May | 2010

Cheakamus/Squamish River Engineered Log Jam Pilot Project

2009 PROJECT FINAL REPORT

Photo Credit: Randall Lewis

prepared for:
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BC Hydro - Bridge Coastal Fish and Wildlife Restoration Program

prepared by:
British Columbia Conservation Foundation

prepared with financial support of:
"BC Hydro Bridge Coastal Fish and Wildlife Restoration Program"

BCRP Project # 09.CMS.04

GREATER GEORGIA BASIN STEELHEAD Recovery Plan
www.SteelheadRecoveryPlan.ca

BCCF Project Report # 04-2009

BRITISH COLUMBIA CONSERVATION FOUNDATION

Executive Summary

Fish use in the mainstem Squamish and low-gradient reaches of its major tributaries includes all five pacific salmonid species (coho, chinook, sockeye, chum and pink), steelhead and sea-run cutthroat and char. Although the reduction in several salmonid species in Squamish River over the past five decades is noted in many Georgia Basin streams, and may be related to common limiting factors, it has been proposed that several specific impacts have acted to reduce the quality and quantity of rearing habitat.

There is a distinct lack of stable rearing habitat in the mainstem channels of Squamish River watershed, much of which would have once been provided by stable instream LWD. The importance of replacing instream large woody debris (LWD) in the Squamish River watershed for this purpose has been acknowledged in many technical reports. The Cheakamus-Squamish River Engineered Logjam Pilot Project was initiated to address some of the broader instream habitat limitations affecting the basin, in particular the issue of LWD habitat. A reach within the lower section of Cheakamus River was selected as being suitable for installation of LWD structures to emulate the natural function of logjams that have historically had a significant role in channel form and process.

A log jam was recently installed by BCCF at Site 2 within this treatment reach. This report outlines the rationale and design conditions under which a similar log structure has been designed at Site 1 within the same reach. The purpose of the Site 1 structure is to address impaired instream fish habitat values as well as to provide additional stability at the head of a threatened side-channel. The structure would work in concert with the existing jam, which has become weakened, to help prevent further loss of riparian forest and control flows into the side-channel.

The proposed structure would span approximately 120 linear metres of bank and be comprised of 73 individual logs. Boulder ballast would be used to overcome the buoyant forces acting on the logs while piles would be driven into the river bed to overcome the sliding forces of the velocity component of the flow. Similar construction methods would be used as were employed to successfully install the log jam at Site 2 in April and May of 2010.

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1. Introduction

Fish use in the mainstem Squamish and low-gradient reaches of its major tributaries includes all five pacific salmonid species (coho, chinook, sockeye, chum and pink), steelhead and sea-run cutthroat and char. Resident fish present include rainbow trout, cutthroat trout, char, mountain whitefish, green sturgeon, coast-range sculpin, three-spine stickleback and lamprey. Although the reduction in several salmonid species in Squamish River over the past five decades is noted in many Georgia Basin streams, and may be related to common limiting factors, it has been proposed that several specific impacts have acted to reduce the quality and quantity of rearing habitat. For instance, from KWL (1998):

- Reduced (rearing) habitat capability associated with changes to inputs of sediment and woody debris;
- Loss of side channel habitat and reduced tributary access associated with changes to flow regime (discharge and timing). Such impacts have been increased by dyking.

Impoundment has reduced coarse sediment recruitment by as much as 50% in the reach between Culliton Creek and Cheekeye River (NHC 2000), a major salmon producing section of the Cheakamus River. Reduced downstream migration of coarse sediment decreases the formation of mid-channel bars, leading to a reduction in channel braiding and the development of side-channel habitat utilized for salmonid rearing and overwintering. Impoundment-related losses of LWD recruitment to the lower Cheakamus River have been estimated at 500 m^3 annually (NHC 2000), and may be as high as 5,000 m^3 during extreme storms and log jam failure in the upper Cheakamus River. LWD recruitment is important for forming lateral and apex log jams to provide erosion protection for established mid-channel bars and side-channel inlets.

Flow diversion from the dam reduces total and base flows, minimizes peak discharge from small to moderate floods, and can eliminate the freshet in extreme low-flow years (NHC 2000). Furthermore, the average channel width in the section of the Cheakamus River between Culliton Creek and Cheekeye River has decreased from 175 m in 1964 to 113 m in 1999, while the length of side and back channels connected to the mainstem has declined substantially. As a result of these impacts, the lower Cheakamus River has experienced a simplification from a braided, meandering system to sinuous, single channel form further impacting channel morphology and reducing available fish habitat, including natural log jams.

Descriptions of hydroelectric impacts of the Daisy Lake reservoir and power generation on the lower Cheakamus River include the loss of instream habitat, reduced LWD and gravel recruitment, diminished overall habitat and capacity, reduced downstream productivity (BC Hydro 2000). From this document, the fish restoration objectives include conserving and improving aquatic habitats in the lower Cheakamus River through an artificial recruitment scheme to restore the delivery of some sediment and wood to the mainstem.

There is a distinct lack of stable rearing habitat in the mainstem channels of Squamish River watershed, much of which would have once been provided by stable instream LWD. The importance of replacing instream LWD in the Squamish River watershed for this purpose has been acknowledged in many technical reports (e.g. Goodings 1997) and applications to watersheds with lack of LWD (Crispin *et al*. 1993; Cederholm *et al*. 1997; Reeves *et al*. 1997).

The Cheakamus-Squamish River Engineered Logjam Pilot Project was initiated to address some of the broader instream habitat limitations affecting the basin, in particular the issue of LWD habitat. A reach within the lower section of Cheakamus River was selected as being suitable for installation of LWD structures to emulate the natural function of logjams that have historically had a significant role in channel form and process (**Figure 1**). Anthropogenic modifications in the channel and human-influenced disturbance in the watershed have altered these natural processes. For instance, forest harvesting of much of the floodplain areas has reduced the natural recruitment of large trees into the channel, while installation of riprap to protect infrastructure adjacent to the channel has negatively affected the retention of LWD.

Public and official support for artificially constructed logjam habitat are coloured by negative perceptions that arise from misconceptions about their purpose and function. For instance, recreational boaters and sports fishers may view artificial (and even natural) logjams as an unacceptable hindrance to their enjoyment of the river. Officials from various levels of government have in the past raised concerns about the potential effects that failed logjams may have on infrastructure or the possible exacerbating effect they may have on local flooding. A properly designed and constructed logjam should function to enhance the natural river processes and the designer needs to consider the non-natural constraints of infrastructure and nearby habitation.

The alteration of flow through which natural woody debris enhances fluvial habitat requires that the LWD remain relatively stable. Various techniques have been used in BC as well as in Washington and Oregon States to anchor, or otherwise stabilise the wood pieces. These techniques either rely on partial burial of the wood in the banks and weighting with other pieces piled above, or they rely on mechanical anchors and ballast. Given the proximity of the site above the Squamish Valley Bridge and the lower cost associated with using cables and boulder ballast, a decision was made to design the structure using these more positive techniques.

A number of potential sites were identified within the treatment reach of Cheakamus River. The purpose of this Project Final Report is to outline the design process that has been undertaken to develop an effective bank stabilisation and logjam enhancement treatment at Site 1.

2. Goals and Objectives

The goal of this project is to develop a suitable design for the Site 1 location within the treatment reach. The design can be constructed using similar techniques as the structure that was installed by BCCF at Site 2 during April and May of 2010.

The objectives of the Site 1 project are to:

- Enhance instream aquatic habitat through the placement of stable LWD;
- Improve bank strength to resist the current trend of lateral migration of the side-channel opening;
- To preserve existing riparian floodplain vegetation by reducing the rate of bank erosion;
- To work in tandem with the existing LWD jam at the site to extend the longevity of this important log jam;
- To help to control the flows entering the head of the side-channel and reduce the risk of a channel avulsion; and
- To recruit additional wood pieces into the logjam.

These objectives are consistent with the identified habitat impacts and resulting restoration goals outlined in Section 1 above.

3. Study Area

The overall project site is the Squamish River watershed, a catchment draining over 3,500 km^2, entering Howe Sound at Squamish, BC, approximately 50 km north of Vancouver, BC (**Figure 1**). Cheakamus River drains an area of approximately 1,010 km^2, meeting Squamish River approximately 12.5 km from the mouth. The identified treatment reach of Cheakamus River in which Site 1 is situated, is located 5 km upstream from the mouth, between the Water Survey of Canada (WSC) gauge and the confluence with Cheekeye River (**Figure 2 and 3**). The reach encompasses a large, semi-stable island and bar complex that has split the river, resulting in the mainstem flowing to river left of the island and a smaller side-channel to flow to river right of the island. Site 1 is located at the head of the smaller side-channel and is characterised by a large accumulation of wood that is presently acting to control flows into the side-channel, providing some protection against a full avulsion into the secondary channel.

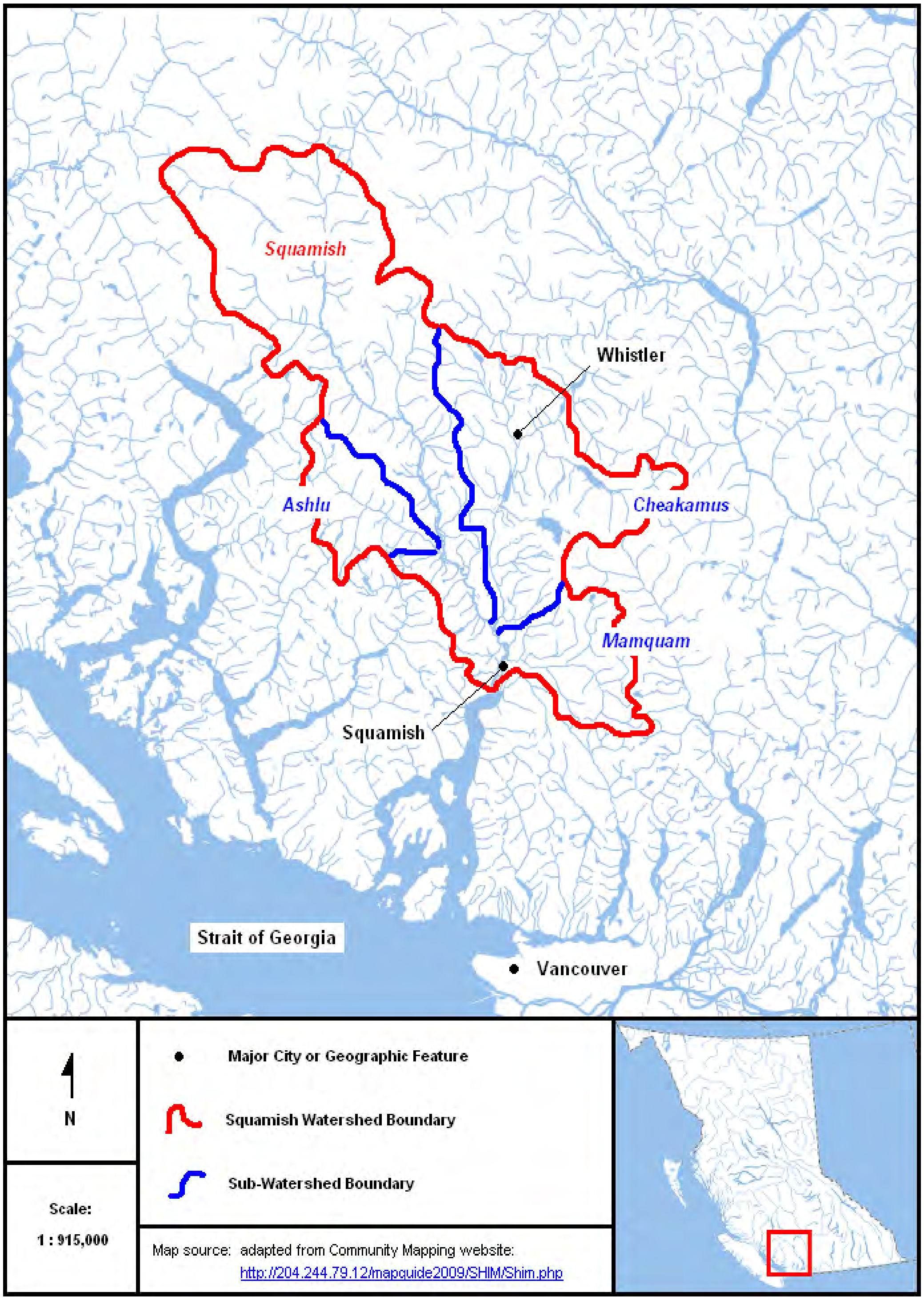

Figure 1 Project overview map highlighting watershed boundaries in relation to major cities.

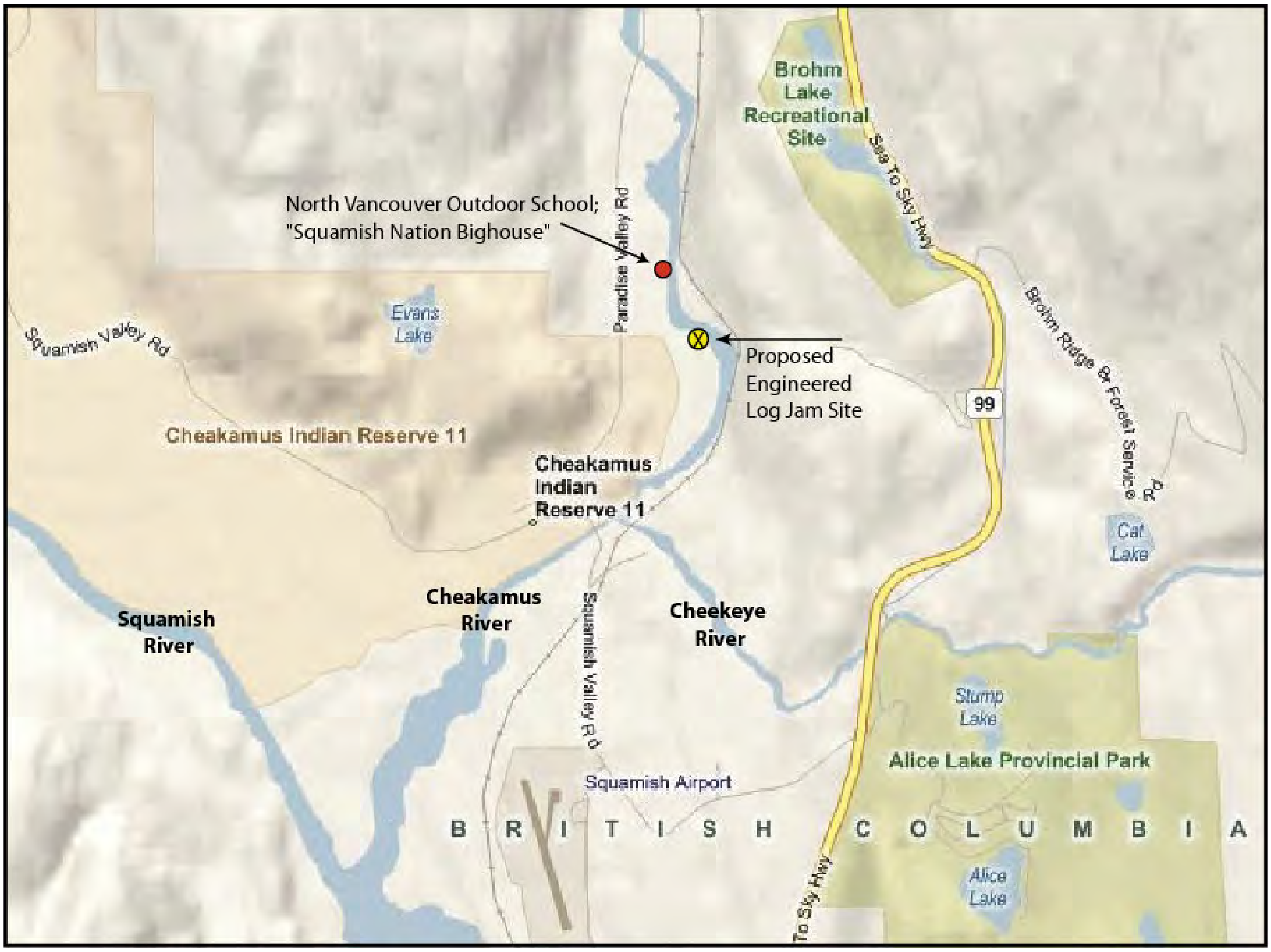

Figure 2 Overview and location of Site 1.

Figure 3 Study reach and location of Site 1.

4. Methods

The methods employed follow a standard approach to the design of instream Large Woody Debris (LWD) structures that has been documented in the Watershed Restoration Program Technical Circular No. 8 publication "Large Woody Debris Fish Habitat Structure Performance and Ballasting Requirements" by D'Aoust and Millar (1999). This approach has been adapted by the design engineers (Northwest Hydraulic Consultants) based on experience and site conditions. The following tasks were completed as part of the design process:

- Overview-level geomorphic analysis of the reach to determine the optimum sites for LWD placement
- Conceptual-level design of the LWD structures
- Site surveys for structure design as well as hydraulic calculations
- Analysis of hydrology to determine design discharge – recommend 50-year flood as the suitable design criteria
- Calculation of design hydraulic conditions using 1-dimensional hydrodynamic model (HEC-RAS)
- Calculation of ballast requirements, pile depth, and other elements relating to structure stability
- Design drawings and memo outlining the recommended construction methodology

The NHC (2010a) report outlines the methodology in more detail as well as providing the specifics of the recommended design. This memo relies in part on the more detailed analysis that was included in the NHC (2010b) memo that was prepared in support of construction of the log jam project at Site 2 in the same reach of Cheakamus River. Both memos are included in **Appendix IV**.

5. Results

The results of the hydrologic analysis indicate that the 50-year daily maximum flow for Cheakamus River is 700 m^3/s. Typically the 200-year flood is referenced in the design of major infrastructure but this higher magnitude design condition is inappropriately conservative for the design of habitat structures in areas where the consequences of structure failure are low.

The HEC-RAS model results indicate that the average channel velocities in the vicinity of Site 1 would be 3.36 ms^{-1} and using a standard ratio to adjust for the expected maximum channel velocities, a design velocity of 5 ms^{-1} was estimated. The height of the 50-year flood water elevation was also computed by the model and indicates that flows would be above the top of bank.

Based on these hydraulic conditions, the adopted design approach assumed that it would not be possible to apply sufficient ballast to overcome the sliding forces of the river and that piles would have to be driven along the bank to add additional lateral stability. Ballast requirements were calculated to overcome the buoyant forces of high water acting on the logs, assuming that they were completely submerged.

The proposed design employs a repeating pattern of V-shaped log spurs aligned along the riverbank to form a continuous revetment that will act in concert with the existing natural log jam at the site. Filler logs and tie-in logs will be used to connect the repeating elements and to fill the space between the structures. **Table 1** summarises the number of logs that would be required to construct the proposed structures along two sections of the bank measuring 40 m and 80 m long respectively. The table includes a provision for up to 10 log piles that would be driven into the river bed near the base of the bank.

Table 1 Log requirements for the Site 1 structure.

Length (m)	Diameter (m)	Typical Root Wad Diameter (m)	Number	Detail
10	0.5	2	33	Key piece
9	0.5	2	16	Filler pieces
8	0.5	2	6	Tie-in pieces
6	0.5	2	5 - 8	Additional filler pieces
5	0.35	-	10	Piles

Table 2 shows the boulder ballast requirements for a single V-shaped spur element in order to overcome the buoyant forces of the logs. The table provides the required weight for a range of boulder sizes. Table 3 provides the same ballast information for the project based on the assumption that a total of 16 spur elements would be constructed.

Table 2 Boulder ballast requirements for a single V-shaped log spur.

Total Weight Required (kg)	Boulder Diameter (m)	Approximate Weight per Boulder (kg)	Total Number Required
10,535	1.0	1390	8
10,200	1.1	1850	6
9,990	1.2	2400	5
9,800	1.3	3050	4

Table 3 Total boulder ballast requirements the project.

Total Weight Required (kg)	Boulder Diameter (m)	Approximate Weight per Boulder (kg)	Total Number Required
168,560	1.0	1390	122
163,200	1.1	1850	89
159,840	1.2	2400	67
156,800	1.3	3050	52

6. Discussion

The design for the Site 1 LWD structures outlined in the NHC (2010a) memo is based on similar principles as the log jam structure that was recently successfully completed by BCCF at Site 2 in the same reach (completed May 2010). The V-shaped spurs that form the repeating elements of the structure are based on a proven design that has been installed at numerous locations throughout the province of BC as well as in Washington and Oregon states.

Construction of the Site 1 structures would follow similar methods as those used to install the LWD jam at Site 2. This structure was successfully installed using standard heavy machinery as well as a specialised ‘spyder’ hoe with no significant adverse impacts on the environment.

The biological importance of large wood in coastal streams and rivers has been well documented (for example Crispin *et al*. 1993; Cederholm *et al*. 1997; Reeves *et al*. 1997). The geomorphic importance of LWD within the river channel has received similar attention in the scientific literature (for example Keller and Tally, 1979; Keller and Swanson, 1979; Brooks and Brierly, 2002). Restoration efforts that focus on the re-introduction of LWD and the proper management of riparian vegetation are therefore based upon a solid scientific background of focused study.

The NHC (2000) study clearly demonstrates the negative impacts of human influences on Cheakamus River, particularly with respect to the loss of LWD and outlines the direct geomorphic influence. Roni and Quinn (2001) have demonstrated a high correlation benefit relating placements of LWD to increased densities and size of juvenile salmonids. A restoration program that focuses on installing stable LWD structures at key locations within Cheakamus River is therefore of prime importance to the future recovery of fish populations within the system.

7. Recommendations

As mentioned, the LWD jam at Site 2 has been installed (construction completed in May, 2010). Ongoing monitoring of this structure will provide valuable information regarding the effectiveness and long-term stability of this type of structure within Cheakamus River. In addition, this successful project can be used to demonstrate the value of LWD structures while allaying fears held by various public groups of their potential negative effects.

The design for Site 1 is intended to address a potential channel avulsion, loss of riparian forest, and alteration of valuable off-channel habitat. The excellent track record that BCCF holds with respect to installing ballasted log structures demonstrates that the potential negative impacts of proceeding with construction of this design are minimal. We recommend that restoration activities continue within this reach with the installation of the proposed structure at Site 1 at the earliest opportunity, which would be during the low-flow season of late-winter and early spring of 2011.

8. Acknowledgements

This project was co-funded through BC Hydro Bridge Coastal Fish and Wildlife Restoration Program ($7,050).

Other financial and in-kind partners included: Living Rivers Georgia Basin/Vancouver Island; CN-Cheakamus Ecosystem Recovery Fund; and the BC Ministry of Environment, totalling $14,407.

All field assessments and survey data collection were conducted by BC Conservation Foundation fisheries technicians, and personnel from Northwest Hydraulic Consultants.

9. References

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Appendices

I. Financial Statement
II. Performance Measures-Actual Outcomes
III. Confirmation of BCRP Recognition
IV. NHC Design Memos

I. Financial Statement

Project #_09.CMS.

Financial Statement Form

	BUDGET		ACTUAL	
	BCRP	Other	BCRP	Other
INCOME				
Total Income by Source	20900.00	61490.00	20900.00	6492.34
Grand Total Income (BCRP + other)	***82390.00***		***27950.20***	
EXPENSES	**Note: Expenses must be entered as negative numbers (e.g. – 1000, etc.) in order for the formulas to calculate correctly.**			
Project Personnel				
Wages - BCCF	2800.00	9350.00	200.33	500.00
Consultant Fees - NHC	2100.00	6900.00	6208.94	5245.43
Wages – govt biologist	4100.00	13500.00	0	0
Wages – RP Bio	2000.00	6000.00	0	0
Materials & Equipment				
Equipment Rental	1750.00	5250.00	0	0
Materials Purchased				
Travel Expenses	2400.00	5050.00	0	0
Permits				
(List others as required)				
Helicopter	3400.00	8600.00	0	0
Safety supplies	250.00	750.00	0	0
Equipment maintenance	50.00	150.00	0	0
Administration				
Office Supplies				
Photocopies & printing	150.00	350.00	0	0
Postage				
(List others as required)				
Admin fee	1050.00	6440.00	640.93	746.91
Total Expenses	***20900.00***	***61490.00***	***7050.20***	***6492.34***
Grand Total Expenses (BCRP + other)	***82390.00***		***13542.54***	
BALANCE (Grand Total Income – Grand Total Expenses)	The budget balance should equal $0 ***0***		*The actual balance might not equal $0** ***14407.66***	

* Any unspent BCRP financial contribution to be returned to: BC Hydro, BCRP
6911 Southpoint Drive (E16)
Burnaby, BC V3N 4X8
ATTENTION: SCOTT ALLEN

II. Performance Measures-Actual Outcomes

Project #09.CMS.04

Performance Measures – Target Outcomes

Project Type	Primary Habitat Benefit Targeted of Project (m^2)	Primary Target Species	Habitat (m^2)									
			Estuarine	In-Stream Habitat – Mainstream	In-stream Habitat – Tributary	Riparian	Reservoir Shoreline Complexes	Riverine	Lowland Deciduous	Lowland Coniferous	Upland	Wetland
Impact Mitigation												
Fish passage technologies	Area of habitat made available to target species											
Drawdown zone revegetation/stabilization	Area turned into productive habitat											
Wildlife migration improvement	Area of habitat made available to target species											
Prevention of drowning of nests, nestlings	Area of wetland habitat created outside expected flood level (1:10 year)											
Habitat Conservation												
Habitat conserved – general	Functional habitat conserved/replaced through acquisition and mgmt											
	Functional habitat conserved by other measures (e.g. riprapping)											
Designated rare/special habitat	Rare/special habitat protected											
Maintain or Restore Habitat forming process												
Artificial gravel recruitment	Area of stream habitat improved by gravel plmt.											
Artificial wood debris recruitment	Area of stream habitat improved by LWD plcmt			Proposed $480m^2$								
Small-scale complexing in existing habitats	Area increase in functional habitat through complexing											
Prescribed burns or other upland habitat enhancement for wildlife	Functional area of habitat improved											
Habitat Development												
New Habitat created	Functional area created											

III. Confirmation of BCRP Recognition

The goal of this project was to develop a suitable design to address the goals outlined in Section 1 of this report. While considerable time and effort was spent gathering data in the field at the site, there was limited opportunity for media involvement at this stage of the project. Future stages will involve ground-breaking and the construction of the ELJ at the proposed site. In these later stages, when there is a product to show to the public and the press, we will take steps to highlight BCRP's financial contribution through various media such as inclusion of the project completion report on the Living Rivers – Georgia Basin/Vancouver Island website, through invitations to local newspaper companies, through on-site signage, and particularly through presentations routinely given to angling and stewardship groups. Prior to the construction stage of this project, this project completion report will be submitted to Living Rivers to add to their website as they provided partnership funding, along with BCRP, for this project.

Presentations to angling and stewardship groups are used to highlight our funding partners, discuss past project and identify upcoming projects. For example, a presentation was given to 40 members of the Kingfishers Rod and Gun Club on February 3, 2010.

On-site signage is an effective way to inform river users of project objectives and to highlight funding partners. The typical project sign measures 36" X 60" and is made of a laminated high resolution vinyl graphic wrapped over aluminum. Signs are positioned at the project site to inform river users of the project objectives and funding partners.

IV. NHC Design Memos