, and avoid existing infrastructure. This would require the construction of approximately 1,850 m of new channel.

The following considerations would help to facilitate an effective final result and maintain cost control:

1. Use the existing surveyor's suggested alignment to estimate cut/fill quantities. Cut quantities can be minimized by varying the channel slope between 0.5% - 5% to accommodate existing topography, and altering the alignment as appropriate.
2. Conduct test pits along the proposed alignment to support the channel design.
3. An average channel width of 4 m would be about the right size for the new channel, since Portage has an average width of 3 m and Bullrun has an average width of 1.2 m. This width would also allow equipment to travel down the new channel corridor during construction without needing to disturb the new future riparian habitat.
4. Develop the channel design to include typical habitat features (determine the number and spacing required).
5. Consider augmenting the newly constructed channel with suitable spawning substrate.

5.0 Conclusions and Recommendations

The following conclusions have resulted from this study:

- Concerns that woody debris accumulations from upstream logging are restricting fish access to tributaries was not validated during any step of this project (*i.e.* literature review, orthophoto review, and field investigations);
- A combination of reservoir operations and high bedload movement are causing access restrictions to five tributaries with reservoir-accessible habitat;
- All reservoir-accessible tributary habitat was comprehensively evaluated. It was estimated that 51,326 m^2 exists (of which 41,570 m^2 is split between Johnson Creek and Gething Creek);
- Accessible tributary habitat appears to be a major factor limiting fish production in the Dinosaur Reservoir;
- This study adequately characterized enhancement opportunities for all tributaries to the Dinosaur Reservoir and determined that:
    - No viable barrier removal opportunities were identified that would significantly increase the amount of accessible tributary habitat;
    - Most accessible tributaries are not considered suitable candidates for habitat complexing initiatives due to chronic bedload movement and unstable canyon conditions;
    - Accessible tributary habitats on stable streams (*i.e.* Moosebar Creek and unnamed creek (230-807600)) are considered functional and provide limited opportunities for habitat complexing enhancements;
    - Converting high value rearing habitat into spawning habitat on Moosebar Creek, and offsetting that alteration by habitat complexing the inlet bay for rearing may achieve an overall net gain to the productive capacity for rainbow trout, but results would have a significant level of uncertainty;
    - The lower end of Johnson Creek is the best candidate location for new side channel creation, but partitioning flow from the existing channel may not result in net gains in productive habitat capacity; and
    - No viable opportunities exist for augmenting flows in accessible streams.

Dredging to remove aggregated bedload at stream confluences may be viable, but would require an ongoing maintenance commitment. Starfish Creek and unnamed creek (230-804398) are the two best candidates.

However, the best opportunities for enhancing the productive capacity for fish in the Dinosaur Reservoir include:

- Diverting Portage Creek and Bullrun Creek into the Dinosaur Reservoir. The greatest benefit of this newly accessible habitat would be for rearing, although an effort could also be made to augment spawning habitat within the 1,850 m long new channel section; and
- Continuing to add woody debris to the reservoir bays is a proven strategy to increase rearing habitat quality.

BC Hydro will utilize the information provided in this report in its implementation of the follow-up Peace Water Use Plan project GMSWORKS#8 – Dinosaur Reservoir Demonstration

Tributary, which is designed to consider the potential fish habitat and/or access restoration in more detail and undertake the required remedial works and maintenance over the five year life of the project. A related Peace WUP project GMSMON#14 – Dinosaur Tributary Habitat, would facilitate baseline and post-construction monitoring to evaluate three key management questions:

1. Is the tributary enhancement work effective at increasing usable habitat?
2. Is the area and quality of fish habitat created by the tributary enhancement work sufficient to noticeably increase spawning and rearing opportunities in the reservoir?
3. Is the area and quality of fish habitat created by the tributary enhancement maintained over time?

6.0 References

Agra Earth and Environmental Limited. 1996. Johnson Creek level 1 watershed assessment. Unpublished report prepared for Ministry of Forests, Dawson Creek Forest District. 13 pp plus appendix.

Aquatic Resources Ltd. 1999a. 1998 reconnaissance (1:20,000) fish and fish habitat inventory of Stott and upper Gaylard creeks, Gething Landscape Unit. Unpublished report completed for Canadian Forest Products Ltd. (Chetwynd Division).

Aquatic Resources Ltd. 1999b. 1998 reconnaissance (1:20,000) fish and fish habitat inventory of Johnson and other tributaries to Dinosaur Reservoir, Johnson Landscape Unit. Unpublished report completed for Canadian Forest Products Ltd. (Chetwynd Division).

BC Hydro. 2008. Peace project water use plan, physical works terms of reference: GMSWORKS-8 and GMSWORKS-9 Dinosaur Reservoir tributary inventory and feasibility.

Blackman, B.G., E.B. Murphy, and D. Cowie. 2004. 2003 Dinosaur Reservoir littoral fish population and habitat enhancement assessments. Peace/Williston Fish and Wildlife Compensation Program, Report No. 298. 13 pp plus appendices.

Blackman, B.G. and D.M. Cowie. 2005. 2004 assessment of habitat improvements in Dinosaur Reservoir. Peace/Williston Fish and Wildlife Compensation Program, Report No. 299. 9 pp.

Cowie, D.M. 2004. Dinosaur Reservoir and Peace River volunteer creel summary 2003 – Permit #SC2003-012, Report No. 292. 8 pp.

Euchner, T. 2006. Identification of potential lake trout spawning areas in the Dinosaur Reservoir, 2003-2004. Prepared for /Williston Fish and Wildlife Compensation Program, Report No. 310. 32 pp plus appendices.

Harvey, K. 1995. Peace Fisheries – field report. Unpublished field report prepared for BC Hydro.

Hatfield Consultants Ltd. 2000. Reconnaissance inventory of Moosecall Lake – WSC: 230-809800-10900-23100, waterbody identifier: 01057UPCE. Unpublished report prepared for Canadian Forest Products Ltd. (Chetwynd Division). 18 pp plus appendices.

Johnston, N.T. and P.A. Slaney. 1996. Fish habitat assessment procedures. Ministry of Environment, Lands and Parks and Ministry of Forests, Watershed Restoration Program, Technical Circular 8.

Joslin, J. 2001a. 1999 Dinosaur Reservoir creel survey report. Peace/Williston Fish and Wildlife Compensation Program, Report No. 238. 19 pp plus appendices.

Joslin, J. 2001b. 2000 Dinosaur Reservoir creel survey report. Peace/Williston Fish and Wildlife Compensation Program, Report No. 257. 22 pp plus appendices.

Langston, A.R. 2008. Gething Creek bull trout translocation project, 1993 to 2005. Peace/ Williston Fish and Wildlife Compensation Program, Report No. 333. 24pp. plus appendices.

Langston, A.R. and E.B. Murphy. 2008. The history of fish introductions (to 2005) in the Peace/Williston Fish and Wildlife Compensation area. Peace/Williston Fish and Wildlife Compensation Program, Report No. 325. 59 pp.

Langston, A.R. and R.J. Zemlak. 1998. A reconnaissance survey of Gaylard Creek and bull trout habitat suitability, 1994. Peace/Williston Fish and Wildlife Compensation Program, Report No. 140. 16 pp plus appendices.

Murphy, E.B. and B.G. Blackman. 2004. Dinosaur Reservoir 2001 fish collection summary. Peace/Williston Fish and Wildlife Compensation Program, Report No. 287. 12 pp plus appendices.

Murphy, E.B., B.G. Blackman, D.M. Cowie, and N. Baccante. 2004. Dinosaur Reservoir 2002 fish collection summary. Peace/Williston Fish and Wildlife Compensation Program, Report No. 297. 19 pp plus appendices.

Newsholme, K. and T. Euchner. 2006. Fish counting fence operation on Johnson Creek, 2006. Peace/Williston Fish and Wildlife Compensation Program, Report No. 308. 15 pp plus appendices.

Pattenden, R. and G. Ash. 1993a. Dinosaur Lake summer creel surveys, Results of the 1988 program and a five year review (1984-1988). Peace/Williston Fish and Wildlife Compensation Program, Report No. 73. 26 pp plus appendices.

Pattenden, R. and G. Ash. 1993b. Fisheries enhancement options for Dinosaur Lake, a review. Peace/Williston Fish and Wildlife Compensation Program, Report No. 72. 38 pp plus appendices.

Peace Country Materials Testing Ltd. 1997. Level II hillslope and road assessment – Burnt Trail Creek sites I and II. Unpublished report prepared for BC Ministry of Forests, Dawson Creek.

Province of British Columbia. 2001. Reconnaissance (1:20,000) fish and fish habitat inventory: standards and procedures – version 2. BC Ministry of Fisheries, Victoria, BC.

Province of British Columbia. 2007a. Ministry of Environment – Cross-linked information resources. Accessed June 30, 2009. http://bing.search.sympatico.ca/?q=clir&mkt=en-ca&setLang=en-CA.

Province of British Columbia. 2007b. Ministry of Environment – Fisheries inventory data queries (FDIQ). Accessed June 30, 2009.

http://a100.gov.bc.ca/pub/fidq/main.do;jsessionid=b2c93ef12a43991fb5f5cdc67dc5d093454428e37a191778793c7bbfd0fbec11.e3uMah8KbhmLe34PaNqTaNaPbxr0n6jAmljGr5XDqQLvpAe.

Province of British Columbia. 2007c. Ministry of Environment – HabitatWizard. Accessed July 2, 2009. http://www.env.gov.bc.ca/habwiz/.

Stiemer, R. 2006. 2005 Dinosaur Reservoir creel survey report. Peace/Williston Fish and Wildlife Compensation Program, Report No. 306. 14 pp plus appendices.

APPENDIX 1

PHOTOGRAPHS

Plate 1. View of unnamed creek (230-803000) from the reservoir.

Plate 2. View of the gradient barrier on unnamed creek (230-803000), 96 m upstream from the reservoir confluence.

Plate 3. Showing the channel bed on unnamed creek (230-803000).

Plate 4. Downstream view toward the reservoir showing dewatering at the lower end of unnamed creek (230-803000).

Plate 5. View of unnamed creek (230-803200) from the reservoir.

Plate 6. View of the gradient barrier on unnamed creek (230-803200), 350 m upstream from the reservoir confluence.

Plate 7. Showing the channel bed on unnamed creek (230-803200).

Plate 8. Downstream view toward the reservoir showing dewatering at the lower end of unnamed creek (230-803200).

Plate 9. View of unnamed creek (230-804398) from the reservoir.

Plate 10. View of the gradient barrier on unnamed creek (230-804398), 647 m upstream from the reservoir confluence.

Plate 11. Downstream view of the channel on unnamed creek (230-804398), 300 m upstream of the reservoir.

Plate 12. Showing the start of wetted channel conditions on unnamed creek (230-804398), 146 m upstream of the reservoir.

Plate 13. View of Starfish Creek from the reservoir.

Plate 14. View of the 4.7 m high, 7 m long cascade barrier on Starfish Creek, 668 m upstream from the reservoir confluence.

Plate 15. Upstream view of the channel on Starfish Creek, ~590 m upstream of the reservoir.

Plate 16. Downstream view of the channel on Starfish Creek, ~460 m upstream of the reservoir.

Plate 17. Downstream view of channel on unnamed creek (230-807600), 80 m upstream of the reservoir.

Plate 18. View of the 10 m falls barrier on unnamed creek (230-807600), 246 m upstream from the reservoir confluence.

Plate 19. Downstream view of channel on unnamed creek (230-807600), 246 m upstream from the reservoir.

Plate 20. Downstream view toward the reservoir at the lower end of unnamed creek (230-807600).

Plate 21. View of unnamed creek (230-806200) from the reservoir showing the 5 m high, 9 m long cascade barrier at the confluence.

Plate 22. Downstream view of channel on unnamed creek (230-806200), 20 m upstream of the reservoir.

Plate 23. View of unnamed creek (230-807100) from the reservoir.

Plate 24. Upstream view of the intermittent channel on unnamed creek (230-807100), 60 m upstream of the reservoir.

Plate 25. View of Johnson Creek from the reservoir.

Plate 26. View of the 6.4 m falls barrier on Johnson Creek, 1043 m upstream from the reservoir confluence.

Plate 27. View of the 25 m high upper falls on Johnson Creek, 1598 m upstream from the reservoir confluence.

Plate 28. Downstream view of channel on Johnson Creek, 475 m upstream from the reservoir.

Plate 29. View of Moosebar Creek from the reservoir.

Plate 30. View of the 1.2 m falls (foreground) and 1.4 m falls (background) on Moosebar Creek, 50 m upstream from the reservoir.

Plate 31. Downstream view of typical channel habitat on Moosebar Creek.

Plate 32. View of the 1.93 m falls (foreground) and 10 m falls (background) on Moosebar Creek, 349 m upstream from the reservoir.

Plate 33. View of Mogul Creek from the reservoir.

Plate 34. View of the 6 m falls barrier on Mogul Creek, 81 m upstream from the reservoir.

Plate 35. View of the 2 m falls (foreground) and 3 m falls (background) on Mogul Creek, 106 m upstream from the reservoir.

Plate 36. Downstream view of the channel on Mogul Creek.

Plate 37. View of Gething Creek from the reservoir.

Plate 38. View of the 6 m falls barrier on Gething Creek, 675 m upstream from the reservoir.

Plate 39. Upstream view of the channel on Gething Creek, 430 m upstream of the reservoir.

Plate 40. Upstream view of the channel on Gething Creek, 600 m upstream of the reservoir.

Plate 41. View of the shoreline where unnamed creek (230-816500) seeps into the reservoir.

Plate 42. Upstream view showing the steep boulder slope through which unnamed creek (230-816500) seeps down to the reservoir.

Plate 43. Upstream view of channel on Bullrun Creek, 290 m upstream of the Peace River confluence.

Plate 44. Downstream view of channel on Bullrun Creek.

Plate 45. Showing the steep (~20 m) drop from Portage Creek down to the Peace River.

Plate 46. Upstream view of channel habitat on Portage Creek, 200 m upstream of the Peace River confluence.

Plate 47. Downstream view of channel habitat on Portage Creek, 200 m upstream of the Peace River confluence.