BC hydro

Columbia River Project Water Use Plan

YEAR 6 (2013) FISH MIGRATION PASSAGE MONITORING AND FINAL REPORT

Reference: CLBMON– 32A

Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program

2014

Ecoscape Environmental Consultants Ltd.
#102 – 450 Neave Court
Kelowna, BC
V1V 2M2

November 2014

PROGRAM NO. CLBMON-32A

YEAR 6 (2013) FISH MIGRATION PASSAGE MONITORING AND FINAL REPORT

Prepared For:

BC HYDRO
6911 Southpoint Drive, 11th Floor
Burnaby, B.C. V3N 4X8

Prepared By:

ECOSCAPE ENVIRONMENTAL CONSULTANTS LTD.

#102 – 450 Neave Court
Kelowna, BC
V1V 2M2

Authors: Kyle Hawes, R.P.Bio.
Danielle Drieschner, R.P.Bio

November 2014
Ecoscape File: 08-249.6

Recommended Citation:

Hawes K., D. Drieschner, and R. Wagner. 2014. Arrow Lakes Tributary Fish Migration Access. Year 6 (2013) Fish Migration Passage Monitoring and Final Report. Program No. CLBMON-32 / Q8-8004. Ecoscape Environmental Consultants Ltd. Kelowna, BC. 40pp + maps and appendices.

CLBMON 32A STATUS OF OBJECTIVES MANAGEMENT QUESTIONS AND HYPOTHESES AFTER YEAR 5			
Objectives	**Management Hypotheses**	**Management Questions**	**Final Status (Year 6)**
To determine the impact of reservoir operations on the upstream passage of key fish species, particularly Rainbow Trout, into Arrow Lakes Reservoir tributaries. Included in the geographic scope of this program are fish bearing tributaries that flow into Arrow Lake Reservoir. The scope of the program includes both a gray literature review of all studies relating to spawning assessments conducted on Arrow Lakes tributaries and a physical assessment of passage conditions into reservoir tributaries under varying reservoir and stream flow conditions. The key fish species for this program is Rainbow Trout (*Oncorhynchus mykiss*), and, to a lesser extent, Kokanee (*O. nerka*), and Bull Trout (*Salvelinus confluentus*).	The current operation (with soft operational constraints) of Arrow Lakes Reservoir results in reservoir elevations that block or impede spawning migrations of key species.	Q.1. Does the operation of the Arrow Lakes Reservoir block or reduce upstream migration of focal fish populations in tributary streams?	A.1. The operations of the Arrow Lakes Reservoir can block or reduce upstream migration of fish populations in tributary streams. This reduced access is a result of low to very low stream flows being conveyed through wider, aggraded, more poorly defined, and braided channels over the drawdown zone. The dynamic channel form exhibited over the drawdown zone of many tributaries is the result of the high vertical fluctuation of the reservoir. When these drawdown zones are exposed and stream flows are low to very low, upstream fish migration can be blocked. In the spring, stream temperature monitoring suggests that **Rainbow Trout migration** may not occur until mid-April and later when passage conditions are good. Good passage conditions continue through June and July and decrease into September with the onset of Kokanee migration and spawning. **Kokanee migration** access has been observed to be reduced in some tributaries in spite of reservoir levels being at or above the 434m soft operating constraint. In these instances, access impairments are the result of very low stream discharges on individual watercourses. **Bull Trout** migrations to spawning grounds can occur as early as April and continue to September. This temporal range makes it difficult to focus on a specific period to monitor tributary drawdown zone conditions for Bull Trout passage. The combined higher stream flows and reservoir levels during earlier tributary access would provide good passage conditions for Bull Trout. There are 28 tributaries known to be frequented by Bull Trout. Twenty one of the streams are in the upper Arrow, 2 are situated in the Narrows, and 5 occur in the north end of Lower Arrow. With the exception of Eagle Creek that has late summer passage concerns and occasionally Drimmie Creek that has the potential to develop a braided channel upstream of the reservoir, the balance of tributaries supporting Bull Trout are not likely to have passage concerns. These tributaries are generally larger (higher order and magnitude streams) or occur in the upper Arrow basin, where higher elevation watersheds (i.e. more prolonged snow melt) and more moist to wet climate regime sustain higher flows throughout the year.
		Q.2. Are there significant reservoir elevation thresholds below which spawner access is impacted?	A.2. The greatest potential for impediments to Rainbow Trout migration in the early spring (late March-early April) occur when reservoir levels are below 429 m and stream flows are low to very low. The 2010-2013 stream temperature monitoring suggests that spring Rainbow Trout migrations may not occur until mid-April or later. Under current operations, tributaries are generally accessible by Rainbow Trout by the second to third week in April. At that time average reservoir elevations are around 427 m, based hydrometric data over the period of record (1984-2012), and relative discharges are rapidly increasing from low to moderate. As a result, passage conditions improve quickly through April with no concerns for Rainbow migration. However, the risk for migration barriers increases if Rainbow migrations were initiated in late March to early April when flows are still low to very low. During Kokanee migration and spawning, the current soft operating constraint of 434 m represents a key elevation threshold. Reservoir elevation passage thresholds are dependent on stream flows. The observed very low stream flows that occur late August – early September on some of the key tributaries sometimes result in passage assess impediments when Arrow Reservoir was at 434 m.
		Q.3. Do high stream flows in tributaries in the spring mitigate impacts of low reservoir elevations?	A.3. Spring surveys in 2013 were completed in mid-May during the period when Rainbow Trout migration and spawning are expected to be in progress. Consistent with observations from previous years, high stream flows in tributaries in the spring mitigated potential impacts of low reservoir elevations.

EXECUTIVE SUMMARY

The Columbia River Water Use Plan Consultative Committee (WUP CC) identified that seasonal changes in the elevation of Arrow Lakes Reservoir have the potential to negatively affect the ability of key fish populations of Kokanee (*Oncorhynchus nerka*), Bull Trout (*Salvelinus confluentus)*, and Rainbow Trout (*O. mykiss*)) to access critical spawning habitats in the Arrow Lakes tributaries. The maximum allowable vertical fluctuation, between full pool and full drawdown, is 21.5 m. Based on hydrometric data from 1984 to 2008, the average seasonal change in reservoir elevation is about 12 meters (m). In the past 5 years of monitoring (2009-2013), the average seasonal change was 10.5 m. The greatest seasonal change monitored was in 2012, when a 13-m change from low water (427.5 m) to high water (440.5 m) occurred. These seasonal changes in reservoir level, in association with the topography of the tributary fans and stream flows, have the potential to restrict tributary access at times of the year when focal fish species are migrating.

The main management objective of the Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program (CLBMON-32) was to determine the extent of reservoir operational impacts on the upstream passage of Rainbow Trout, Kokanee, and Bull Trout. The goal of the project was to address the following management questions (BC Hydro 2007b):

1. **Does the operation of the Arrow Lakes Reservoir block or reduce upstream migration of focal fish populations in tributary streams? Are there significant reservoir elevation thresholds below which spawner access is impacted?**

2. **Do high stream flows in tributaries mitigate impacts of low reservoir elevations?**

During Year 1 of the CLBMON-32 program, Ecoscape conducted a thorough grey literature and data review on Kokanee, Rainbow Trout, and Bull Trout distributions and life histories in the Arrow Reservoir and tributaries (Drieschner et al. 2008). This Status of Knowledge report indicated that spawner access was generally not impeded by low reservoir levels in most tributaries. Instead, seasonally low stream flows were an identified concern to Kokanee access over the drawdown zone in the fall (Drieschner et al. 2008).

Tributaries with known or potential impediments to upstream fish access were identified. Of these, creeks identified in the literature as having moderate to high fisheries production value were selected as key tributaries for the subsequent five-year monitoring program.

In 2013, spring surveys to evaluate Rainbow Trout migration passage conditions were conducted from May 21-28, 2013, and Kokanee access monitoring was carried out from September 9–12, 2013. An additional inspection was carried out from October 7 – 10, 2013 to assess tributary passage conditions at combined different flow and reservoir levels to help close out gaps in the passage matrix.

The lowest recorded level for Arrow Reservoir in 2013 was 427.93 m, which occurred on February 15. At the beginning of April the reservoir level was around 430.2 m. Elevations remained relatively constant around 430 m until May 8 when levels began to increase sharply to over 434 m by May 23.

The soft constraints target objective for fishes as established by the Consultative Committee is to

> "*Ensure appropriate reservoir elevations for tributary access during the Kokanee spawning period (late August – early November). Reservoir levels of 434 m (1425 ft) could cause tributary access to be restricted.*"

At the beginning of September the reservoir level was 433 m, 1-m below the soft constraint (434 m). Levels continued to drop and were 1.5 m below the soft constraint by September 15.

There were no passage concerns during the May Rainbow Trout migration and spawning passage assessments, when stream flows were at moderate stages and the reservoir was at about 430 m. Six (6) of the 18 tributaries had passage concerns during September Kokanee passage assessments. Increased fall passage concerns were attributed to lower reservoir levels and low to very low stream flows. A slight increase in flows in the key tributaries resulted in improved passage conditions in early October, which may have benefitted Bull Trout migration and spawning.

Monitoring over the past 5 years documented highly variable and dynamic conditions over the drawdown zone of Arrow Reservoir tributaries. High vertical fluctuations of the reservoir contribute to channel instability, aggrading and braiding in some tributary fans. Reduced fish migration access is a result of low to very low stream flows and wider, more poorly defined channels over the drawdown zone.

The greatest impacts to fish migration access in the spring occur when reservoir levels are below 429 m and stream flows are low to very low. However Rainbow Trout life history and stream temperature monitoring indicate that RB migration does not begin until mid- April or later when stream flows are increasing and the reservoir level is at or above 429 m. This indicates that high stream flows mitigate passage concerns during low reservoir levels. Over the 5-years of field monitoring, nine (9) tributaries had passage concerns identified. Of these, six (6) tributaries are identified as priority for potential action and monitoring.

TABLE OF CONTENTS

TABLES

FIGURES

MAP SHEETS WITH HYDROMETRIC DATA AND REPRESENTATIVE PHOTOS

APPENDICES

1.0 INTRODUCTION

Construction of the Hugh Keenleyside Dam in 1968, Mica Dam in 1973, and Revelstoke Dam in 1984 had considerable implications for Arrow Lakes' fish populations. With flooding of the Arrow Reservoir in 1969, it was estimated that nearly 30% of the available spawning and rearing habitats were lost in the inundated reaches of tributaries of the Lower Arrow Lake. Coupled with this, it was conservatively estimated that 20% of the available spawning and rearing habitat of the Upper Arrow Lake tributaries was flooded (BC MOE 1984; CCRIFC 2006; Schindler et al. 2006).

The losses in stream habitat also appeared to vary by species: for instance, the percentage of Kokanee spawning habitat lost was estimated between 20-30%, while Rainbow Trout spawning habitat losses in Arrow Lakes and Columbia River tributaries were reported to be approximately 75% (Toth and Tsumara 1996). Flooding also resulted in the loss of the productive littoral area of the Arrow Lakes (BC MOE 1983; Andrusak and Slaney 2004). The end result of flooding the reservoir was that remaining tributaries now have higher gradient and cooler temperatures, which are more conducive to Bull Trout than Rainbow Trout or Kokanee spawning (Sebastian et al. 2000).

Throughout the course of the year, fluctuating reservoir levels can render spawning habitats both within and above the drawdown zone inaccessible or non-functional and egg mortality can occur because of stranding, desiccation, freezing, or siltation/smothering due to increased stream bank erosion (Ford et al. 1995). Furthermore, fry rearing in shallow, low velocity areas along stream margins can also become stranded - this is of particular concern for Bull Trout fry seeking refuge within streambed substrates (McPhail and Baxter 1996).

The Columbia River Water Use Plan Consultative Committee (WUP CC) identified that seasonal changes in the elevation of Arrow Lakes Reservoir have the potential to negatively affect the ability of key fish populations (Kokanee (*Oncorhynchus nerka*), Bull Trout (*Salvelinus confluentus)*, and Rainbow Trout (*O. mykiss*)) to access critical spawning habitats in the Arrow Lakes tributaries. The focal fish species for field survey efforts to date has been Rainbow Trout, as Rainbow Trout spawning in the spring typically coincides with low reservoir levels. Assessment of Kokanee spawning in the fall has also occurred consistently throughout the monitoring program to evaluate passage during typically reduced stream flows.

The maximum allowable vertical fluctuation between full pool and full drawdown is 21.5 m. Based on hydrographic data from 1984 to 2008, the average seasonal change in reservoir elevation is about 12 meters (m). These seasonal changes in reservoir levels, coupled with varying stream flows and topographic configuration of tributary fans, present potential obstacles to fish passage. Attributes associated with the topographic configuration of the tributary fan include gradient, channel depth, and channel morphology (e.g., braiding). Depending on the configuration of the fan, surface

flows may become discontinuous to absent during seasonal low flow periods, which can restrict upstream fish passage and furthermore, lead to fish stranding and potential fish mortality.

The program CLBMON-32A Arrow Reservoir Tributary Fish Migration Access Assessment and Monitoring Program is a six year study to assess passage conditions at Arrow Lakes Reservoir tributaries under a range of operating levels and stream flow conditions to determine threshold reservoir levels below which fish passage is prevented. The following final report presents the 2013 tributary access monitoring results, summarizes the five years of observations, and draws conclusions with respect to the Management Questions. The Status of Knowledge report and results of the first four years of tributary access monitoring are presented under separate cover as follows:

Status of Knowledge Report - Drieschner, D., K. Hawes, M.A. Olson-Russello, and J. Schleppe. 2008. Arrow Lakes Tributary Fish Migration Access. Status of Knowledge Report. Program No. CLBMON-32 / Q8-8004. Ecoscape Environmental Consultants Ltd. Kelowna, BC. 99pp. + appendices.

Year 1 (2009) Passage Monitoring - Hawes K., and R. Wagner. 2010. Arrow Lakes Tributary Fish Migration Access. Year 2 (2009) Fish Migration Passage Monitoring Summary Report. Program No. CLBMON-32 / Q8-8004. Ecoscape Environmental Consultants Ltd. Kelowna, BC. 63pp.

Year 2 (2010) Passage Monitoring - Hawes K., D. Drieschner, and R. Wagner. 2011. Arrow Lakes Tributary Fish Migration Access. Year 3 (2010) Fish Migration Passage Monitoring Summary Report. Program No. CLBMON-32 / Q8-8004. Ecoscape Environmental Consultants Ltd. Kelowna, BC. 43 pp + appendices.

Year 3 (2011) Passage Monitoring – Hawes K., D. Drieschner. 2012. Arrow Lakes Tributary Fish Migration Access. Year 4 (2011) Fish Migration Passage Monitoring Summary Report. Program No. CLBMON-32 / Q8-8004. Ecoscape Environmental Consultants Ltd. Kelowna, BC. 50pp + maps and appendices.

Year 4 (2012) Passage Monitoring - Hawes K. and D. Drieschner, 2013. Arrow Lakes Tributary Fish Migration Access. Year 5 (2012) Fish Migration Passage Monitoring Summary Report. Program No. CLBMON-32 / Q8-8004. Ecoscape Environmental Consultants Ltd. Kelowna, BC. 46pp + maps and appendices.

2.0 BACKGROUND

2.1 Operational Overview

The Columbia River Project Water Use Plan (WUP) guides operating conditions of BC Hydro's hydroelectric facilities on the Columbia River (BC Hydro 2007a). The preferred operating strategy of this plan was developed from the recommendations of the Columbia River Water Use Plan Consultative Committee (CRWUPCC). The CRWUPCC is a multi-stakeholder group consisting of members of BC Hydro, municipal, provincial and federal government agencies, industry, First Nations and local stakeholders (BC Hydro and CRWUPCC 2005).

The consultation process spanned four years and was completed in June 2004. This process established fundamental objectives for several key interests within the Columbia River system, including: Culture and Heritage, Fish and Aquatic Resources, Flood Erosion Control, Learning, Navigation, Power Generation, Recreation and Wildlife and Vegetation (BC Hydro and CRWUPCC 2005).

Rather than imposing strict operating limitations on the Arrow Lakes Reservoir within the Water Use Plan, the Consultative Committee brought forth a series of "soft constraints" to guide operations in a manner that would reflect positively on the key interests/values identified within the reservoir (BC Hydro and CRWUPCC 2005; CCRIFC 2006; BC Hydro 2007a). The soft constraints target objective for fishes as established by the Consultative Committee is to

> "*Ensure appropriate reservoir elevations for tributary access during the Kokanee spawning period (late August – early November). Reservoir levels of 434 m (1425 ft) could cause tributary access to be restricted.*"
> (BC Hydro and CRWUPCC 2005 – page 10, Table 2)

The full pool elevation of the Arrow Lake reservoir is 440.14 m (Sebastian et al. 2000; den Biesen and Ord 2002; Andrusak and Slaney 2004; BC Hydro 2007a). The maximum allowable drawdown level (minimum elevation) is 418.64 m (Andrusak and Slaney 2004; BC Hydro 2007a). The Arrow Lakes Reservoir generally experiences its lowest levels in March - April and September - October, and is highest in July - August, reaching full pool in July (RL & L Environmental Services 1997; Bray and Mylechreest 1999; Andrusak and Slaney 2004).

2.2 Management Objectives and Questions

The main management objective of the Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program is to determine the extent of reservoir operational impacts on the upstream passage of Rainbow Trout, Kokanee, and Bull

Trout. The goal of the project is to address the following three management questions (BC Hydro 2007b):

1. **Does the operation of the Arrow Lakes Reservoir block or reduce upstream migration of focal fish populations in tributary streams? Are there significant reservoir elevation thresholds below which spawner access is impacted?**

2. **Do high stream flows in tributaries mitigate impacts of low reservoir elevations?**

2.2.1 Management Hypothesis

The primary null management hypothesis (H_o) to be evaluated by the monitoring program is:

> **The current operation (with soft operational constraints) of Arrow Lakes Reservoir results in reservoir elevations that block or impede spawning migrations of key species.**

The key species of interest for Program CLBMON-32A include Rainbow Trout, Kokanee and Bull Trout. The Status of Knowledge Report (Drieschner et al. 2008) indicated that spawner access of the key species was generally not impeded by low reservoir levels in most tributaries. Instead, low stream flows in the fall, rather than reservoir elevations, were of concern to Kokanee access over the drawdown. The soft operating constraint for Kokanee, established at 434 m geodetic reservoir level is intended to facilitate tributary access during the Kokanee spawning period (late August to early November) (BC Hydro and CRWUPCC 2005). This should also facilitate Bull Trout tributary access, as Bull Trout spawning occurs from September to November (Ford et al. 1995; Sebastian et al. 2000), with most Bull Trout spawning in the Arrow Lakes reported to occur from September to October (Ford et al. 1995; McPhail and Baxter 1996). The passage assessments within this program reviewed Kokanee and Bull Trout tributary access and drawdown zone use in relation to this soft operating constraint. Fall survey timing has focused on early to mid-September as Kokanee are more conspicuous and have a lower vertical threshold (0.5 m) (CCRIFC 2006). Spring monitoring surveys, occurring at low reservoir levels and during the period of Rainbow Trout spawning migrations (April-May), also assessed whether high stream flows in the spring may mitigate impacts of low reservoir to these migrations.

2.3 Study Sites (Key Tributaries)

During Year 1 of the CLBMON-32A program, a thorough grey literature and data review was completed on Kokanee, Rainbow Trout, and Bull Trout distributions and life histories in the Arrow Reservoir and tributaries (Drieschner et al. 2008). Tributaries with known or potential impediments to upstream fish access were identified. Of these, creeks flagged as having moderate to high potential fisheries production value were selected as key tributaries for the subsequent five-year monitoring program. As a result, 23 tributaries were selected for fish migration access monitoring in 2009. Following the 2009 field season, focal tributaries were further refined. Dog Creek (watershed code: 300-703500) occurring in Upper Arrow Lake (UARL), Jenning Creek (UARL), Montana Creek (UARL), Turner Creek (UARL), and Inonoaklin Creek (Lower Arrow Lake (LARL)) were not revisited in 2010 due to their small magnitude and overall low fisheries production capacity. Inonoaklin was not monitored further due to the fact that a waterfall barrier was around 431.5 m and the LARL typically backwaters to the base of these falls from mid-late May through to February. While these streams were removed from intensive field monitoring, Eagle Creek was added to the field sampling program in 2010, due to observed severe aggrading and low flow impediments to Kokanee access in September 2009. Table 1 provides a list of all 18 key tributaries monitored in 2013, as well as presence of drawdown zone barriers. The location of these watercourses along the Arrow Lakes Reservoir is shown in Figure 1. Table 2 identifies key fish species (Rainbow, Kokanee, and Bull Trout) distributions, species richness, and relative habitat ratings for key tributaries.

Table 1. Key tributaries monitored in 2013 for fish migration access during spring Rainbow Trout migration and late summer Kokanee and Bull Trout staging and migration.

Tributary	Watershed Code	Drawdown Barriers
Dog Creek[1]	300-656100	Potential
Renata Creek	300-656400	Yes for Kokanee due to low stream flows in the fall
Johnston Creek	300-669900	Potential
Caribou Creek	300-690300	Potential
Burton Creek	300-690200	Potential
Taite Creek	300-676400	Potential
Octopus Creek	300-673700	Potential
Deer Creek	300-653800	Potential
Little Cayuse Creek	300-653000	Potential
Bannock Creek	300-729800	Yes
Cranberry Creek	300-735400	Potential
Blanket Creek	300-743400	Potential
Drimmie Creek	300-744600	Potential
Crawford Creek	300-737300	Potential
MacKenzie Creek	300-730500	Potential
Payne Creek	300-729900	Potential
Nacillewaet Creek	300-728800	Potential
Eagle Creek	300-674700	Yes

1. Two watercourses named Dog Creek feed into the Arrow Reservoir. That occurring in the UARL basin was removed from the monitoring program after 2009. However, Dog Creek occurring in LARL (watershed code: 300-656100) near Renata remains in the monitoring program.

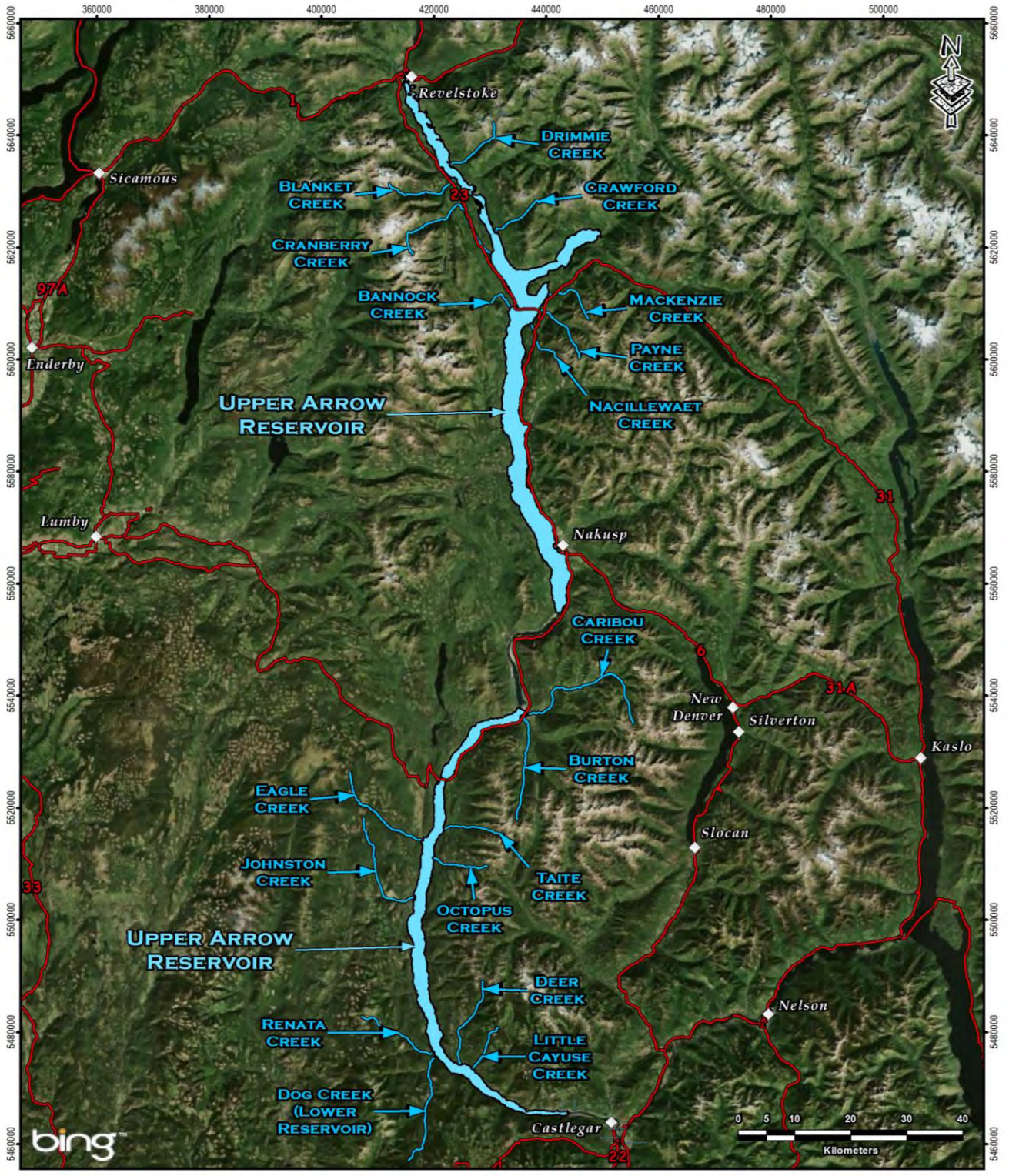


Figure 1. Arrow Reservoir and Location of key streams assessed in Year 5 fish migration passage assessments.

Table 2. Summary of key fish species distributions (Rainbow, Kokanee, and Bull Trout), species richness, and relative habitat ratings for key tributaries.

			Species		
Tributary Name	**Habitat Rating**	**Fish Species Richness**	**RB**	**KO**	**BT**
Bannock Creek	Moderate	2	✓	✓	
Blanket Creek	Moderate	4	✓	✓	✓
Burton Creek	High	5	✓	✓	✓
Caribou Creek	High	8	✓	✓	✓
Cranberry Creek	Moderate	2	✓	✓	
Crawford Creek	Moderate	3	✓	✓	✓
Deer Creek	High	5	✓	✓	
Dog Creek	High	6	✓	✓	
Drimmie Creek	Moderate	3	✓	✓	✓
Eagle Creek	High	6	✓	✓	✓
Johnston Creek	Moderate	5	✓	✓	
Little Cayuse Creek	High	3	✓	✓	
Mackenzie Creek	High	4	✓	✓	✓
Nacillewaet Creek	Moderate	2	✓	✓	
Octopus Creek	Moderate	2	✓	✓	
Payne Creek	Moderate	2	✓	✓	
Renata Creek	Moderate	5	✓	✓	
Taite Creek	High	4	✓	✓	✓

3.0 METHODS-YEAR 5 (2013) TRIBUTARY PASSAGE ASSESSMENTS/MONITORING

Inventory and study elements were designed to investigate spawning distribution and tributary access. Field surveys were timed to coincide with Rainbow Trout, Kokanee and Bull Trout staging and spawning activities.

3.1 Timing of Field Activities

Three (3) assessment periods were completed during the fifth year of passage assessments.

- Rainbow Trout migration passage condition assessments were carried May 21 - 28.
- Kokanee and Bull Trout passage condition assessments were carried out from September 9–12.
- An additional Field assessment of passage conditions was carried out from October 7 – 10 to assess tributary passage conditions at combined different flow and reservoir levels to help close out gaps in passage matrix.

3.2 Transport Logistics and Safety

Lake access to key tributaries was provided by an 18 foot aluminum hull Hewes Craft boat powered by a 115 hp outboard (*Commercial License: C-17345BC*). All field personnel were Marine Emergency Duty (MEDA3) certified and the principal biologist was a certified Small Vessel Operator (SVOP). Prior to initiating the field program, it was ensured that all crew members had current first aid and spinal immobilization and transportation endorsement certification.

Access and launch sites used throughout the monitoring program included:

- Edgewood (access to tributaries of Lower Arrow Lake)
- Shelter Bay (access to tributaries of Upper Arrow Lake)

3.3 Habitat Assessments

Biophysical surveys of the tributary fans used a modified version of the data collection methods and standards of Sensitive Habitat Inventory and Mapping (SHIM) (Mason and Knight, 2001). Georeferenced data were recorded using a Trimble Nomad and XH GPS Receiver and entered into a digital data dictionary. Data collection methods and processing standards can be reviewed in full at:

http://www.shim.bc.ca/methods/SHIM_Methods.html

The drawdown zone was stratified into a series of sections (segments), each characterized by different attributes or biophysical characteristics (e.g., hydraulic class, channel characteristics, substrate compositions, etc.). Features such as key habitats, photo locations, and obstructions were recorded as GPS point features. Associated physical characteristics including gradient, length/width/height/water depth, and general descriptive comments were attached to each spatial reference point.

The extents of the right and left bank wetted levels and reservoir wetted level were recorded during each of the assessment periods using the handheld GPS Trimble Nomad and XH Receiver. The respective data field collected are summarized in Table 3.

Table 3. Overview of mapped channel limit data fields collected using the Trimble data dictionary.

Segment length	linear measure of channel (m)
Stage	dry; low; moderate; high ; very high; flood
Bank and channel stability	eroding; low; moderate; high
Passage	passable; marginal; impassable
Wetted channel limit	wetted limits
Gradient	% grade
Spawning Habitat	Yes/No; Species
Hydraulic Character	Beaver Pond; Cascade; Cascade-Pool; Falls; Pool; Run; Riffle; Riffle-Pool; Slough; Standing; Wetland; Other
Channel Pattern	Straight; Sinuous; Irregular; Irregular meandering; Regular meanders; Tortuous meanders
Bars	Side; Diagonal; Mid-channel; Spanning; Braided
Islands	Occasional; Split; Frequent – Irregular; Frequent – Regular; Anastomosing
Predominant Substrate	Organic; Fines; Gravel; Cobble; Boulder; Bedrock
Substrate Composition	% Organic; % Fines; % Gravel; % Cobble; % Boulder; % Bedrock
Embeddedness/Compaction	Degree of embeddedness of coarse substrates in fines (sand/silt)
% Instream Cover	Boulder; Deep Pool; Instream Vegetation; Large Woody Debris; Overstream Vegetation

3.4 Stream Hydrologic Monitoring

Detailed cross section surveys were completed during all three (3) field sampling periods in 2013. Discharge data calculated from these surveys has been used to inform the passage matrix described in Section 3.7, which computes passage scores based on relative stream discharge classes (i.e., very low, low, moderate, and high) and concurrent reservoir levels.

Stream cross sections were established upstream of the present natural boundary of the reservoir; where stream channels were more stable and confined by established treed riparian communities. Survey locations were recorded with a Trimble Nomad hand held GPS coupled to a ProXH Receiver marked in the field with flagging tape and either galvanized spikes or rebar along the left and right banks.

Table 4 lists the location coordinates of the detailed cross sections for the 18 streams surveyed during the 2013 monitoring program.

Table 4. Detailed cross section locations established for each of the 18 watercourses surveyed during the 2013 field surveys.

Tributary	Location Coordinates (UTM 11N)
Dog Creek	5475715 N 420135 E
Renata Creek	5476342 N 419773 E
Johnston Creek	5503929 N 416373 E
Little Cayuse Creek	5473453 N 426743 E
Deer Creek	5474277 N 424860 E
Taite Creek	5516140 N 421837 E
Octopus Creek	5512640 N 419891 E
Eagle Creek	5514238 N 417710 E
Burton Creek	5536236 N 436026 E
Caribou Creek	5536684 N 436678 E
Nacillewaet Creek	5606280 N 437229 E
Payne Creek	5608850 N 438930 E
MacKenzie Creek	5611586 N 440330 E
Bannock Creek	5609358 N 433486 E
Cranberry Creek	5618876 N 430036 E
Blanket Creek	5632288 N 423280 E
Drimmie Creek	5634760 N 422810 E
Crawford Creek	5622822 N 430883 E

Limitations to collection of cross section data included high stream flows that prohibited safe wading in some of the larger tributaries during the May 2013 monitoring visits. In some instances, measurements were taken along much of the stream width where the channel was safely accessible. Where possible, interpolation of data gaps occurred to establish an approximate discharge.

For data collection, cross sections were laid out by securing a fibreglass metric tape measure across the bankfull width of the channel from the left bankfull limit to the right bankfull limit, perpendicular to the direction of flow. Measurements recorded at each cross section location included the following:

- Wetted depth (m)
- Bankfull depth (m)
- Velocity (m/s)
- Stream gradient (upstream and downstream gradients were recorded using a hand held clinometer)
- Bankfull width (m)
- Wetted width (m)
- In situ water quality measurements, including stream temperature, pH, TDS and electric conductivity

Depth and velocity measurements were generally taken at 0.5 m intervals, which in most instances met or exceeded the 20 to 25 recommended number of vertical measurement positions collected to calculate discharge (BC MoE, 2009). In the case of small streams, such as Payne Creek with a 4-m bankfull width, verticals were spaced at 0.25 m intervals to obtain the optimum number of measurements and a more accurate discharge calculation.

Velocities were measured using a Swoffer Current Metre with Model 2100 sensor, including 1.4 m top set wading wand/rod, 3 m sensor cable, propeller rotor assemblies and 2100 digital readout indicator with neck strap. Velocity measurements were read at 6/10 of the water column depth from the stream surface, as this provides an estimate of the average velocity in the water column (BC MoE, 2009; Swoffer Instruments Inc. product info; Washington State Department of Ecology, 2009). When water depths were less than 0.75 m, the 6/10 measurement was used. When water depths exceeded 1 m, and when safe to do so, the 2 point system was used whereby the 2/10 and 8/10 velocity measurements were recorded to calculate mean velocity (BC MoE, 2009).

One crew member recorded data in written field notes, while the other crew member collected the velocity and depth measurements and called them out to the recorder. Prior to recording, the numbers were repeated by the recorder to the data collector, ensuring that the number was heard correctly and that no erroneous readings occurred. For data consistency and quality assurance and control, crew members and their duties were generally consistent throughout the 2013 field season.

Cross section data were transcribed into an Excel™ sheet for quality control and ease of data processing. Discharge was calculated with the formula:

Discharge (Q) = Water Velocity (V)*Area (A).

Discharges were calculated for each stream cross section in May, September, and October and are presented in Table 6 in Section 4.0 Results.

3.5 Stream Temperature Monitoring

Onset HOBO Pendant Temperature/Light data loggers (UA-002-64) were installed in all 18 tributaries for a period throughout the monitoring program. The purpose of these loggers was to collect hourly temperature information over the year, which could be related back to stream discharges and fish life history timing.

Loggers were installed using a combination of galvanized wire attached to T-stakes or rebar which was hammered into creek substrates. In some instances, large galvanized spikes were used where timber bridge abutments or stable rooted large woody debris (LWD) was present.

Factors considered in selecting locations for the data loggers included:

- stream depth such that the logger would be submerged year-round
- inconspicuous location to minimize detection and vandalism
- size of substrate for attachment – large boulders that would withstand high flows during freshet
- accessibility for data retrieval
- protection from mobile stream substrates/bedload moving downstream
- hydraulic character – calm water downstream with small substrates is ideal (Isaak and Horan, 2010)

Each of the data loggers were launched onsite by connecting a laptop to the loggers with a PC interface cable. HOBOware Lite Software 3.0 was used to launch the HOBO loggers. Software updates were completed upon installation. Ecoscape ensured that all data loggers were recording temperature data prior to leaving the site. The loggers were programmed to record stream temperature readings at one (1) hour intervals.

All data loggers were re-checked during each subsequent survey period to retrieve data and to verify that they are still intact and functioning. In the event that damage or loss occurs, the data logger was replaced. Battery life was monitored during each field visit, with replacement 3 volt CR-2032 lithium batteries available as needed.

All loggers were retrieved in October 2013 at the completion of the field monitoring program.

3.6 Fish Sampling

Active fish sampling using a backpack electrofisher was not carried out during the 2013 survey period. Consistent with previous years, mid to late May stream flows were too

high for safe sampling on many of the tributaries. In both spring and fall inspections, visual observations of reservoir elevation, stream flow and channel conditions, and identification of drawdown zone obstructions supplanted the need to sample fish to determine passage conditions. Incorporation of velocity measurements at cross-sections and stream temperature data also helped to assess timing of life history stages in relation to reservoir elevation and fish passage.

3.7 Passage Score Matrix

The passage matrix, that was developed following the 2009 and 2010 field data collection, produces a passage score (P) based on reservoir levels and relative stream discharge classes (i.e., very low, low, moderate, and high). This matrix was again tested during the 2011-2013 monitoring programs to assess its reliability. The matrix is intended to provide an index to assess fish migration access potential into tributaries by factoring the combined effect of relative stream discharge (% Qmax) and reservoir elevations. Field assessments (2009-2013) of passage conditions on key tributaries at a range of reservoir elevation and stream flows was used to identify the passage threshold score using the matrix.

3.7.1 Matrix Development and Calibration

The two (2) components of the matrix are relative stream discharge, and reservoir elevation. Relative stream discharge is the flow proportionate to an individual creek. Assuming that continuous stage-flow data would not be available for all tributaries, a four (4) class categorical system was used for the matrix. An arbitrary value was assigned to each category in ascending order from the lowest relative discharge to the highest. Reservoir elevation was divided into 25 categories (classes) based on a 1-m elevation gradient spanning the maximum range between the extreme low water (418 m asl) and full pool (442 m asl) levels.

The two components were then weighted by proportionately adjusting category values so the maximum initial category value (i.e. high stream flow = 4; full pool reservoir level = 25) equaled 1. To do this, individual category scores were divided by the maximum category score as shown below.

Relative Discharge Class	Initial Score	Adjusted Score
Very Low	1	0.25
Low	2	0.5
Moderate	3	0.75
High	4	1

Reservoir Elevation Class	Initial Score	Adjusted Score
418m	1	0.04
419m	2	0.08
420m	3	0.12
.	.	.
.	.	.
.	.	.
442m	25	1

The relationship between flow and biological response is usually non-linear (Jowett 1997). Calibration and various iterations of the matrix were performed with reference to the observed passage conditions observed over the 5-year monitoring program (2009-2013). As a result, the adjusted scores were squared to fit a parabolic distribution, giving an exponentially greater weighting (score) to successive higher classes in both matrix components. This exponential rate of increase in scores was found to better represent field observations of passage condition changes and threshold values relative to stream flow and reservoir elevation.

Transformed, the weighted matrix components are:

Relative Discharge	
Class	**Matrix Score (D_s)**
Very Low	0.0625
Low	0.25
Moderate	0.5625
High	1

Elevation	
Elev. Class	**Elev. Score (E_s)**
418m	0.0016
419m	0.0064
420m	0.0144
.	.
.	.
.	.
442m	1

The matrix is summarized in Figure 2, where the **Passage Score (P) = $D_s \cdot E_s$.**

			Reservoir Elevation (m)													
			425	426	427	428	429	430	431	432	433	434	435	436	437	438
		Score	0.1024	0.1296	0.16	0.1936	0.2304	0.2704	0.3136	0.36	0.4096	0.4624	0.5184	0.5776	0.64	0.7056
Relative Discharge	High	1.0000	0.1024	0.1296	0.1600	0.1936	0.2304	0.2704	0.3136	0.3600	0.4096	0.4624	0.5184	0.5776	0.6400	0.7056
	Mod	0.5625	0.0576	0.0729	0.0900	0.1089	0.1296	0.1521	0.1764	0.2025	0.2304	0.2601	0.2916	0.3249	0.3600	0.3969
	Low	0.2500	**0.0256**	0.0324	0.0400	0.0484	0.0576	0.0676	0.0784	0.0900	0.1024	0.1156	0.1296	0.1444	0.1600	0.1764
	Very Low	0.0625	0.0064	**0.0081**	**0.0100**	**0.0121**	**0.0144**	**0.0169**	**0.0196**	**0.0225**	**0.0256**	0.0289	0.0324	0.0361	0.0400	0.0441

Figure 2. Passage score matrix. Passage scores (P) shown in the matrix are a product of reservoir elevation scores and relative discharge class scores. The lower and upper reservoir levels (418m-424m; 439m-442m) have been cropped from the matrix range presented above. Refer to Table 5 for passage score interpretation.

To establish a reference for relative stream discharge, current and historic flow data was obtained from the Water Survey of Canada for four (4) watercourses in the mid and lower Columbia River drainages:

Illecillewaet River (Station: 08ND013)
Duhamel Creek (Station: 08NJ026)
Slocan River (Station: 08NJ013)
Kaslo River (Station: 08NH005)

These reference creeks/rivers have a period of record (POR) from between 15 to 85 years and therefore provide a good representation and understanding of the relative discharge curves for Arrow Reservoir tributaries. While Duhamel Creek, Slocan River, and Kaslo Creek are not within the Arrow Reservoir catchment, their climatic position and character is similar to tributaries ranging throughout the Arrow Lakes basin.

To compare the relative discharges among the four (4) watercourses, which vary widely in magnitude, the mean daily discharge (Q) for each watercourse was divided by the maximum recorded mean daily discharge (Qmax) for the same watercourse in that calendar year to give a daily %Qmax value. The average of the daily %Qmax values for the four watercourses was then calculated to give the mean%Qmax value.

The 2009 hydrometric data and calculated mean%Qmax values represent the reference year for relative stream discharge and corresponds with the initiation of the CLBMON-32 monitoring program. The mean daily discharge measured in the four watercourses for subsequent years in the monitoring program (2010, 2011, 2012, and 2013) were divided by the 2009 value for the same day and mean%Qmax values were calculated relative to the 2009 reference year.

The resulting daily mean%Qmax was plotted (Figure 3) and the four (4) relative discharge classes, used in the passage matrix, were identified. The relative discharge class interpreted from the plot (Figure 3) closely resemble the scores assigned to the matrix; where very low = 0.0625, low = 0.25, moderate = 0.5625, and high = 1.0. Thus

we can translate the mean%Qmax values into the four (4) relative discharge classes (i.e., very low, low, moderate, and high) of the passage matrix. From this, the calculated daily mean%Qmax yields a continuous variable relative discharge score that fits within the 4-class simplified categorical range. Daily relative discharge scores can be anticipated using the hydrometric data over the period of record, which in-turn can be multiplied with the reservoir elevation score to give the Passage Score.

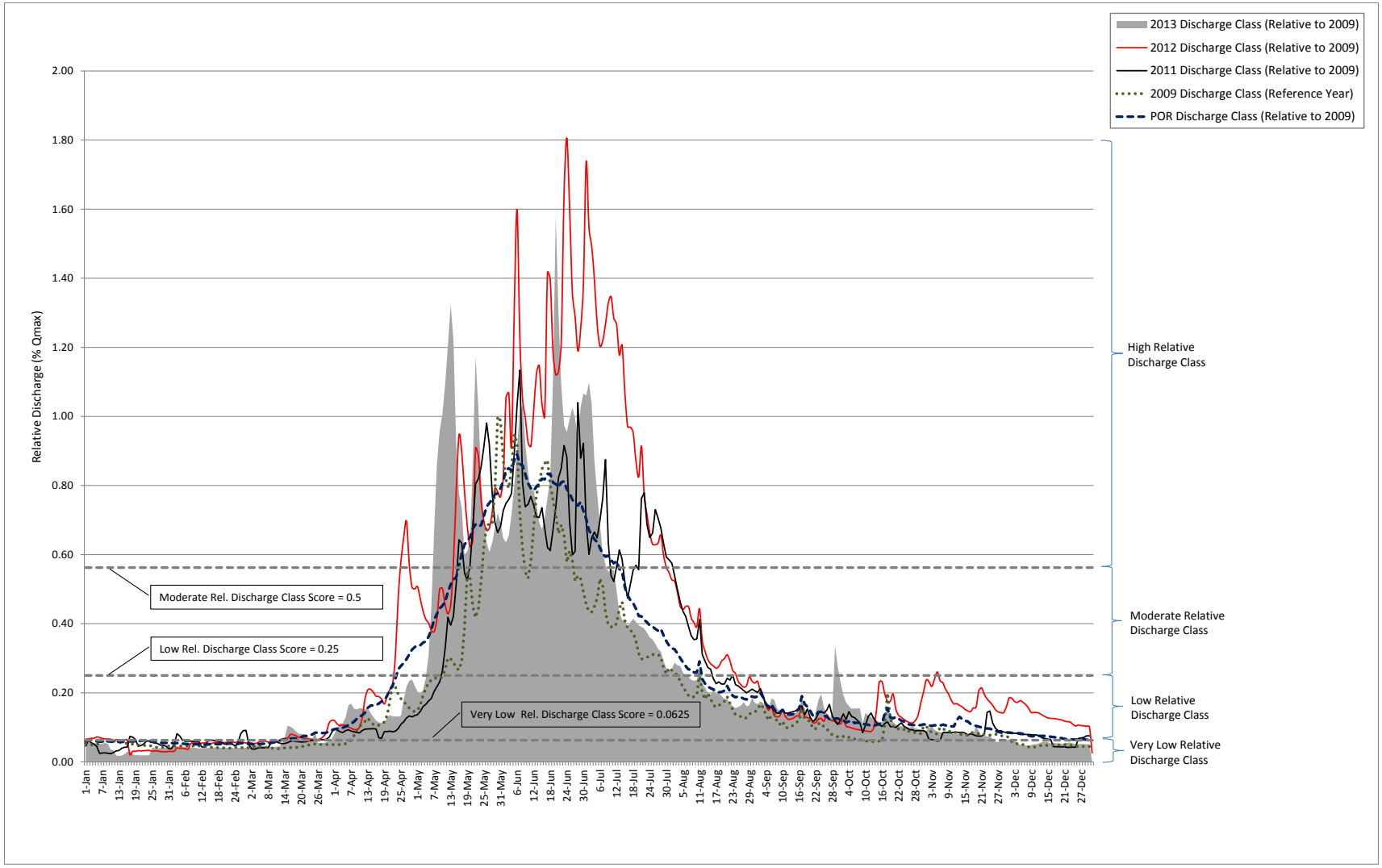


Figure 3. Relative discharge curves (% Qmax) developed from the four reference watercourses within the middle and lower Columbia River catchments and interpretation of relative discharge classes assigned to the passage matrix for the Arrow Reservoir. The reference year is 2009 hydrometric data obtained from the Water Survey of Canada. The period of record (POR) is based on 15-85 years of historical discharge data available for the four reference water courses.

Further calibration and validation of the matrix involved examining the matrix passage scores in relation to 2009 through 2013 monitoring observation results, which describe tributary access at various reservoir elevation and stream stages. In particular, potential passage thresholds identified during field inspections were compared to the preliminary matrix results based on relative discharge and reservoir elevations. These are presented in Table 5.

Table 5. Passage score threshold values based on interpretation of the matrix and field inspections.

Passage Score	Fish Migration Access Condition
<0.03	No Passage
0.03-0.049	Marginal passage conditions. About 50% of key tributaries were still deemed passable to fish.
0.05-0.09	Passage conditions improving with occasional concerns on some tributaries depending on channel dynamics (e.g. increased channel braiding following reservoir drawdown).
>0.09	No Passage Concerns. Reservoir above mean elevation of drawdown zone barriers and combined higher stream flows and reservoir levels result in high passage scores.

4.0 RESULTS

Passage assessments, timed with Rainbow Trout migration and spawning, were completed from May 21-28, 2013, Kokanee access monitoring was carried out from September 9–12, 2013, and Bull Trout access monitoring was carried out from October 7 – 10, 2013.

The lowest recorded level for Arrow Reservoir in 2013 was 427.93 m which occurred on February 15. At the beginning of April the reservoir level was around 430.2 m (Figure 4). Elevations remained relatively constant around 430 until May 8 when levels began to increase sharply to over 434 by May 23. At the beginning of September the reservoir level was 433 m, 1-m below the soft constraint (434 m). Levels continued to drop and were 1.5 m below the soft constraint by September 15.

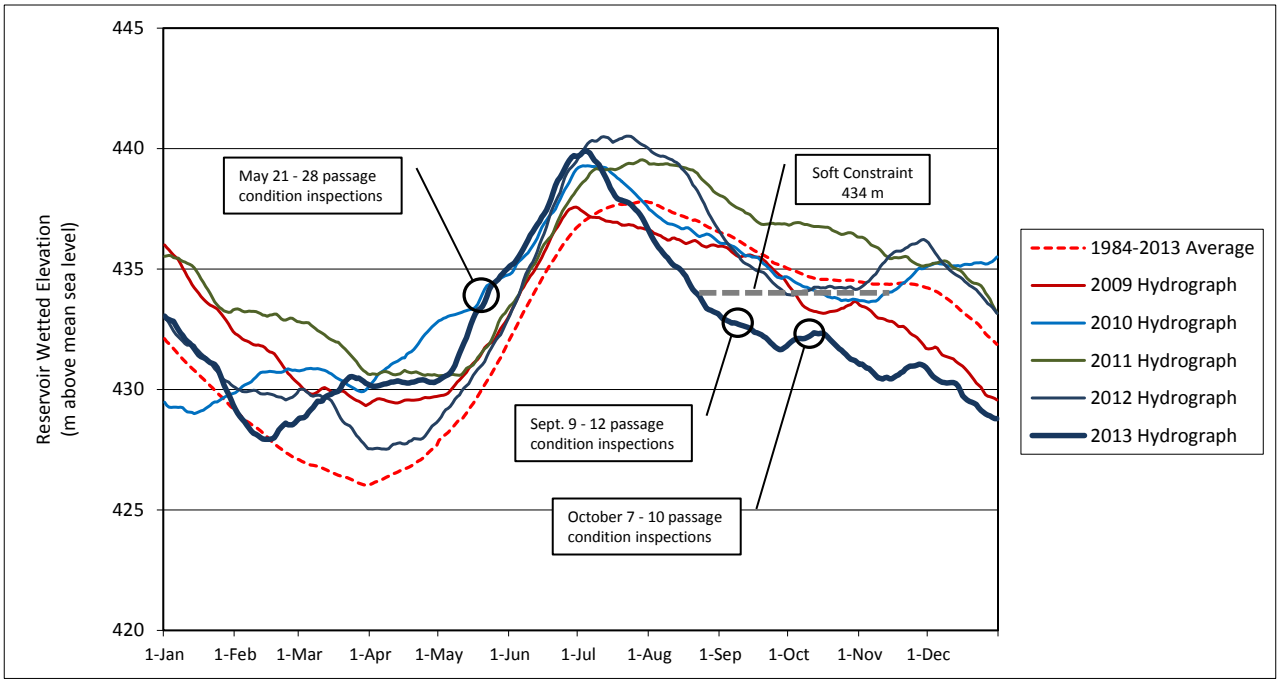


Figure 4. Arrow Lakes Reservoir hydrograph for 2009-2013, and mean hydrograph from 1984-2013.

There were no passage concerns during the May Rainbow Trout migration and spawning passage assessments, when stream flows were at moderate stages and the reservoir was at about 430 m. Six (6) of the 18 tributaries had passage concerns during the September Kokanee passage assessments. Increased fall passage concerns were attributed to lower reservoir levels (i.e., over 1 m below the soft constraint target) and low to very low stream flows (Table 6).

Observations in September 2012 had noted channel morphology changes that occurred as a result of flood stage discharges occurring simultaneously with peak summer 2012 reservoir levels. On many tributaries, new sand/gravel fans had formed at the upper limit of the drawdown zone. Subsequent channel scour in the spring 2013 freshet removed these perched sediment wedges that obstructed fish passage in fall 2012 and in September 2013, these features were no longer causing passage concerns. A slight increase in flows in the key tributaries resulted in improved passage conditions in early October, which may have benefited Bull Trout migration and spawning.

Rainbow Trout Migration

Based on the reference passage score, tributaries were becoming accessible over the drawdown zone around April 3, 2013 as the passage threshold (0.03) was surpassed (Figure 5). Rainbow Trout migration is generally initiated when stream temperatures reach 5°C. Temperature loggers indicated that most creeks did not sustain temperatures at or above 5°C until mid to late April. Only Caribou and Burton Creeks had recorded temperatures greater than 6°C at the end of March. Drimmie, Mackenzie, Nacillewaet and Little Cayuse Creeks began reaching mean daily temperatures of 5°C by early May, while Blanket and Octopus were not consistently reaching 5°C until the latter half of May. Rainbow Trout have been noted to spawn in Arrow Lakes tributaries between 6 and 9°C (Drieschner et al. 2008 and references within), although Rainbow Trout spawning typically occurs at temperatures between 7.2 to 13.3°C (Ford et al. 1995). Tributaries with available data met this temperature range in the Lower Arrow beginning around late May through to the end of June, when passage scores were in excess of 0.05 indicating no passage concerns. Based on stream temperatures, Rainbow Trout spawning within Arrow Lakes Reservoir tributaries may not be initiated until late May through June. Over this period passage scores of 0.1 had been surpassed meaning there were no tributary access concerns for Rainbow Trout. In the 5-years of field monitoring, only one Rainbow Trout was observed in spawning condition – in Octopus Creek on May 23, 2009.

Kokanee Migration

Kokanee spawning occurs between 4 to 15°C (Ford et al. 1995), and all tributaries surveyed fell within this temperature range during the Kokanee observation period (September 9-12). During this time passage scores were between 0.02 and 0.05 indicating that there were migration barriers on some tributaries while on others passage conditions were marginal.

Bull Trout Migration

Bull Trout are cued to spawn around 9°C and are observed to cease spawning when temperatures drop below 5°C (Ford et al. 1995; McPhail and Baxter 1996; Watry and Scarnecchia 2008). Stream temperatures were recorded to drop below 9°C towards the third week in September and below 5°C by late October to early November (Figure 5). An adult Bull Trout was observed in Drimmie Creek on October 10, 2013. During this time, the stream temperature was 7°C.

Table 6 . Key tributary monitoring dates, discharge, relative discharge class, corresponding reservoir elevations, and passage observations (field observations) with passage index (matrix) scores, for the 2013 fish migration access monitoring program (CLBMON-32A).

	Survey/Monitoring Period																			
	May Surveys							September Surveys							October Surveys					
Tributary	Date	Res. Elev. (m)	Disch. (m^3/sec)	Rel. Dish. Class	Stream Temp (°C)	Passage (field obs./ index score)	Passage Score	Date	Res. Elev. (m)	Disch. (m^3/sec)	Rel. Dish. Class	Stream Temp (°C)	Passage (field obs./ index score)	Passage Score	Date	Res. Elev. (m)	Disch. (m^3/sec)	Rel. Dish. Class	Stream Temp (°C)	Passage (field obs./ index score)	Passage Score
Bannock Creek	22-May	433.86	0.581	Moderate	10.9	Passable	0.48	9-Sep	432.70	0.054	Low	11.1	Passable	0.05	9-Oct	432.15	0.105	Low-Mod	7.7	Passable	0.04
Blanket Creek	28-May	434.72	7.247	High	6.9	Passable	0.29	9-Sep	432.70	2.491	Low-Mod	12.5	Passable	0.09	9-Oct	432.15	1.639	Moderate	6.68	Passable	0.04
Burton Creek	21-May	433.63	NA	Mod-High	7.9	Passable	0.36	10-Sep	432.68	2.282	Low	13.7	Passable	0.05	8-Oct	432.11	3.552	Low-Mod	7.1	Passable	0.06
Caribou Creek	21-May	433.63	NA	Moderate	8.9	Passable	0.36	10-Sep	432.68	1.648	Low	14.2	Passable	0.05	8-Oct	432.11	2.630	Low-Mod	7.7	Passable	0.06
Cranberry Creek	22-May	433.86	NA	Moderate	6.5	Passable	0.48	10-Sep	432.68	1.232	Low-Mod	10.9	Mainstem Passable	0.09	9-Oct	432.15	0.678	Low-Mod	6.4	Mainstem Passable	0.04
Crawford Creek	28-May	434.72	2.414	High		Passable - high TSS from active scour in lower DDZ may cause passage concerns	0.29	9-Sep	432.70	0.259	Low	11.6	Passable - Less braided over DDZ than in previous years	0.05	9-Oct	432.15	0.323	Low-Mod	5.9	Passable	0.04
Deer Creek	23-May	434.14	4.732	High	4.7	Passable	0.47	12-Sep	432.61	0.190	Low	11.7	Passable	0.05	8-Oct	432.11	0.4	Low-Mod	7.1	Passable	0.06
Dog Creek	23-May	434.14	NA	High	4.8	Passable	0.47	12-Sep	432.61	0.105	Very Low	13.2	Marginal to impassable	0.02	7-Oct	432.10	1.008	Low-Mod	7.3	Passable	0.06
Drimmie Creek	28-May	434.72	2.290	Moderate		Passable	0.29	9-Sep	432.70	0.342	Low	10.8	Passable	0.05	10-Oct	432.20	0.395	Low-Mod	7.0	Passable - BT observed upstream of reservoir	0.05
Eagle Creek	23-May	434.14	NA	High	5.0	Passable but with very high TSS	0.47	11-Sep	432.64	0.103	Low	13.4	Poor to Marginal	0.05	8-Oct	432.11	0.634	Low-Moderate	8.0	Passable	0.06
Johnston Creek	23-May	434.14	NA	High	6.1	Passable	0.47	11-Sep	432.64	0.167	Moderate	12.7	Passable	0.09	7-Oct	432.10	0.204	Moderate	7.9	Passable	0.06
Little Cayuse Creek	23-May	434.14	1.647	High	4.8	Passable	0.47	11-Sep	432.64	0.020	Low	14.4	Marginal just above lake wetted level	0.05	8-Oct	432.11	0.027	Low	7.5	Marginal for Larger bodied fish	0.06
Mackenzie Creek	22-May	433.86	2.136	Moderate	5.7	Passable	0.48	10-Sep	432.68	.0.09	Low	10.9	Passable	0.05	9-Oct	432.15	0.073	Low	7.2	Passable	0.04
Nacillewaet Creek	22-May	433.86	2.400	Moderate	6.0	Passable	0.48	10-Sep	432.68	0.310	Low	11.5	Impassable due to debris and waterfalls	0.05	9-Oct	432.15	0.302	Low	6.8	Impassable	0.04
Octopus Creek	23-May	434.14	NA	Mod-High	5.8	Concerns due to very high TSS and active channel scour	0.47	11-Sep	432.64	0.062	Very Low	14.2	Marginal just above lake wetted level	0.05	8-Oct	432.11	0.234	Low	8.2	Marginal up to about 435 m elevation	0.06
Payne Creek	22-May	433.86	0.681	Moderate	7.5	Passable	0.48	10-Sep	432.68	0.059	Low	11.7	Passable	0.05	9-Oct	432.15	0.117	Low	7.8	Passable - KO still spawning	0.04
Renata Creek	23-May	434.14	5.381	High	5.0	Passable	0.47	12-Sep	432.61	0.009	Very Low	17.4	Impassable	0.02	7-Oct	432.10	0.088	Low	7.5	Marginal	0.06
Taite Creek	23-May	434.14	NA	Moderate	5.0	Passable	0.47	11-Sep	432.64	0.417	Low	12.7	Passable	0.05	8-Oct	432.11	1.165	Low-Mod	6.6	Passable	0.06

* Physical/structural barriers are present restricting passage, regardless of flows, up to full pool reservoir levels.

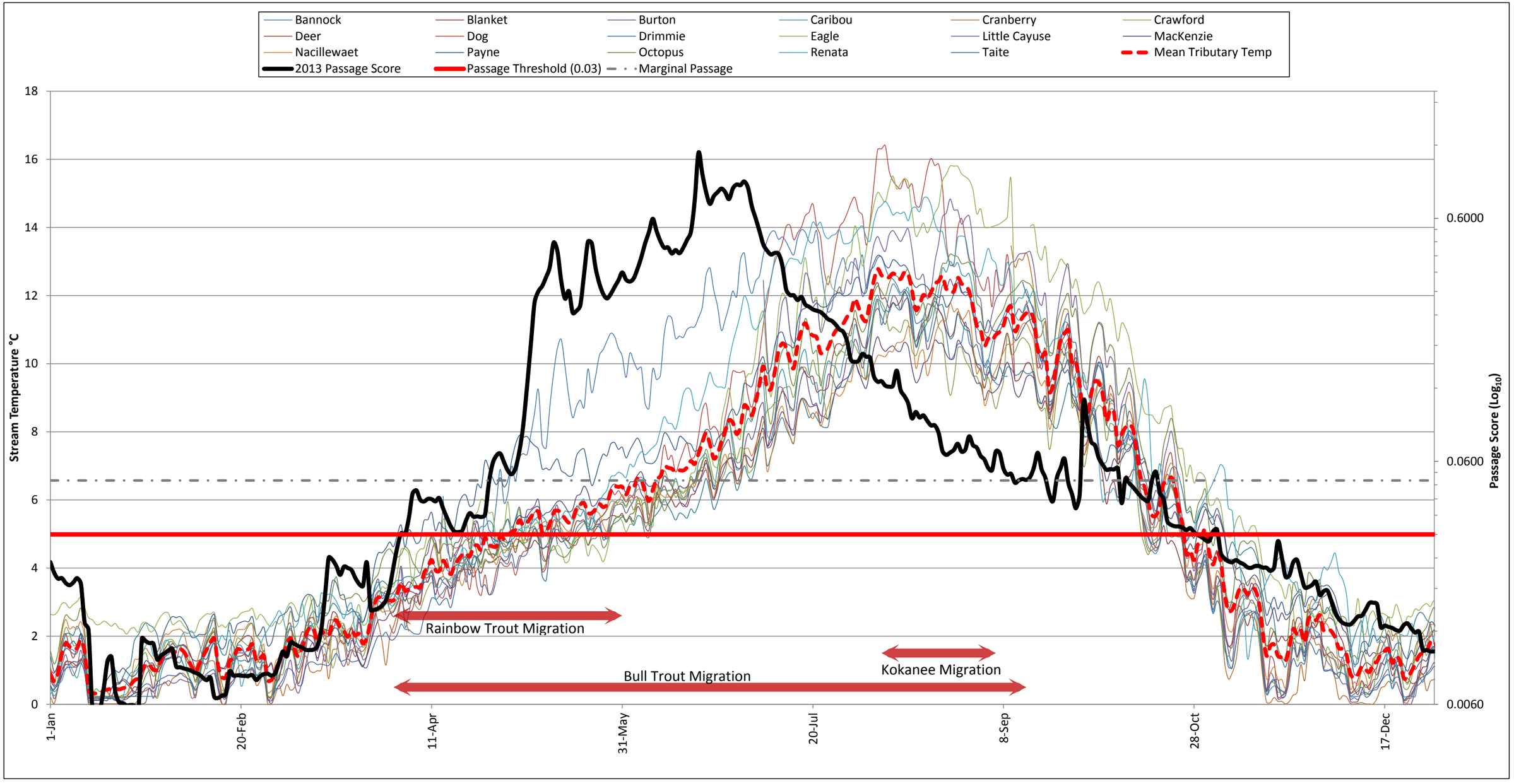


Figure 5. Mean daily stream temperatures recorded from 2011-2013 with HOBO temperature data loggers on Arrow Lakes tributaries, with reference to spawning migration timing of Rainbow Trout, Kokanee, and Bull Trout (Shaded bands). The 2013 Passage Score is plotted on the secondary axis - illustrating the marginal passage threshold (0.03) being surpassed in early April just when stream temperatures begin to reach the 5°C temperature cue for Rainbow Trout migration.

4.1 Drawdown Barriers/Obstructions

The highly dynamic and unstable nature of braided channels within many of the drawdown zones of tributaries translates into constant movement and migration of mainstem and secondary channels. Consequently, it is conceivable that individual barriers may migrate upstream or downstream (unravelling of shallow riffle zones) as a result of bedload movement, and may become greater or even be eliminated by ever-changing channel characteristics within the drawdown.

Table 7 provides a summary of observations made to date of confirmed or potential obstructions and their surveys elevations occurring on tributaries included within the CLBMON-32A monitoring program. No new obstructions were recorded in 2013 in addition to those observed in the previous four (4) years.

Table 7. Drawdown zone obstruction features and attributes observed during 2009, 2010, 2011, 2012, 2013 tributary access monitoring. Highlighted cells indicate features/obstructions recorded in 2013 field inspections.

Tributary	Date Assessed	Character	Effective Period	Feature Elevation (m)	Stream Stage	Reservoir Elevation	Comment
Akolkolex	15/04/2009	Falls	Spring and Fall	431.8 (falls)	Moderate	429.5	Impassable regardless of reservoir elevation. More attention with respect to potential drawdown zone spawning for rainbow. Reservoir was inundated up to waterfall by May and drawdown zone spawning by rainbow not likely. No passage possible in 2010 or 2011. While no spawning Rainbow Trout were observed during the April 12, 2011 site survey, the drawdown zone was not completely inundated. By July 7, 2011, the drawdown zone was completely inundated up to the falls.
Bannock	13/04/2009	Cascade	Spring	433.6	Moderate	429.4	Passable along left bank. There were no concerns with fish passage in spring or fall in 2010 or 2011. Kokanee were observed in 2011 upstream of the culvert crossing.
Cranberry	09/09/2009	Low Flows	Fall	438.3	Very Low	435.5	No concerns with fish passage in 2010 or 2011.
Crawford	14/04/2009	Braiding	Spring	438.3	Moderate	429.5	Potential low flow barrier over braided section even at current flows. There were no passage issues in 2010 or 2011.
Crawford	14/04/2009	Braiding	Spring	431.5	Moderate	429.5	Potential low flow barrier over braided riffle. Wetted depth = 0.03m (3cm)
Crawford	09/09/2009	Braiding	Fall	436.5	Moderate	435.5	Currently passable with the way the channel has braided this year. However may be impassable in other years due to high channel/bedload mobility. There were no passage issues in 2010 or 2011.
Crawford	09/09/2009	Low Flows / Braiding	Fall	439.4	Low	435.5	KO able to pass now with current flows. However, without the rains over past week, flows may have been too low for passage over braided fan. There were no passage issues in 2010 or 2011.
Crawford	09/09/2009	Low Flows / Braiding	Fall	439.6	Low	435.5	Flow challenges over upper braided section. There were no passage issues in 2010 or 2011.
Deer	30/03/2012	Braiding	Spring	428.5	Low	427.6	Upper limit of barrier at current flows and reservoir levels.
Deer	08/04/2009	Braiding	Spring	431.1	Moderate	429.5	Potential low flow barrier when LARL levels below this spatial point in elevation. No passage issues observed in 2010 or 2011.
Dog	13/09/2010	Beaver Dam	Fall	438.5	Very low	435.6	Beaver Dam with 1 m height along right bank side channel- not an issue for passage up mainstem.
Dog							
Drimmie	16/04/2009	Braiding	Spring	430.4	Moderate	429.6	Potential low flow barrier over braided channels. No passage issues in 2010 spring to fall, although widespread braiding combined with low flows in September remains a potential passage issue. The drawdown zone was inundated upstream of the culvert crossing in July and September 2011; there were no passage concerns in 2011.
Eagle	01/04/2012	Braiding	Spring	428.3	Low	427.5	Low flow barrier over braided and aggraded drawdown zone.
Eagle	10/09/2012	Low Flow Barrier	Fall	435.9	Very Low	435.4	Potential low flow impediment - creek channel still well defined (not braided)
Eagle	10/09/2012	Low Flow Barrier	Fall	437.50	Very Low	435.4	Potential low flow impediment - creek channel still well defined (not braided)
Eagle	10/09/2012	Low Flow Barrier	Fall	437.70	Very Low	435.4	Potential low flow impediment - creek channel still well defined (not braided)
Eagle	10/09/2009	Low Flows	Fall	441.1	Very Low	435.5	Low flow barrier over braided and aggraded drawdown zone. Serious potential migration barrier - only 16 KO recorded upstream. Eagle Creek recommended for addition in subsequent years of CLBMON-32 monitoring program.
Eagle	21/04/2010	Low flows/Braiding	Spring	431.77 to 435.54	Moderate	431.8	The stream is marginally passable at current flows, due to severe braiding, with some channels more passable than others. Access from the drawdown zone to the mainstem is somewhat perched above the left bank side channel.
Eagle	14/09/2010	Low flows/Braiding	Fall	435.5	Low	435.5	Severe braiding throughout the wide fan results in several channels, many of which are not passable during low flows during Kokanee spawning migration. This creek would benefit from enhancement within the drawdown zone that would result in increased structure and channel definition.
Eagle	18/03/2011	Low flows/Braiding	Spring	434.6	Low	432.0	Very shallow riffles observed over braiding posing barrier to fish passage towards the right bank wetted level.
Eagle	14/09/2011	Low flows/Braiding	Fall	438.5	Very Low	437.3	Inadequate flows towards the left bank combined with braiding poses a barrier to fish passage. Main stem flows were towards the right bank wetted level during the survey period and Kokanee were observed upstream of the drawdown zone.
Eagle							
Little Cayuse	11/09/2012	Falls	Fall	439.0	Very Low	435.3	Steep gravel bar built during high flows and reservoir high reservoir levels - 1 KO observed below
Little Cayuse	30/03/2012	Braiding	Spring	429.0	Low	427.6	Upper limit of barrier at current flows
Little Cayuse	11/09/2009	Low Flows	Fall	435.9	Very Low	435.5	Little Cayuse at LARL level - low flows may inhibit passage - only 5 Kokanee observed upstream of high water level. There were no passage issues in 2010 or 2011 - Kokanee were able to migrate upstream of the cross section and cascade feature.
Little Cayuse	17/03/2011	Low flows/Braiding	Spring	432.0	Low	432.0	Potential passage concerns noted immediately above LARL wetted level. Below this elevation passage would be of concern at current flows and reservoir level-begins to braid downstream. While the creek was still passable, the stream temperature during the March 17 site visit was less than 2°C and Rainbow Trout would not likely be migrating until water temperatures and stream flows increase. Water temperature on Little Cayuse did not reach 5°C until April 24, 2011.
Little Cayuse							
Mackenzie	09/09/2012	Log Jam	Fall	439.8	Low	435.6	New LWD jam from 2012 high water level. High sediment deposition. The creek was still passable but the feature was marked as concern.
Nacillewaet	13/04/2009	Falls/step-pools	Spring	432.8	Moderate	429.4	Potential low flow barrier at current stage and may be velocity barrier at flood stage. There were no passage concerns during 2011 spring and summer surveys.
Nacillewaet	10/09/2010	Falls/step-pools	Fall	432.8	Low	435.7	Kokanee were migrating upstream of step-pools and reservoir wetted level in September 2010, with 400-500 staging at the reservoir/creek confluence. Possible that not all will ascend and that shoal spawning may occur near reservoir confluence. There were no passage concerns in 2011.
Nacillewaet							
Octopus	01/04/2012	Braiding	Spring	430.0	Low	427.5	Low flow-Low Reservoir combined factors with channel braiding at about 430m.asl
Octopus	10/09/2012	Other	Fall	438.5	Low	435.4	New channel spilling over debris fan from summer 2012 debris flow. Channel avulsed.
Octopus	08/04/2009	Braiding	Spring	432.3	Moderate	429.5	Potential barrier even at moderate stage. Point represents upper limit of braiding. No passage issues in 2010 or 2011.
Octopus							
Payne	09/09/2012	Persistent Debris	Fall	441.0	Low	435.6	2012 high reservoir levels re-sorted LWD and packed more into creek mouth. KO still passing but may become more impeded.
Renata	30/03/2012	Braiding	Spring	429.3	Low	427.6	Low flows braid out over lower fan and cascade over steep edge of fan to wetted reservoir level.
Renata	11/09/2012	Low Flow Barrier	Fall	436.9	Very Low	435.3	Potential low flow impediment - creek not braided so not function of reservoir
Renata	07/04/2009	Braiding	Spring	431.7	Moderate	429.6	Greatest potential for low flow barrier when LARL levels below elevation of this point.
Renata	11/09/2009	Subsurface - aggraded fan	Fall	435.4	Dry	435.5	Streambed dry above wetted; level no passage possible. Subsurface flows through drawdown zone with dry stream bed extending upstream to nearly full pool level. No Kokanee passage in 2010. Kokanee were observed upstream of the drawdown zone and cross-section in 2011; reservoir elevation was 437.43 m.
Renata	11/09/2009	Subsurface - aggraded fan	Fall	436.9	Dry	435.5	Surface flows go beneath alluvium at this location. No Kokanee passage in 2010. With the reservoir elevation at 437.43 m in 2011, much of the drawdown zone was inundated and Kokanee were observed upstream of the drawdown zone and cross-section location.
Renata							
Taite	10/09/2012	Braiding	Fall	438.5	Low	435.4	Right channel of braided section impassable. KO still passing but feature was marked as concern.

4.2 Passage Score Matrix Results

The passage score matrix was first incorporated into data analysis in 2010, with further calibrations of the matrix occurring following the 2011 tributary assessments. Figures 2 and 3 and Table 5 (Section 3.7.1) introduce the interpretation of relative discharge classes and passage score threshold values, respectively.

The period of greatest tributary access concern occurs from late winter to early spring before the onset of Rainbow Trout migrations. During this period, the combination of low reservoir levels and low to very low relative stream discharges results in very low passage scores (<0.03). In 2013, relative stream discharge class scores increased from very low to low, approximately two weeks earlier than the 2009 reference values, in late March to early April (Figure 6). Passage scores subsequently increased sharply from 0.05 in late April to over 0.1 on by the beginning of May – coinciding with increased reservoir levels and stream discharges.

Over the period of record (POR) for the reference creeks used to establish the relative discharge curve, stream discharges typically increased from Very Low to Low stage classes by early to mid-March. Using the relative discharge curve developed from the POR (1984-2013), the passage matrix suggests that tributaries are passable by the end of March, provided that the reservoir level is around 430 m, as was observed on March 31, 2011. The 2013 relative discharge score at the end of March was similar to the period of record. However, with 2013 reservoir levels observed from early April onward being greater than 430 m, the matrix score indicated that the threshold of greatest passage concern (0.03) would have been surpassed at the beginning of April.

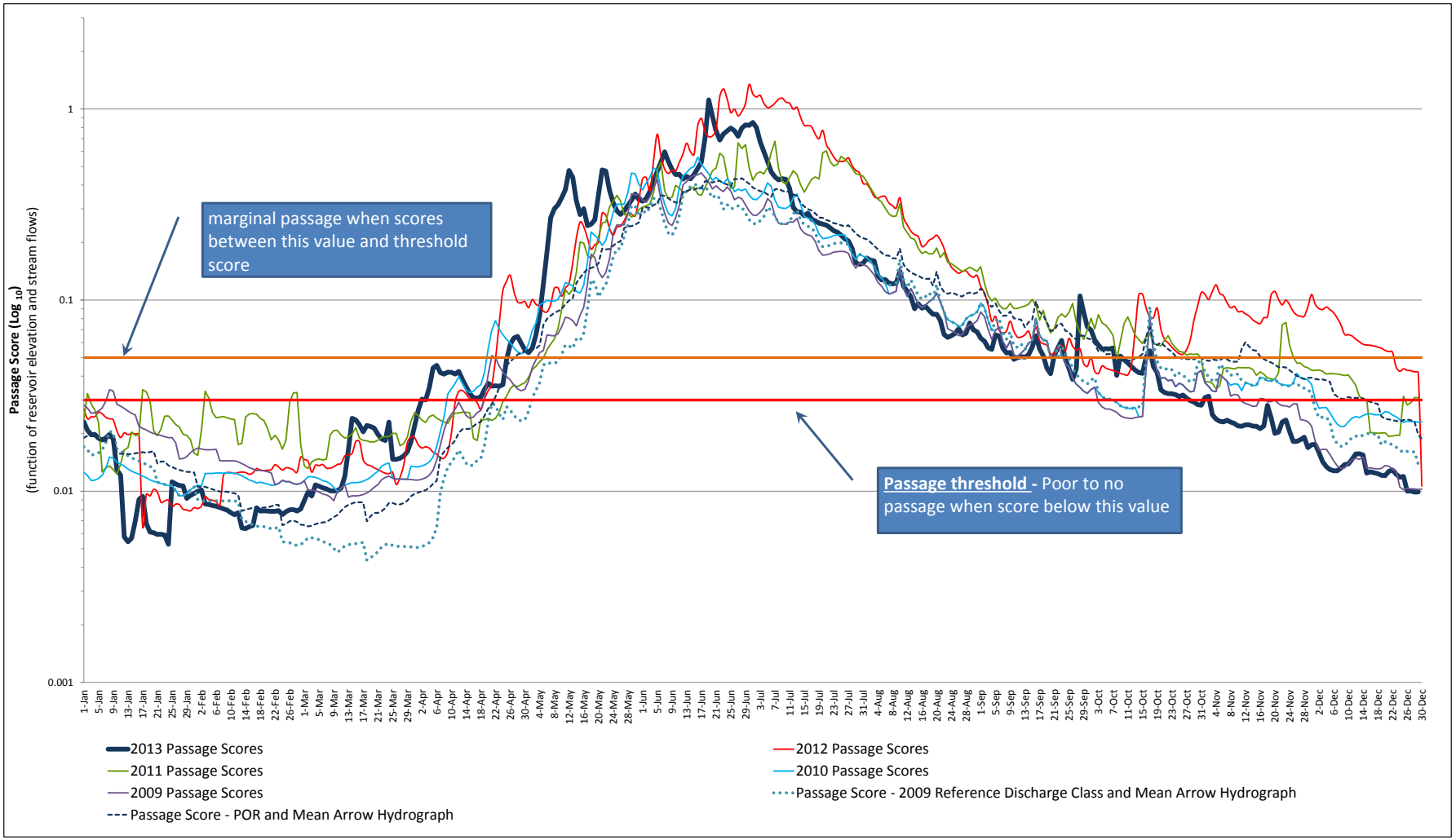


Figure 6. Tributary passage score plot based on the reservoir elevation and relative discharge passage matrix.

4.3 Tributary Access by Focal Fish Species

4.3.1 Rainbow Trout Access

The timing of Rainbow Trout stream migration and spawning (based on recorded stream temperatures) is shown in Figure 7. Passage scores, derived from the mean Arrow Lakes Reservoir hydrograph (1984-2013) against the 2009 reference discharge values, were below the 0.03 passage threshold through March to early April suggesting that tributary fish access at this time would be blocked. In 2013, lower reservoir levels and a stream discharge class close to the average for the period of record delayed passage scores from meeting the 0.03 threshold until April 3 (Figure 8). At this time, stream temperatures of some tributaries were just beginning to reach daily highs of 5°C, with the majority of creeks not reaching 5°C until mid-April to early May. Passage scores climbed to over 0.05 by April 27, and exceeded 0.1 by May 6. This suggests that Rainbow Trout migration would not have been impeded by reservoir operations in 2013 since passage scores were exceeding the marginal passage condition when stream temperatures were beginning to reach 5°C, presumably initiating Rainbow Trout migration. However, in reference to the passage score derived from the period of record for both the Arrow Reservoir hydrograph and mean relative discharge of reference creeks, the passage threshold is not surpassed until about April 20 (Figure 8).

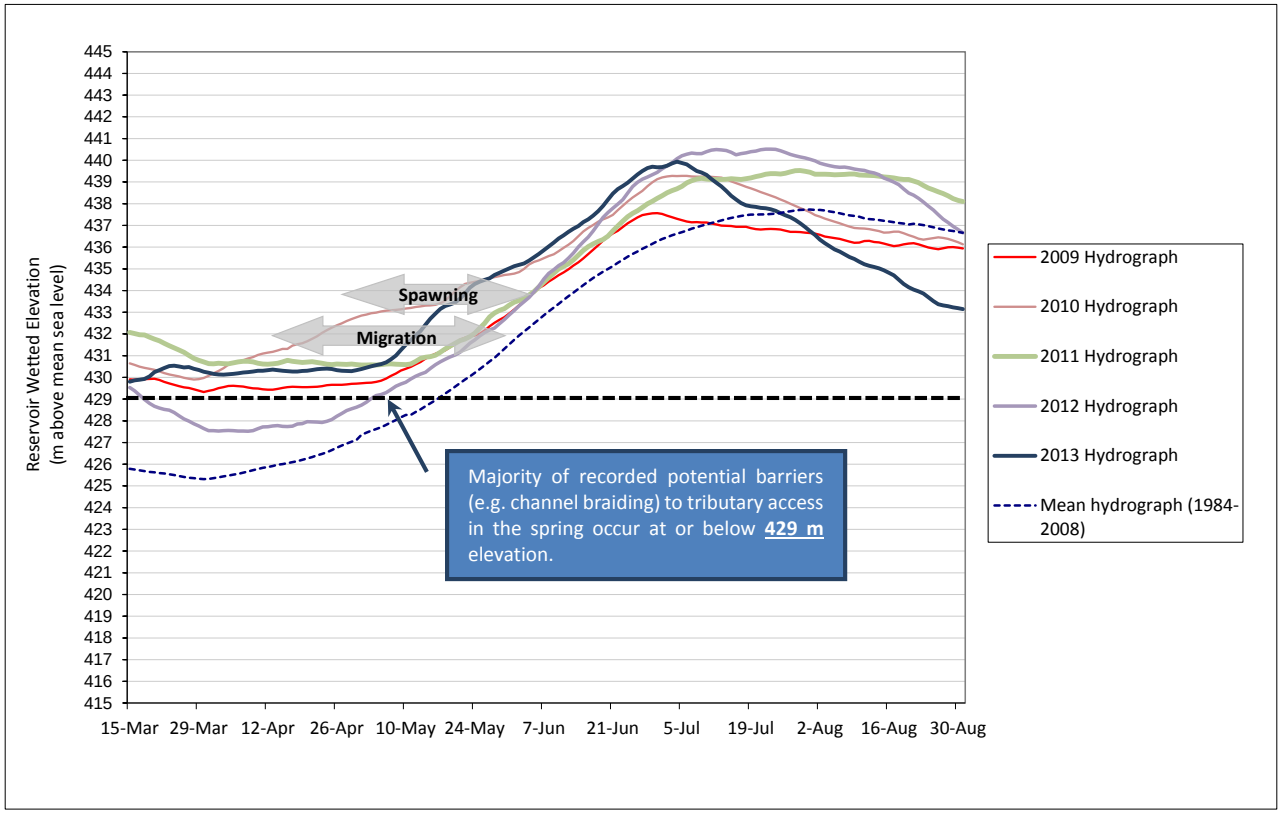


Figure 7. Life history timing of Rainbow Trout projected over the Lower Arrow Reservoir (LARL) hydrograph.

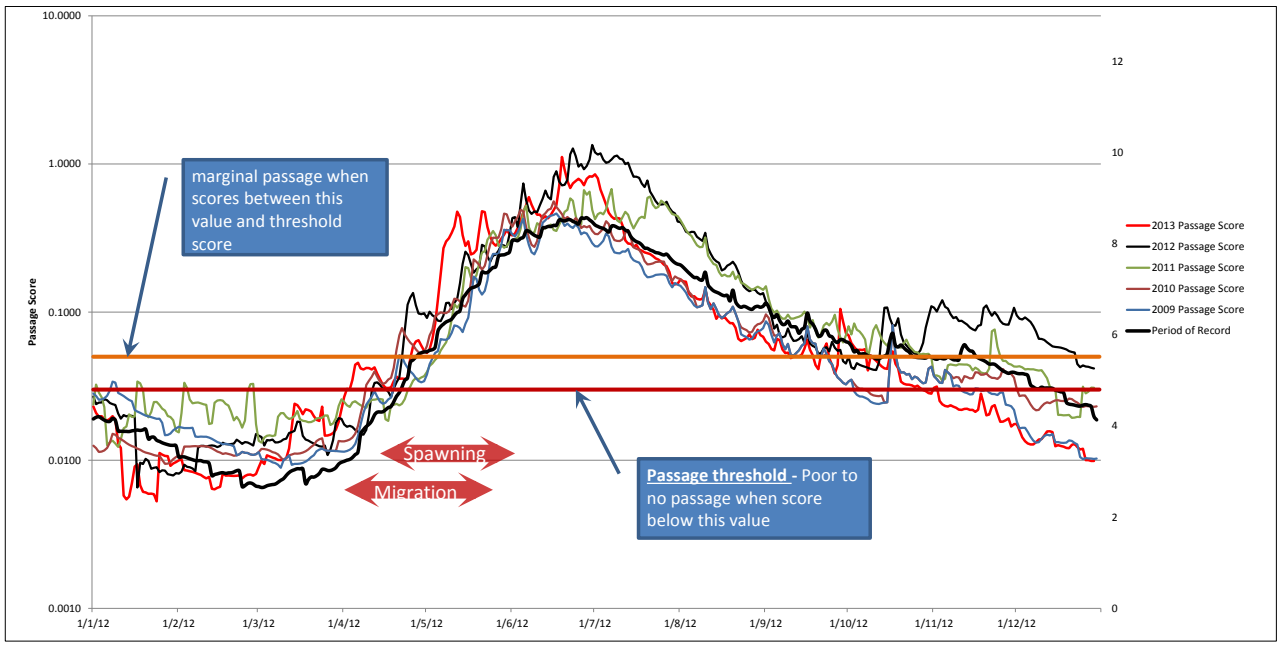


Figure 8. Passage score curve in relation to Rainbow Trout life history.

4.3.2 Bull Trout Access

Bull Trout migration to spawning grounds can occur as early as April and continue to September. In the Arrow Lakes tributaries, most spawning occurs from September to October (Ford et al. 1995; McPhail and Baxter 1996; Watry and Scarnecchia 2008) when water temperatures have dropped to 9ºC (McPhail and Murray 1979). This temporal range makes it difficult to focus on a specific period during which to monitor tributary drawdown zone conditions (flows and reservoir levels) for Bull Trout passage.

Juvenile Bull Trout have been observed in the drawdown zone of tributaries during previous spring passage assessments for Rainbow Trout. An adult Bull Trout was observed in Drimmie Creek on October 10, 2013. During this time, the stream temperature was 7°C – corroborating the assumption that Bull Trout spawning is likely to commence mid to late September as temperatures of Upper Arrow tributaries usually drop to 9°C (Section 4.0, Figure 5). From mid-September through October 2013, passage scores were between 0.03 and 0.05. Scores then dropped below 0.03 at the end of October (Figures 9 and 10). By this time stream temperatures were at or below 5 ºC. This suggests that Bull Trout access to Arrow tributaries was not impeded in 2013. Of the six tributaries identified in as being impassable or marginally passable during September 2013 field inspections Eagle Creek is the only tributary known to be frequented by Bull Trout.

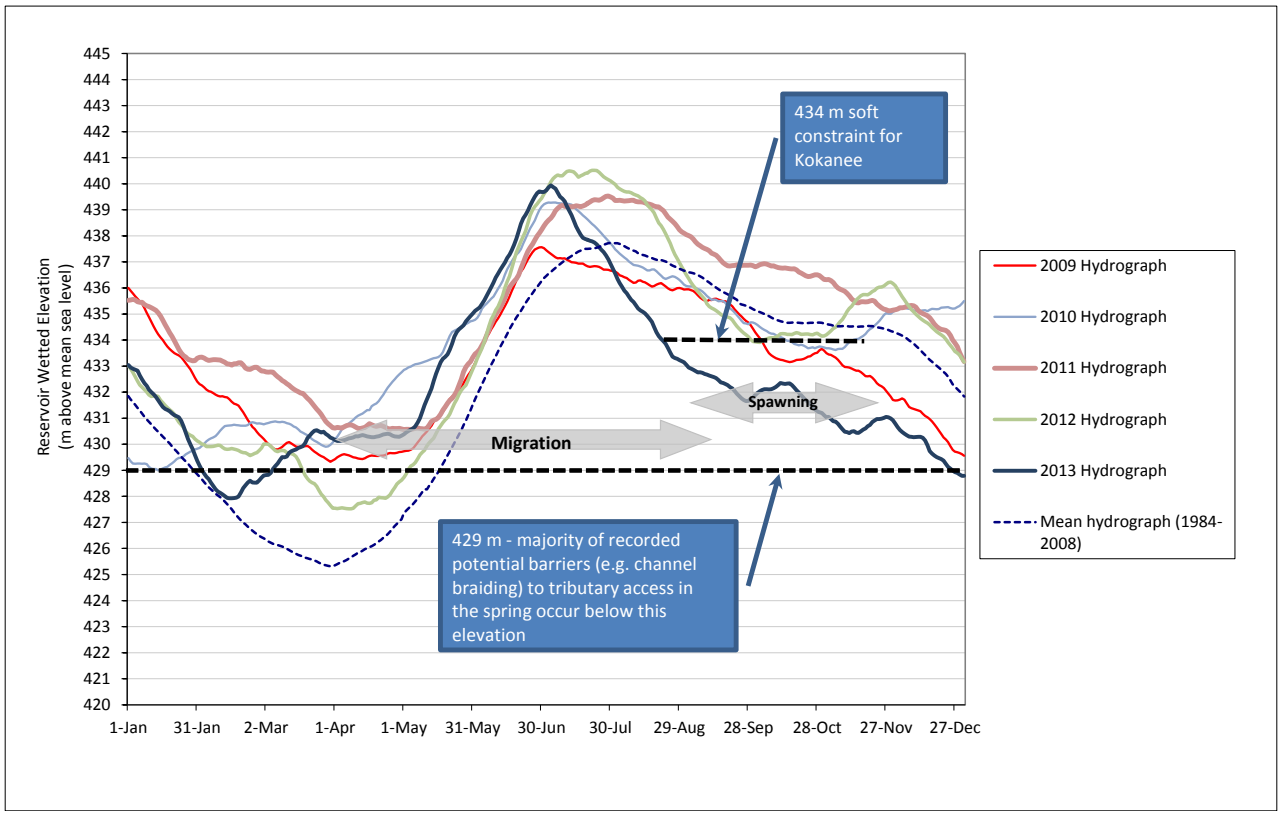


Figure 9. Life history timing of Bull Trout projected over the Lower Arrow Reservoir (LARL) hydrograph.

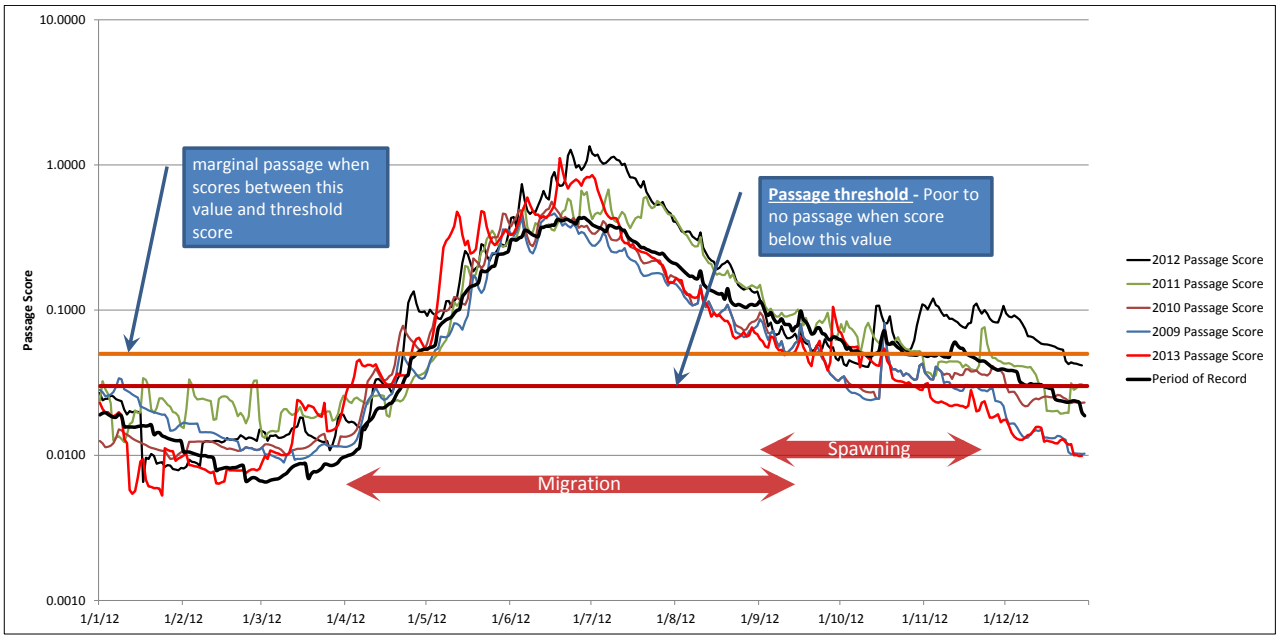


Figure 10. Passage score curve in relation to Bull Trout life history.

4.3.3 Kokanee Access

Low stream flows and channel braiding within the drawdown zone have been identified as factors limiting tributary access for fall spawners, primarily Kokanee (BC Hydro 1992; Anonymous 2001; Anonymous 2002; CCRIFC 2006). This is consistent with observations made throughout the five years of monitoring.

During the 2013 September passage assessments, 6 of the 18 tributaries were assessed as impassable or had notable passage concerns. Discharge from these specific creeks was *Very Low* compared to the *Low* relative discharge score derived from the reference watercourses – resulting in an overall passage score (for Arrow Tributaries) being in excess of the 0.03 passage score threshold.

The reservoir was between 1 and 2 m below the 434 m soft constraint during Kokanee migration and spawning in 2013 (Figures 11 and 12). The lower reservoir elevations combined with very low stream flows on some tributaries resulted in passage scores (when the matrix was applied exclusively to the flow conditions present in these creeks alone) below the 0.03 threshold on two tributaries (Renata and Dog Creek). Thirteen tributaries had marginal passage condition scores (0.03 - 0.05), while Johnston Creek, Blanket Creek, and Cranberry Creek had passage scores of 0.09 due to having higher moderate flows.

The Renata Creek drawdown zone was dry during the 2013 field assessment (September 12), preventing upstream Kokanee migration. However, a small number of Kokanee were observed in a residual pool upstream of the drawdown zone, indicating that in spite of very poor passage conditions, some fish may still be able to pass.

Kokanee were not documented staging or spawning in Nacillewaet Creek in 2013. In 2010, approximately 400-500 Kokanee were observed staging at the reservoir confluence with Nacillewaet Creek, and redds were recorded within the wetted reservoir level just below the bottom waterfall. In 2011, Kokanee were documented throughout the drawdown zone of Nacillewaet Creek, primarily spawning in gravel patches along the stream margins. No Kokanee were observed in Bannock Creek in 2013, where they had been documented spawning in 2011.

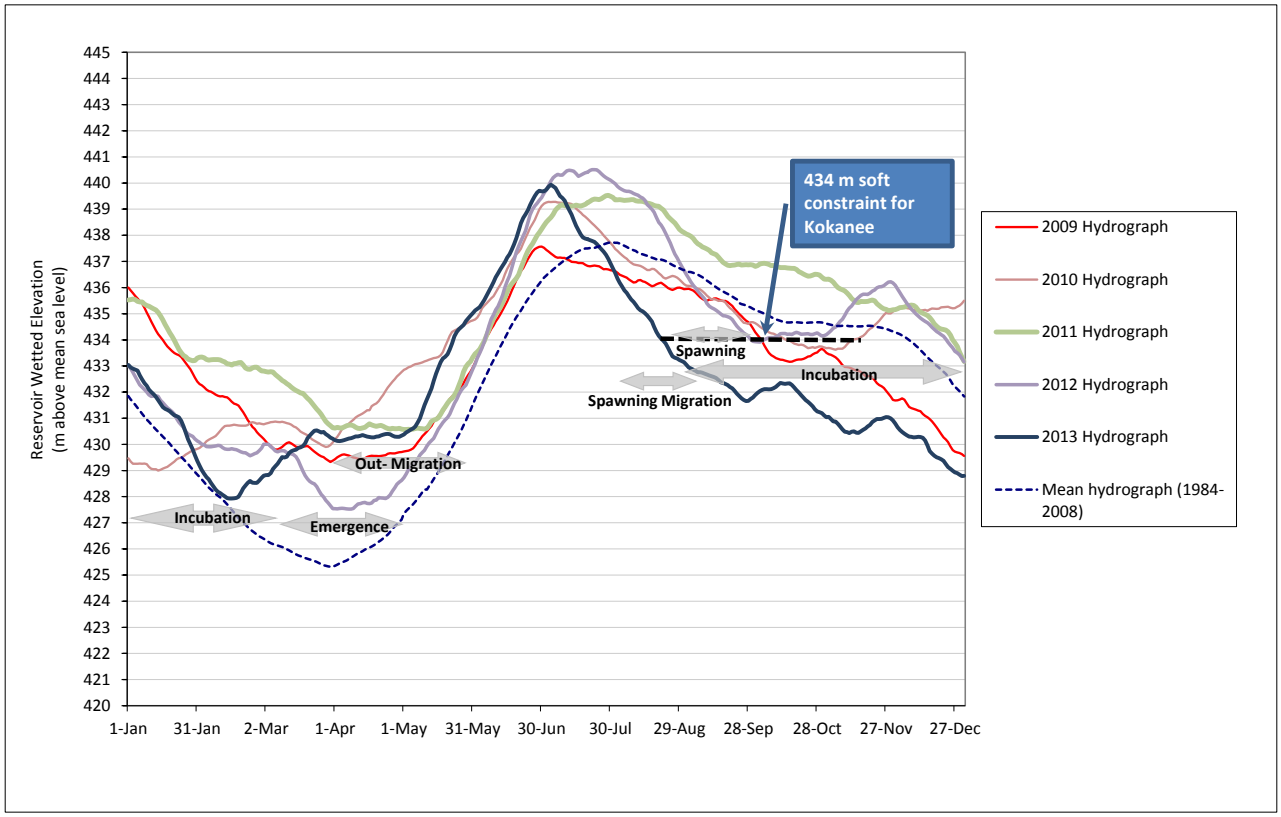


Figure 11. Life history timing of Kokanee projected over the Lower Arrow Reservoir (LARL) hydrograph.

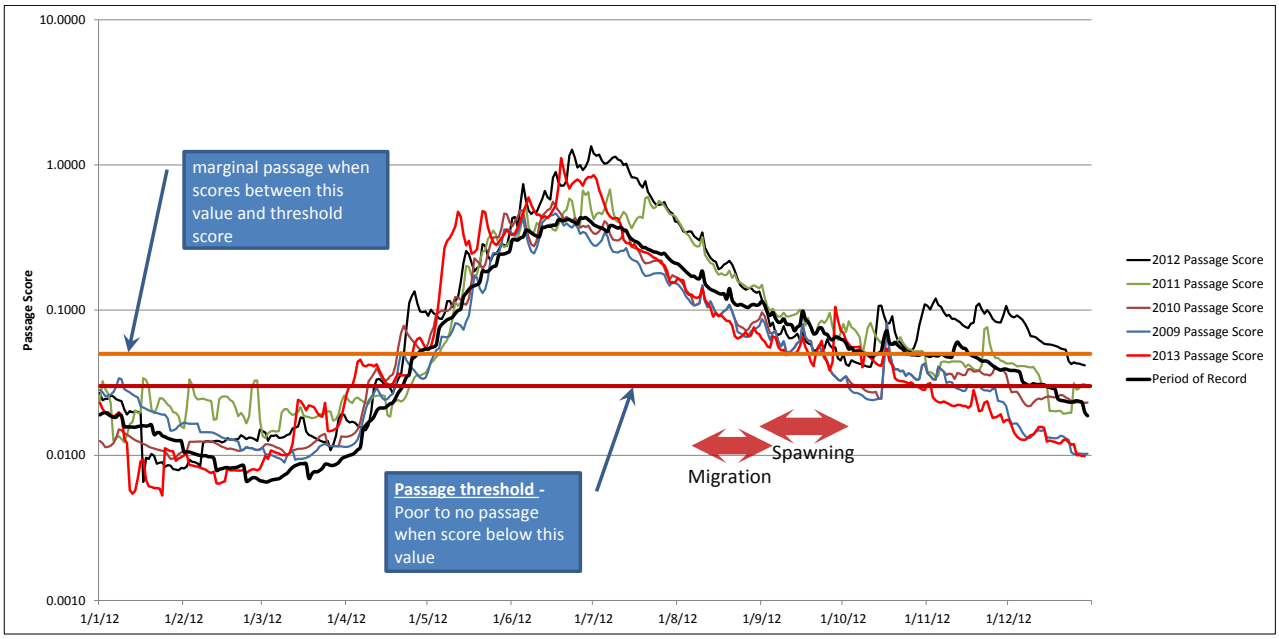


Figure 12. Passage score curve in relation to Kokanee life history.

5.0 SUMMARY OF TRIBUTARY ACCESS MONITORING

The previous five (5) years of field monitoring results suggest the following:

Q 1 - Does the operation of the Arrow Lakes Reservoir block or reduce upstream migration of focal fish populations in tributary streams?

The operations of the Arrow Lakes Reservoir can block or reduce upstream migration of fish populations in tributary streams. This reduced access is a result of low to very low stream flows being conveyed through wider, aggraded, more poorly defined, and braided channels over the drawdown zone. The dynamic channel form exhibited over the drawdown zone of many tributaries is the result of the high vertical fluctuation of the reservoir. When these drawdown zones are exposed and stream flows are low to very low, upstream fish migration can be blocked. However in the spring, stream temperature monitoring suggests that Rainbow Trout migration may not occur until mid-April through May when passage conditions are good (>0.05). Good passage conditions continue through June and July and decrease into September with the onset of Kokanee migration and spawning. Kokanee migration access has been observed to be reduced in some tributaries in spite of reservoir levels being at or above the 434m soft operating constraint. In these instances, access impairments are the result of very low stream discharges on individual watercourses.

Based on existing information summarized by Drieschner et al. (2008) and from field surveys carried out from 2009-2013, there are 28 Arrow Reservoir

tributaries known to be frequented by Bull Trout. Twenty one of the streams are in the Upper Arrow Lake basin, two are situated in the Narrows, and five occur in the north end of the Lower Arrow Lake basin. With the exception of Eagle Creek, that has late summer passage concerns and occasionally Drimmie Creek that has the potential to develop a braided channel upstream of the reservoir, the balance of tributaries supporting Bull Trout are not likely to have passage concerns. These tributaries are generally larger (higher order and magnitude streams) or occur in the Upper Arrow Lake basin, where higher elevation watersheds (i.e. more prolonged snow melt) and more moist to wet climate regime sustain higher flows throughout the year.

Q 2 - Are there significant reservoir elevation thresholds below which spawner access is impacted?

Based on the passage matrix and field measurements, the greatest impacts to fish migration access in the spring occur when reservoir levels are below 429 m and stream flows are low to very low. This combination of factors results in a passage score of 0.01 at very low stream discharge and up to 0.05 at low stream discharge. Below 0.03, there is a high risk that tributaries will not be accessible to fish. At a passage score of between 0.03 and 0.05, field observation indicate that about half of the key tributaries will have migration barriers in the drawdown zone. At scores greater than 0.05, all the key tributaries would be passable.

The 2010-2013 stream temperature monitoring suggests that spring Rainbow Trout migrations may not occur until mid-April or later. Under current operations, passage scores using average stream flow conditions and the mean Arrow Reservoir hydrograph in the matrix suggest that tributaries are generally accessible by Rainbow Trout by the second to third week in April. At this time average reservoir elevations are around 427 m based hydrometric data over the period of record (1984-2012) and relative discharges are rapidly increasing from low to moderate. As a result passage scores increase quickly to 0.05 by the end of April and to 0.1 by the second week of May. However, the risk for migration barriers increases if Rainbow Trout migrations were initiated in late March to early April when flows are still low to very low.

During Kokanee migration and spawning, the current soft operating constraint of 434 m represents a key elevation threshold. Reservoir elevation passage thresholds are dependent on stream flows that occur during the same point in time. The discharge in some tributaries was documented as very low by late August – early September, which results in passage scores of about 0.03 when Arrow Reservoir is at 434 m.

Q 3 - Do high stream flows in tributaries in the spring mitigate impacts of low reservoir elevations?

Spring surveys in 2013 were completed in mid-May during the period when Rainbow Trout migration and spawning are expected to be in progress. Consistent with observations from previous years, high stream flows in tributaries in the spring mitigate potential impacts of low reservoir elevations.

5.1 Summary and Recommendations

Monitoring from 2009 to 2013 has documented highly variable and dynamic conditions over the drawdown zone of Arrow Reservoir tributaries. The morphological condition of tributary fans (braiding etc.) is strongly influenced by Arrow Lakes Reservoir operations, which increase the vulnerability of tributaries to develop barriers in the drawdown zone. While high streamflows mitigate passage concerns in the spring, low to very low late summer flows are the primary factor controlling Kokanee tributary migration access.

Tributary access concerns are most prevalent in the Lower Arrow tributaries that have low flow issues. Reference watercourses used for tributary access monitoring provide a period of record for flows for the last 15-85 years (range dependent on the tributary). Based on this information, very low stream flows in Arrow Reservoir tributaries typically are not experienced until late November through to the end of March. However, some tributaries to Lower Arrow experience very low flows in late August and early September with subsurface conveyance over the drawdown zone preventing upstream migration at a wide range of reservoir levels.

Over the years of field monitoring, nine (9) tributaries had passage concerns identified. Of these, six (6) tributaries have been identified as priority for potential action (e.g. passage mitigation) and monitoring (Table 8).

Table 8. Summary of Kokanee migration access and tributaries where passage concerns were identified. Priority tributaries (shaded orange) were identified based on observed conditions and relative habitat value.

Tributary Name	Passage Concern Summary					Summary
	2009	2010	2011	2012	2013	
Crawford Creek	*			*		High instability of fine-textured substrates in the drawdown zone result in high seasonal change in channel form (i.e. from well-defined channel to severely braided channel that may block fish passage).
Octopus Creek				*	*	Debris flow in summer 2012 blocked upstream fish passage. Some scour in 2013 has improved conditions but they should be monitored.
Taite Creek				*		High aggradation in summer 2012 resulted in passage concerns. Some scour in 2013 has improved conditions but they should be monitored.
Nacillewaet Creek	*			*	*	Steep cascade, limited upstream access limits upstream habitat gained
Renata Creek	*	*	*	*	*	Aggrading and subsurface conveyance of low flows in the fall over drawdown zone.
Drimmie Creek	*	*		*		Braiding and low flow passage concerns in fall upstream of culvert.
Little Cayuse Creek	*	*		*		Low flow concerns. Channel generally well defined through drawdown therefore limited opportunity for action.
Dog Creek	*	*	*	*	*	Low flow concerns and more poorly defined and split channels over the drawdown zone.
Eagle Creek	*	*	*	*	*	Severe aggrading and braiding over drawdown zone.

5.2 Use and Interpretation of the Arrow Reservoir Passage Matrix

The passage matrix that has been refined through five years of monitoring is provided in Table 9. This matrix presents passage scores based on the Arrow Reservoir elevation scores (E_s) and the categorical 4-class stream discharge scores (D_s). To estimate tributary passage conditions for fish throughout the year (Table 10), the daily relative discharge score (calculated using the period of record data of reference watercourses) can be multiplied by the actual or forecast reservoir elevation score to obtain the passage score. Table 11 guides interpretation of the passage score and determination of fish migration tributary access potential and anticipated passage conditions.

Table 9. Passage matrix using the simplified 4-class relative stream discharge scores and Arrow Reservoir elevation scores.

			Reservoir Elevation (E_s)																				
			421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441
		Score	0.0256	0.04	0.0576	0.0784	0.1024	0.1296	0.16	0.1936	0.2304	0.2704	0.3136	0.36	0.4096	0.4624	0.5184	0.5776	0.64	0.7056	0.7744	0.8464	0.9216
Relative Stream Discharge Classes (D_s)	High	1	0.026	0.040	0.058	0.078	0.102	0.130	0.160	0.194	0.230	0.270	0.314	0.360	0.410	0.462	0.518	0.578	0.640	0.706	0.774	0.846	0.922
	Mod	0.5625	0.014	0.023	0.032	0.044	0.058	0.073	0.090	0.109	0.130	0.152	0.176	0.203	0.230	0.260	0.292	0.325	0.360	0.397	0.436	0.476	0.518
	Low	0.25	0.006	0.010	0.014	0.020	0.026	0.032	0.040	0.048	0.058	0.068	0.078	0.090	0.102	0.116	0.130	0.144	0.160	0.176	0.194	0.212	0.230
	Very Low	0.0625	0.002	0.003	0.004	0.005	0.006	0.008	0.010	0.012	0.014	0.017	0.020	0.023	0.026	0.029	0.032	0.036	0.040	0.044	0.048	0.053	0.058

Table 10. Generalized daily relative stream discharge score (based on period of record of reference watercourses) and Arrow Reservoir elevation scores. The daily relative discharge score is multiplied by the reservoir elevation score to obtain the passage score ($P = D_s \cdot E_s$).

Daily relative stream discharge scores **(D_s)** based on period of record of reference watercourses.												
Day	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1	0.061	0.054	0.052	0.095	0.337	0.814	0.703	0.329	0.19	0.122	0.108	0.085
2	0.062	0.054	0.051	0.096	0.337	0.846	0.672	0.325	0.199	0.12	0.105	0.084
3	0.063	0.054	0.051	0.098	0.345	0.85	0.657	0.314	0.187	0.114	0.104	0.083
4	0.061	0.054	0.051	0.099	0.349	0.844	0.644	0.301	0.167	0.117	0.106	0.083
5	0.06	0.053	0.052	0.102	0.362	0.873	0.636	0.288	0.159	0.119	0.105	0.082
6	0.058	0.052	0.052	0.107	0.383	0.891	0.619	0.277	0.167	0.113	0.105	0.081
7	0.058	0.051	0.053	0.111	0.412	0.863	0.601	0.268	0.152	0.113	0.108	0.079
8	0.061	0.051	0.053	0.116	0.428	0.858	0.594	0.267	0.143	0.113	0.106	0.076
9	0.059	0.051	0.055	0.124	0.444	0.831	0.597	0.259	0.144	0.11	0.103	0.074
10	0.058	0.051	0.057	0.13	0.452	0.806	0.584	0.258	0.151	0.109	0.103	0.074
11	0.058	0.05	0.058	0.135	0.464	0.792	0.574	0.291	0.139	0.108	0.103	0.076
12	0.058	0.049	0.061	0.142	0.491	0.785	0.581	0.24	0.138	0.105	0.12	0.075
13	0.058	0.049	0.064	0.156	0.514	0.796	0.559	0.226	0.137	0.105	0.13	0.075
14	0.058	0.05	0.066	0.163	0.527	0.805	0.549	0.218	0.139	0.107	0.124	0.075
15	0.058	0.051	0.067	0.163	0.534	0.82	0.505	0.213	0.148	0.109	0.119	0.075
16	0.059	0.051	0.068	0.164	0.569	0.818	0.482	0.209	0.153	0.113	0.117	0.073
17	0.059	0.052	0.067	0.169	0.603	0.834	0.468	0.204	0.19	0.14	0.11	0.072
18	0.059	0.051	0.068	0.175	0.629	0.834	0.46	0.202	0.167	0.156	0.106	0.071
19	0.059	0.051	0.068	0.178	0.638	0.808	0.444	0.202	0.16	0.129	0.104	0.07
20	0.06	0.051	0.072	0.192	0.651	0.804	0.422	0.206	0.148	0.126	0.102	0.068
21	0.06	0.052	0.075	0.209	0.675	0.795	0.421	0.22	0.133	0.13	0.099	0.067
22	0.062	0.053	0.075	0.221	0.687	0.81	0.411	0.204	0.134	0.125	0.096	0.066
23	0.062	0.053	0.077	0.241	0.682	0.812	0.404	0.191	0.145	0.12	0.097	0.065
24	0.059	0.051	0.08	0.268	0.685	0.789	0.394	0.187	0.145	0.116	0.096	0.065
25	0.058	0.052	0.085	0.278	0.712	0.777	0.392	0.19	0.134	0.11	0.093	0.064
26	0.057	0.054	0.085	0.286	0.739	0.759	0.385	0.187	0.131	0.108	0.09	0.065
27	0.056	0.054	0.083	0.297	0.749	0.747	0.38	0.182	0.123	0.107	0.087	0.066
28	0.055	0.053	0.083	0.311	0.76	0.742	0.385	0.181	0.12	0.106	0.085	0.065
29	0.055		0.085	0.324	0.775	0.752	0.366	0.187	0.126	0.106	0.083	0.064
30	0.055		0.087	0.332	0.777	0.727	0.349	0.189	0.125	0.106	0.085	0.063
31	0.054		0.092		0.791		0.336	0.187		0.109		0.06

Reservoir Elevation Scores **(E_s)**	
Reservoir Elevation	Elevation Score
421	0.0256
422	0.04
423	0.0576
424	0.0784
425	0.1024
426	0.1296
427	0.16
428	0.1936
429	0.2304
430	0.2704
431	0.3136
432	0.36
433	0.4096
434	0.4624
435	0.5184
436	0.5776
437	0.64
438	0.7056
439	0.7744
440	0.8464
441	0.9216

Table 11. Interpretation of passage scores derived from the simplified passage matrix (Table 9) or through calculation of passage scores using the daily relative stream discharge score (Table 10).

Passage Score	Fish Migration Tributary Access / Passage Conditions
<0.03	No Passage
0.03-0.049	Threshold passage conditions. About 50% of key tributaries were still deemed passable to fish.
0.05-0.089	Passage conditions improving with occasional concerns on some tributaries depending on channel dynamics (e.g. increased channel braiding following reservoir drawdown).
>0.09	No Passage Concerns. Reservoir above mean elevation of drawdown zone barriers and combined higher stream flows and reservoir levels result in high passage scores.

LITERATURE CITED

Andrusak, H. and P. Slaney. 2004. Status of Kokanee in the Arrow Lakes Reservoir and Initial Assessment of Two Arrow Lakes Reservoir Tributary Streams with Restoration Potential for Spawning Kokanee and Rainbow Trout. 44 pp.

Anonymous. 2001. Background Information for CLBMON#32 included with the Request for Proposal (Q8-004, March 5 2008) – Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program, Feb 2008. Email correspondence sent: 2001, May 09 12:06 pm. Subject: Assessment of Kokanee spawning tributaries to Arrow Lakes Reservoir. Attachments: Table 1. Summary of watercourse observation taken from helicopter on 10 April 2001 for major Kokanee spawning tributaries to Arrow Lakes Reservoir and Table 2. Assessment of Kokanee access into major spawning tributaries to Arrow Lakes Reservoir under six surface discharge and reservoir elevation scenarios.

Anonymous. 2002. Background Information for CLBMON#32 included with the Request for Proposal (Q8-004, March 5 2008)- Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program, Feb 2008. Email correspondence sent: 2002, September 08 2:22 pm. Subject: Observations collected during September 5, 2002 flight of Arrow reservoir basin and tributaries. Attachment: Table 1. Summary of watercourse observations taken from helicopter on 10 April 2001 for major Kokanee spawning tributaries to Arrow Lakes Reservoir. Secondary observations added from surveys on August 9 and 30, 2002 and September 5, 2002 (Fauquier elevation – 1428.5 ft).

Bayes, M. M. and W. R. Olmstead. 1997. A Fisheries Assessment of Selected Arrow Lakes Tributaries Volume I. Prepared by BC Hydro Kootenay Generation Area. 181 pp +appendices.

BC Hydro. 1992. Arrow Lakes Tributary Access Survey Summary. Personnel completing survey were Owen Fleming, Jim Scouras and Brian Gadbois. 57 pp. This report was provided to Ecoscape by David DeRosa of BC Hydro, Castlegar, BC and is potentially an internal BC Hydro document with unknown author.

BC Hydro. 2007a. Columbia River Project Water Use Plan. Revised for Acceptance by the Comptroller of Water Rights. 58 pp.

BC Hydro. 2007b. Columbia River Project Water Use Plan Monitoring Program. Terms of Reference - Arrow Lakes Reservoir Operations Management Plan. CLBMON-32 Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program. 14pp.

BC Hydro Project Team and the Columbia River Water Use Plan Consultative Committee (CRWUPCC). 2005. Consultative Committee Report Columbia River Water Use Plan. Vol 1.

Bray, K and P. Mylechreest. 1999. Columbia Basin Fish and Wildlife Compensation Program. Arrow Reservoir Trout Radio Telemetry Interim Report 1998/1999. 10 pp.

British Columbia Ministry of Environment. 1983. Lower Arrow Reservoir Fisheries Compensation Proposal. Working Report by Kootenay Regional Office and Planning and Assessment Branch Ministry of Environment. File No: 20275. 32 pp.

British Columbia Ministry of Environment. 1984. Arrow Basin Fisheries Compensation Proposal. File No: 20318. 24 pp.

British Columbia Ministry of Environment. 2009. Manual of British Columbia Hydrometric Standards. Prepared by Ministry of Environment Science and Information Branch for the Resources Information Standards Committee. 204 pp.

Canadian Columbia River Inter-Tribal Fisheries Commission (CCRIFC). 2006. Kokanee Use of Arrow Lakes Reservoir Drawdown Zone 2005-2006. Contract Number J511-05-12. Submitted to: Karen Bray BC Hydro Columbia Basin Generation. 86 pp.

den Biesen, D. and S. Ord, BC Hydro Kootenay Generation Area. 2002. A Fisheries Assessment of Selected Arrow Lakes Tributaries Volume II. 120 pp.

Decker, S, J. Hagen, and J. Baxter. 2005. Feasibility of Juvenile and Adult Bull Trout Monitoring in Selected Tributaries of the Arrow Lakes Reservoir, 2004-2005. Prepared for: Columbia Basin Fish and Wildlife Compensation Program and BC Hydro and Power Authority. 81 pp.

Drieschner, D., K. Hawes, M.A. Olson-Russello, and J. Schleppe. 2008. Arrow Lakes Tributary Fish Migration Access. Status of Knowledge Report. Program No. CLBMON-32 / Q8-8004. Ecoscape Environmental Consultants Ltd. Kelowna, BC. 99pp. + appendices.

Ford, B.S., P.S. Higgins, A.F. Lewis, K.L. Cooper, T. A. Watson, C.M. Gee, G.L. Ennis and R. L. Sweeting. 1995. Literature Reviews of the Life History, habitat requirements, and mitigation/compensation strategies for thirteen sportfish species in the Peace, Liard and Columbia River Drainages of British Columbia. Can. Manusc. Rep. Fish. Aquat. Sci. 2321:xxiv+342 p.

Gebhart, D.J. 1999. Arrow Lake Tributary Debris Survey and Evaluation. Prepared for BC Hydro West Kootenay Production Area. Prepared by Aquatic Resources Limited. Report 311-1. 37pp

Hawes K., and R. Wagner. 2010. Arrow Lakes Tributary Fish Migration Access. Year 2 (2009) Fish Migration Passage Monitoring Summary Report. Program No. CLBMON-32 / Q8-8004. Ecoscape Environmental Consultants Ltd. Kelowna, BC. 63pp.

Jowett, I. G. 1997. Instream Flow Methods: A comparison of approaches. Regulated Rivers: Research and Management, Vol. 13, 115–127 (1997).

Isaak, D and D, Horan. 2010. A Simple Method Using Underwater Epoxy to Permanently Install Temperature Sensors in Mountain Streams. Prepared by the US Forest Service Air, Water and Aquatics Program – Boise Aquatic Sciences Lab. 15 pp.

Lindsay, R. A. 1976. Sport Fishery Compensation Study on Tributary Streams of the Upper Arrow Lake. Prepared by Fish and Wildlife Branch, Nelson, BC. Prepared for: BC Hydro and Power Authority. File No: 20261. 66 pp.

Lindsay, R. A. And D. J. Seaton. 1978. Sport Fishery Compensation Study on Selected Streams Tributary to the Lower Arrow Lake 1978. Prepared for the Kootenay Region Fish and Wildlife Branch, Nelson, BC File No. 20185. 58 pp.

Mason, B., and R. Knight. 2001. Sensitive Habitat Inventory and Mapping. Community Mapping Network, Vancouver, British Columbia. 315pp + viii. M. Johannes, Editor.

McPhail, J. D. and C. B. Murray. 1979. The Early Life History and Ecology of Dolly Varden (Salvelinus malma) in the Upper Arrow Lakes. Prepared for the BC Hydro and Power Authority and Kootenay Fish and Wildlife Branch. File no. 20171. 107 pp + appendices.

McPhail, J. D. and J.S. Baxter. 1996. A review of Bull Trout (*Salvelinus confluentus*) life-history and habitat use in relation to compensation and improvement opportunities. Fisheries Management Report No. 104. 35 pp.

Miller, D. 1998. Lower Arrow Lake Kokanee Spawner Enumeration-Eagle Creek, Taite Creek, Octopus Creek, Dog Creek. Prepared by: Kootenay Wildlife Services Ltd.

Oliver, G.G. 2001. 2001 Fish Access Assessment of Selected Tributaries to Kinbasket Reservoir. Prepared for BC Hydro Kootenay Generation Office. Prepared by G.G. Oliver and Associates Environmental Science. 61 pp.

RL & L Environmental Services Ltd. 1997. A Fisheries Assessment of Selected Arrow Lakes Tributaries. Report Prepared for Columbia Basin Fish and Wildlife Compensation Program, Fisheries Technical Committee. RL & L Report No. 533F:195 p+3 app.

Schindler, E. U., Sebastian, D. and H. Andrusak. 2006. Arrow Lakes Reservoir Fertilization Experiment Summary Report – 1999 to 2004. Fisheries Project Report No. RD 116 (MS). 45 pp.

Seaton, D. J. 1978. Stream Assessment of Streams Tributary to the Lower Arrow Lake 1978. Prepared by: Fish and Wildlife Branch, Nelson, BC. Prepared for: Ministry of Environment Fish and Wildlife Branch, Nelson, BC.

Sebastian, D., H. Andrusak, G. Scholten and L. Brescia. 2000. Arrow Reservoir Fish Summary. Stock Management Report 2000. Prepared by the Province of British Columbia Ministry of Fisheries. Prepared for Columbia Basin Fish and Wildlife Compensation Program, BC Hydro and Ministry of Environment, Lands and Parks. 87 pp + appendices.

Swoffer Industries Inc. MODEL 2100 Current Velocity Meter Product Description Sheet. http://www.swoffer.com. 2 pp.

Toth, B. M. and K. Tsumara. 1996. Arrow Lakes Rainbow Trout Broodstock Collection Draft. Fisheries Project Report No. RD60. Prepared for BC Hydro, Ministry of Environment Fisheries Branch and Columbia Basin Fish and Wildlife Compensation Program. 18 pp + appendices.

Watry, C.B. and D.L. Scarnecchia. 2008. Adfluvial and fluvial life history variations and migratory patterns of a relict char, *Salvelinus confluentus*, stock in west-central Idaho, USA. *Ecology of Freshwater Fish* **17**: 231-243.

Washington State Department of Ecology. 2009. Standard Operating Procedure for Measuring and Calculating Stream Discharge. Version 1.0. 33 pp.

TRIBUTARY MAPS AND DATA

Bannock Creek

Year 6 (2013) Fish Migration Passage Monitoring Reference: CLBMON– 32A

Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program

Location:	Arrow Lakes
Project No.:	08-249
Prepared for:	BC Hydro and Power Authority
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	July, 2014
Survey Date:	May 22, September 9, and October 9, 2013

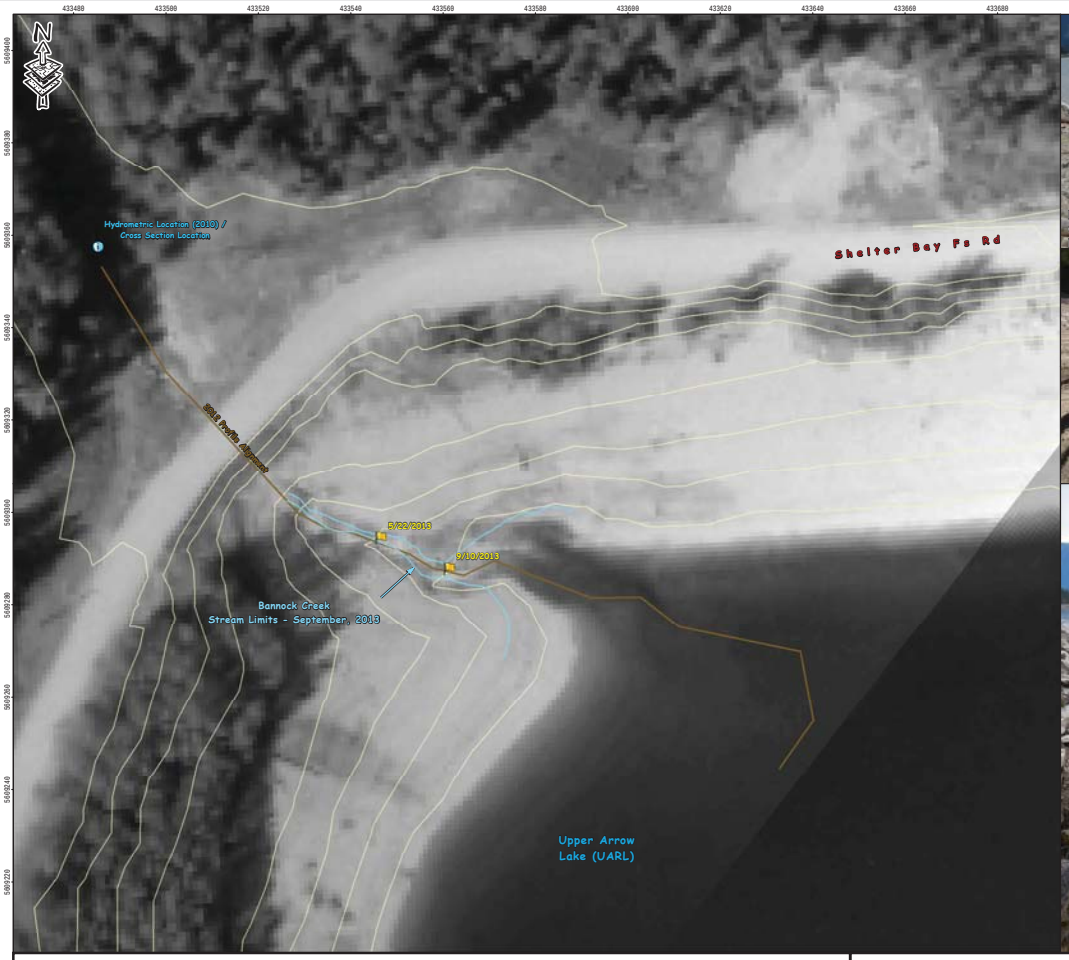



Photo: P1110804 - Photo taken looking downstream over the exposed drawdown zone. There were no passage concerns in May (May 22, 2013).


Photo: P1110808 - Photo taken looking downstream at the cross section location (May 22, 2013).


Photo: 325 - Photo Taken looking upstream at the drawdown zone from the reservoir level. Although passable, there were some marginal fish passage concerns in sections of the armoured cascade (September 9, 2013).


Photo: 336 - Photo taken looking downstream over the drawdown zone from the culvert outlet. (September 9, 2013).


Photo: DSCN0594 - Photo taken looking downstream over exposed drawdown zone (October 9, 2013).


Photo: DSCN0588 - Photo taken looking onshore at the exposed drawdown zone. (October 9, 2013).


Photo: DSCN0589 - Photo taken looking upstream the exposed drawdown zone from the reservoir level (October 9, 2013).

Legend

- Fish Habitat
- Obstruction
- Erosion
- Reservoir Elevation Level
- Hydrometric Location (2010) / Cross Section Location
- Temperature Logger
- Stream Limits (September, 2013)
- 2012 Profile Alignment
- 2 Metre Contours

Bannock Creek is a known rainbow trout, bull trout, and kokanee spawning stream (RL & L Environmental Services, 1997; Andrusak and Slaney, 2004). The stream has been classified as a low value stream (den Biesen and Ord, 2002), possibly due to the high level of siltation noted and potential barriers that occur with a debris jam approximately 0.66 km upstream (RL & L Environmental Services, 1997). Aside from the potential barriers, spawning habitats within the stream may be limited by the depth of pools and siltation due to upstream forestry practices (den Biesen and Ord, 2002; RL & L Environmental Services, 1997). Spawning habitats for kokanee and bull trout were rated as moderate to high for approximately 1 km upstream of the reservoir.

The 2009 survey identified the rock apron downstream of the culvert as a potential upstream migration barrier at both low reservoir levels and stream flows. However, spring flows were suitable for allowing passage over this structure. Kokanee access through the drawdown zone was not an issue in 2009, as the reservoir level was above the rock apron and baffles through the culvert enable passage above. However, no kokanee were observed staging or migrating during September surveys, despite suitable stream temperatures.

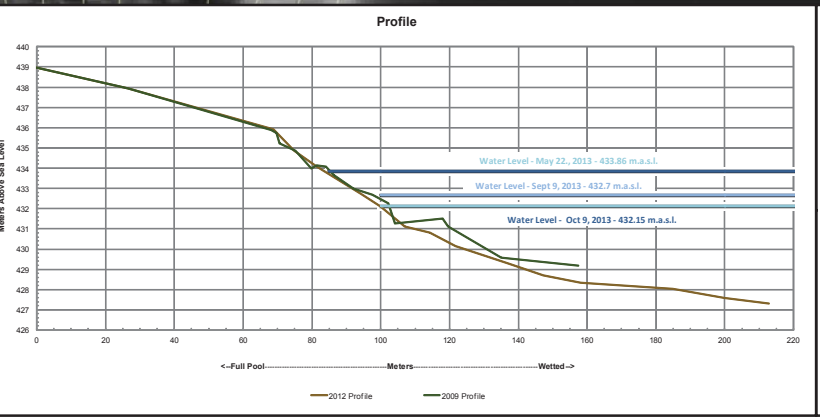
2013 Observations:

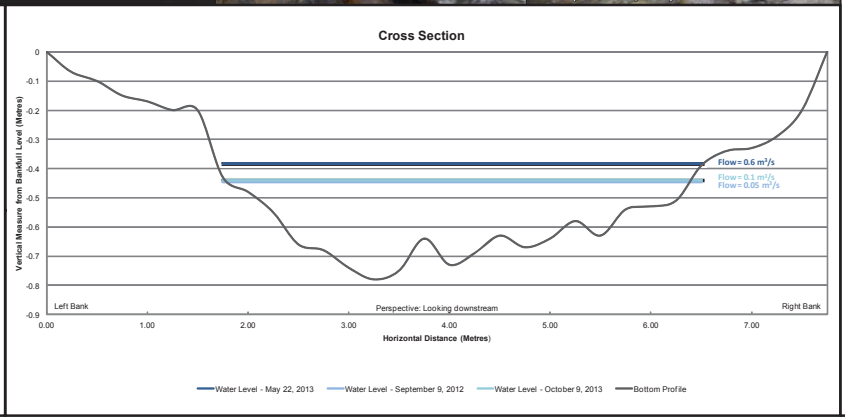
May 22, 2013 – There were no passage concerns observed.

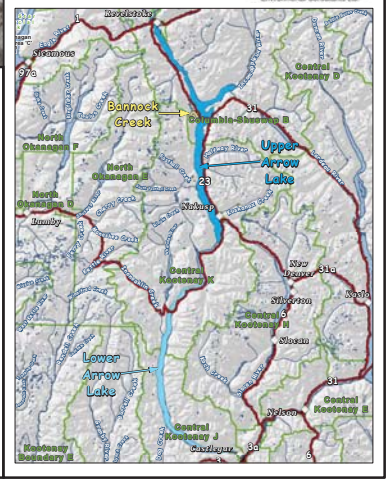
September 9, 2013 – There were no passage concerns at the existing flows and reservoir levels in spite of levels being about 1-m below the 434 m soft constraint.

October 9, 2013 – There were no passage concerns at the existing flows and reservoir levels.

10 5 0 10 20 30 40 50
Meters
1 : 5 0 0







Blanket Creek

Year 6 (2013) Fish Migration Passage Monitoring Reference: CLBMON– 32A

Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program

Location:	Arrow Lakes
Project No.:	08-249
Prepared for:	BC Hydro and Power Authority
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	July, 2014
Survey Date:	May 28, September 9, October 9, 2013

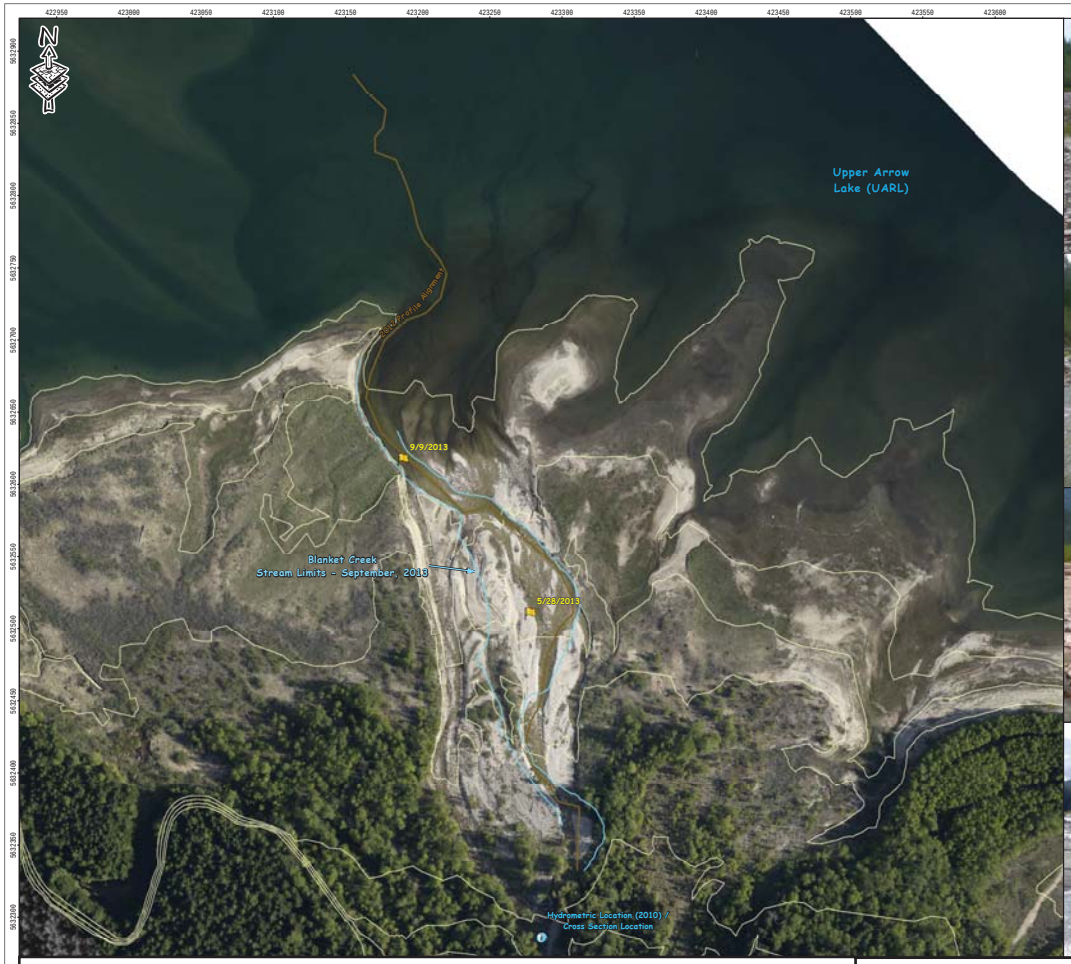



Photo: P1120114 - Photo taken looking upstream over the drawdown zone (May 28, 2013).


Photo: P1120116 - Photo taken looking upstream over the drawdown zone (May 28, 2013).


Photo: P1070343 - Photo taken looking upstream over the drawdown zone (September 9, 2013).


Photo: P1130747 - Photo taken looking upstream over the drawdown zone from the reservoir level. There were no passage concerns during Kokanee spawning migrations(September 9, 2013).


Photo: DSCN0430 - Photo taken looking upstream over the drawdown zone from the reservoir level (October 9, 2013).


Photo: DSCN0444 - Photo taken looking downstream over the drawdown zone showing the well-defined and passable channe (October 9, 2013).

Legend

- Fish Habitat
- Obstruction
- Erosion
- Reservoir Elevation Level
- Hydrometric Location (2010) / Cross Section Location
- Temperature Logger
- Stream Limits (September, 2013)
- 2012 Profile Alignment
- 2 Metre Contours

Blanket Creek is not considered to have significant access issues. A set of falls occur 1.5 km upstream from the reservoir high water level. However, spawning habitat for kokanee and bull trout was only estimated at 1 km of habitat (Sebastian et al, 2000).

During the 2009 survey period, no passage concerns were noted during both spring and fall migration periods – primarily attributed to adequate stream flows - maintaining sufficient residual pool depth and passage over lower braided sections within the drawdown zone.

2013 Observations:

May 28, 2012 – There were no passage concerns at the existing flows and reservoir levels.

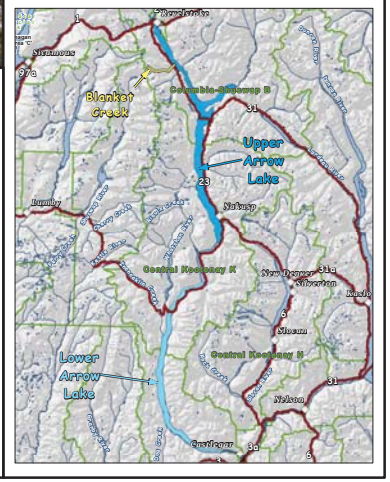
September 9, 2013 – There were no passage concerns at the existing flows and reservoir levels. Sustained higher flows from high elevation snow packs and glacial meltwater maintain good passage conditions at all reservoir levels.

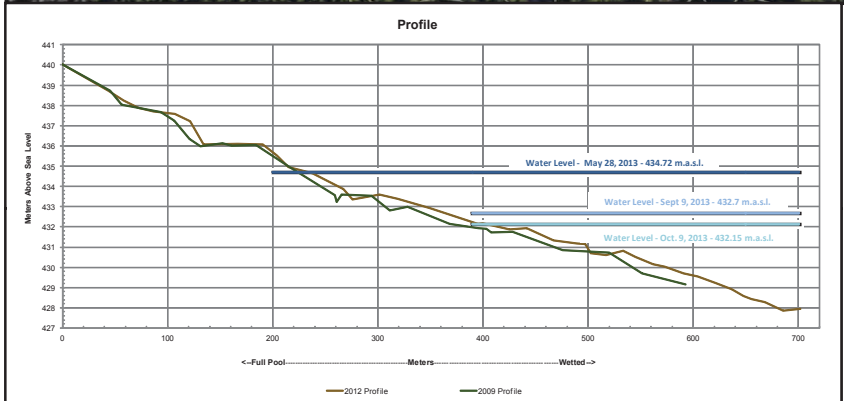
October 9, 2013 – There were no passage concerns at the existing flows and reservoir levels.

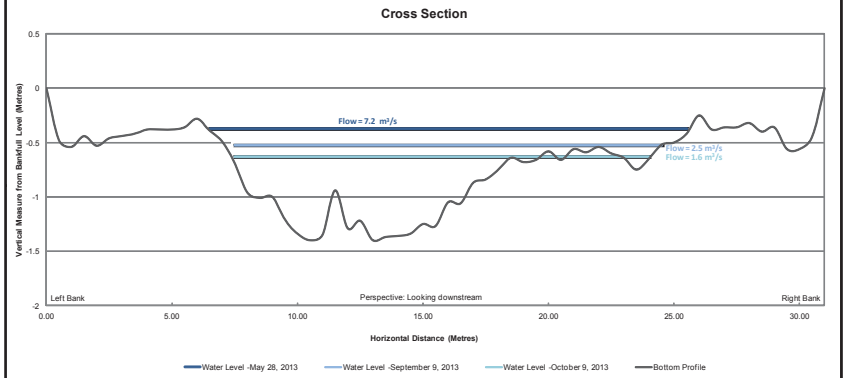
30 15 0 30 60 90 120 150
Meters
1 : 1 , 6 0 0

BC hydro

ECOSCAPE Environmental Consultants Ltd.







Burton Creek and Caribou Creek Confluence

Year 6 (2013) Fish Migration Passage Monitoring Reference: CLBMON– 32A

Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program

Location:	Arrow Lakes
Project No.:	08-249
Prepared for:	BC Hydro and Power Authority
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	July, 2014
Survey Date:	May 21, September 10, October 8, 2013

Legend

- Fish Habitat
- Obstruction
- Erosion
- Hydrometric Location (2010) / Cross Section Location
- Reservoir Elevation Level
- Temperature Logger
- Stream Limits (May, 2013)
- 2012 Profile Alignment
- 2 Metre Contours

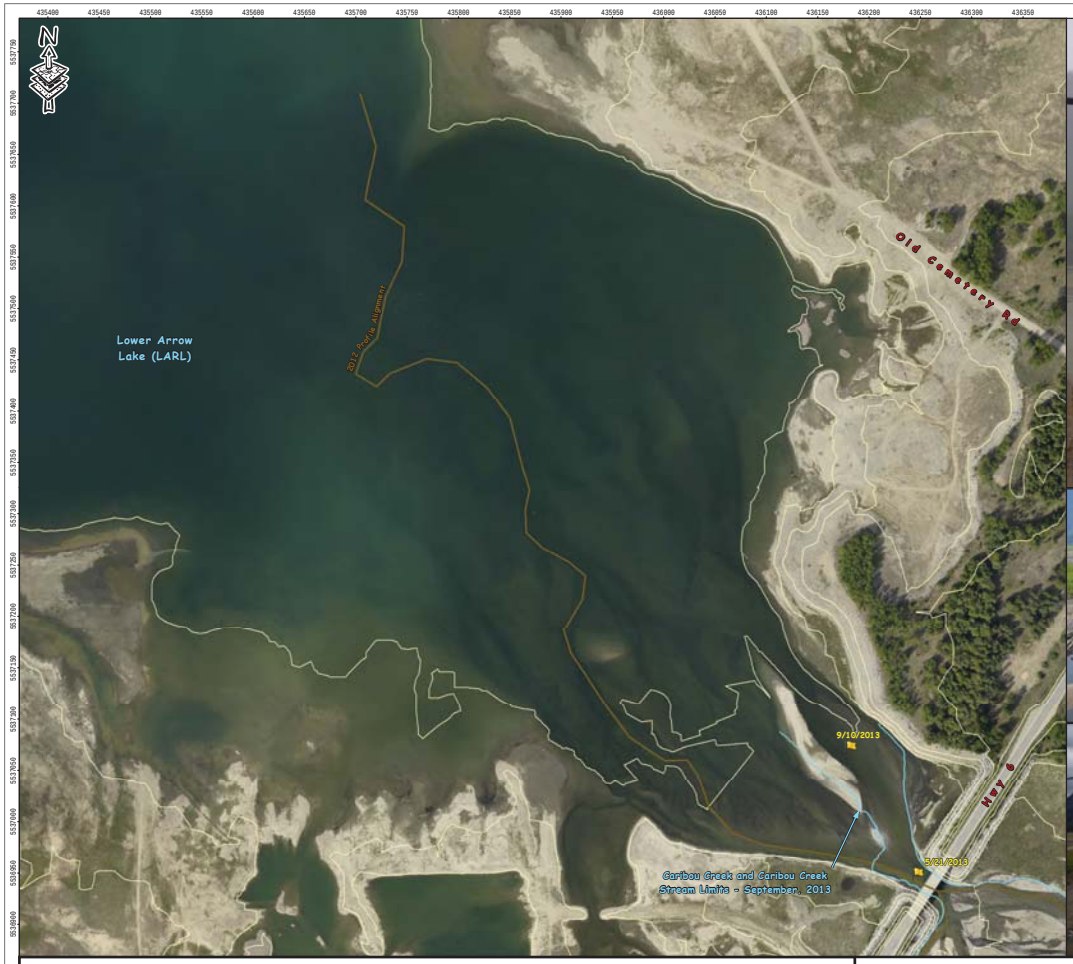


Photo: Photo taken looking over the Caribou Burton drawdown zone (currently inundated) from the Hwy 6 Bridge (May 21, 2013).

Photo: Photo taken looking over the Caribou Burton drawdown zone from the Hwy 6 Bridge. Kokanee migration and spawning was in process with no passage concerns noted (September 10, 2013).

Photo: Photo taken looking over the Caribou Burton drawdown zone from the Hwy 6 Bridge. Flows and passage conditions were similar to September Kokanee access surveys (October 8, 2013).

The limiting factors for kokanee and bull trout production include: limited overhead cover, limited low velocity habitat (pools) for adult staging, and limited suitable substrate for salmonid spawning during fall low flow periods (RL and L Environmental Services Ltd, 1997).

No obstructions were noted in the drawdown zone during the 2009 survey period. While the fan downstream of the Highway 6 Bridge is wide and heavily braided at low reservoir levels, the spring creek flows maintained good channelization and depth and no access problems were noted. During kokanee staging and migration periods, the reservoir levels reached upstream of the bridge and, combined with adequate stream flows, kokanee access through the drawdown zone was not impeded. While overall the lack of instream cover/structure relative to the magnitude of the drawdown zonefan was of concern, the deep pool beneath the Highway 6 Bridge provides significant cover for staging fish.

2013 Observations:

May 21, 2013 – There were no passage concerns at the existing flows and reservoir levels.

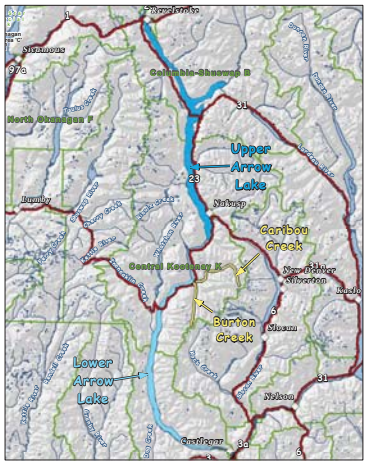
September 10, 2013 - There were no passage concerns at the existing flows and reservoir levels in spite of the reservoir being about 1.3 m below the 434 m soft constraint. Sustained higher flows from high elevation snow packs maintain good passage conditions.

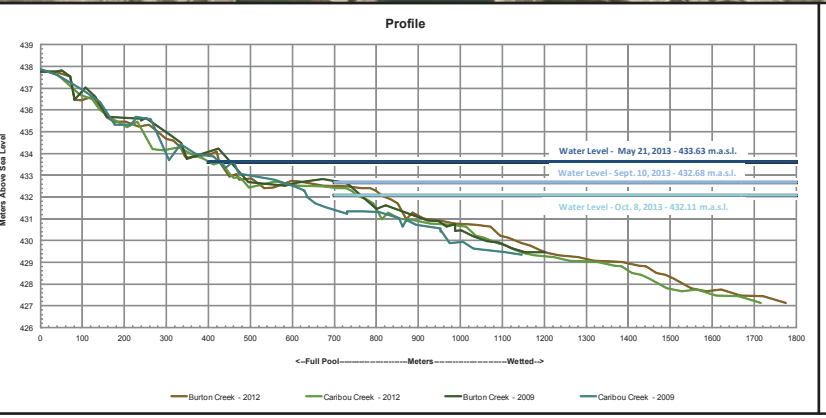
October 8, 2013 – There were no passage concerns at the existing flows and reservoir levels.

40 20 0 40 80 120 160 200

Meters

1 : 2 , 2 5 0





Hydrometric cross-section was not completed.

Burton Creek

Year 6 (2013) Fish Migration Passage Monitoring Reference: CLBMON– 32A

Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program

Location:	Arrow Lakes
Project No.:	08-249
Prepared for:	BC Hydro and Power Authority
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	July, 2014
Survey Date:	May 24, September 10, and October 8, 2013

Photo: Photo taken of Burton Creek looking upstream from the Hwy 6 Bridge. No passage concerns at high flow (May 21, 2013).

Photo: Photo taken of Burton Creek looking upstream from the Hwy 6 Bridge (September 10, 2013).

Photo: Photo taken of Burton Creek looking upstream from the Hwy 6 Bridge (October 8, 2013).

Legend

- Fish Habitat
- Obstruction
- Erosion
- Reservoir Elevation Level
- Hydrometric Location (2010) / Cross Section Location
- Temperature Logger
- Stream Limits (September, 2013)
- 2012 Profile Alignment
- 2 Metre Contours

The limiting factors for kokanee and bull trout production include: limited overhead cover, limited low velocity habitat (pools) for adult staging, and limited suitable substrate for salmonid spawning during fall low flow periods (RL and L Environmental Services Ltd, 1997).

No obstructions were noted in the drawdown zone during the 2009 survey period. While the fan downstream of the Highway 6 Bridge is wide and heavily braided at low reservoir levels, the spring creek flows maintained good channelization and depth and no access problems were noted. During kokanee staging and migration periods, the reservoir levels reached upstream of the bridge and, combined with adequate stream flows, kokanee access through the drawdown zone was not impeded. While overall the lack of instream cover/structure relative to the magnitude of the drawdown zone/fan was of concern, the deep pool beneath the Highway 6 Bridge provides significant cover for staging fish.

2013 Observations:

May 21, 2013 – There were no passage concerns at the existing flows and reservoir levels.

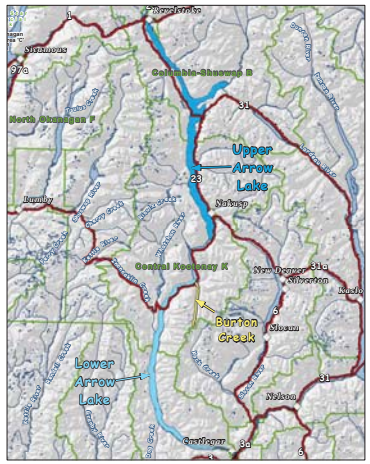
September 10, 2013 - There were no passage concerns at the existing flows and reservoir levels. Sustained higher flows from high elevation snow packs maintain good passage conditions. However, low instream cover over the drawdown zone may expose Kokanee to increased predation.

October 8, 2013 - There were no passage concerns at the existing flows and reservoir levels.

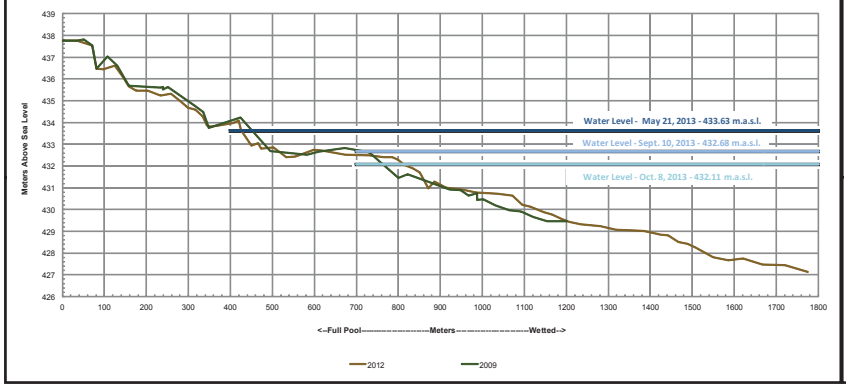
50 25 0 50 100 150 200
Meters
1 : 2 , 0 0 0

BC hydro

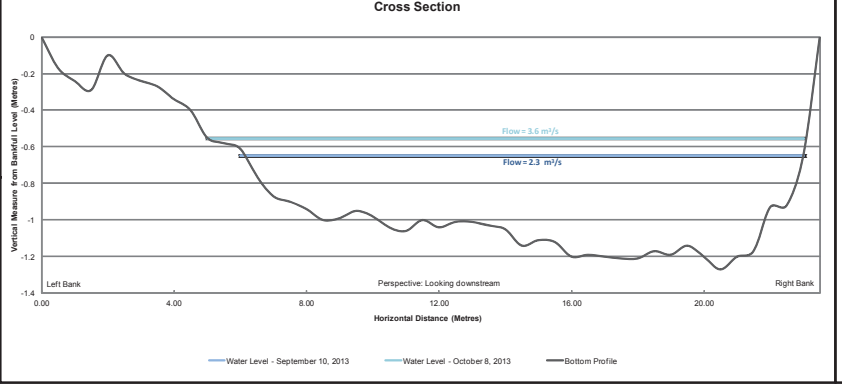
ECOSCAPE Environmental Consultants Ltd.



Profile



Cross Section



Caribou Creek

Year 6 (2013) Fish Migration Passage Monitoring Reference: CLBMON– 32A

Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program

Location:	Arrow Lakes
Project No.:	08-249
Prepared for:	BC Hydro and Power Authority
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	July, 2014
Survey Date:	May 21, September 10, October 8, 2013

Photo: Photo taken looking upstream from the Hwy 6 Bridge. No passage concerns at high flows (May 21, 2013).

Photo: P1070191 - Looking downstream toward highway bridge from cross section location (May 15, 2012).

Photo: Photo taken looking upstream from the Hwy 6 Bridge (October 8, 2013).

Legend

- Fish Habitat
- Obstruction
- Erosion
- Reservoir Elevation Level
- Hydrometric Location (2010) / Cross Section Location
- Temperature Logger
- 2012 Profile Alignment
- Stream Limits (September, 2013)
- 2 Metre Contours

The limiting factors for kokanee and bull trout production include: limited overhead cover, limited low velocity habitat (pools) for adult staging, and limited suitable substrate for salmonid spawning during fall low flow periods (RL and L Environmental Services Ltd, 1997).

No obstructions were noted in the drawdown zone during the 2009 survey period. While the fan downstream of the Highway 6 Bridge is wide and heavily braided at low reservoir levels, the spring creek flows maintained good channelization and depth and no access problems were noted. During kokanee staging and migration periods, the reservoir levels reached upstream of the bridge and, combined with adequate stream flows, kokanee access through the drawdown zone was not impeded. While overall the lack of instream cover/structure relative to the magnitude of the drawdown zone/fan was of concern, the deep pool beneath the Highway 6 Bridge provides significant cover for staging fish.

2013 Observations:

May 21, 2013 – There were no passage concerns at the existing flows and reservoir levels.

September 10, 2013 - There were no passage concerns at the existing flows and reservoir levels. Sustained higher flows from high elevation snow packs maintain good passage conditions. However, low instream cover over the drawdown zone may expose Kokanee to increased predation.

October 8, 2013 - There were no passage concerns at the existing flows and reservoir levels.

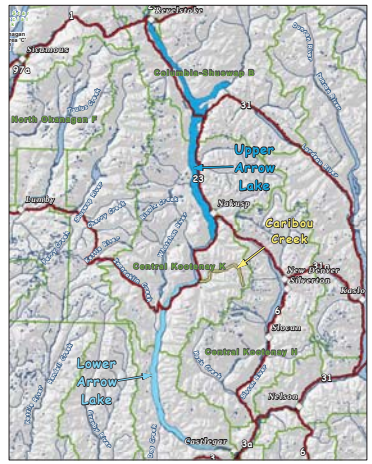
30 15 0 30 60 90 120 150

Meters

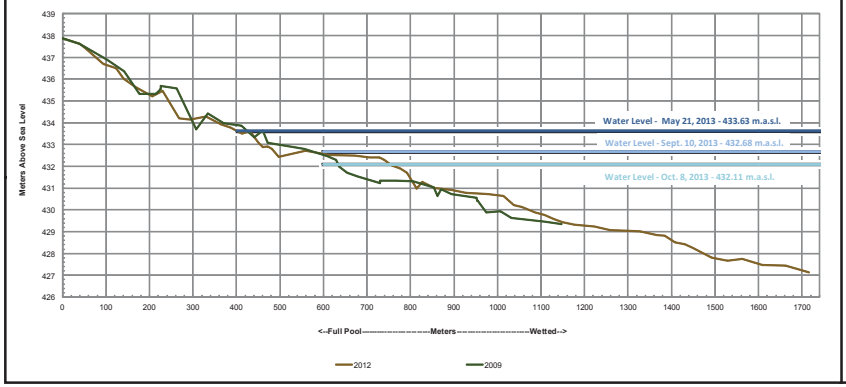
1 : 1,250

BC hydro

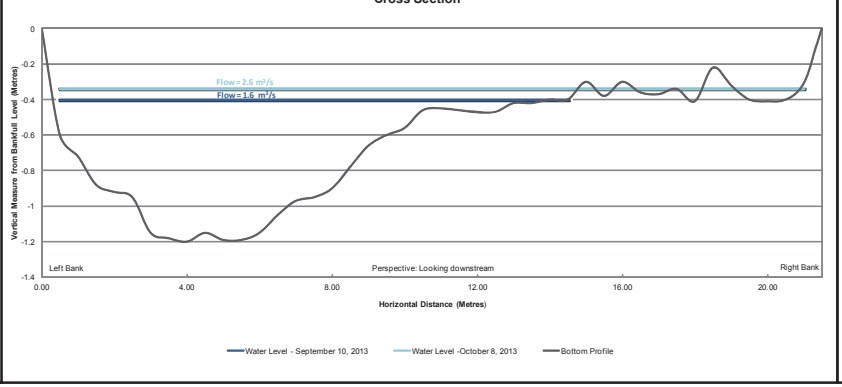
ECOSCAPE
Environmental Consultants Ltd.



Profile



Cross Section



Cranberry Creek

Year 6 (2013) Fish Migration Passage Monitoring Reference: CLBMON– 32A

Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program

Location:	Arrow Lakes
Project No.:	08-249
Prepared for:	BC Hydro and Power Authority
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	July, 2014
Survey Date:	May 22, September 10, October 9, 2013

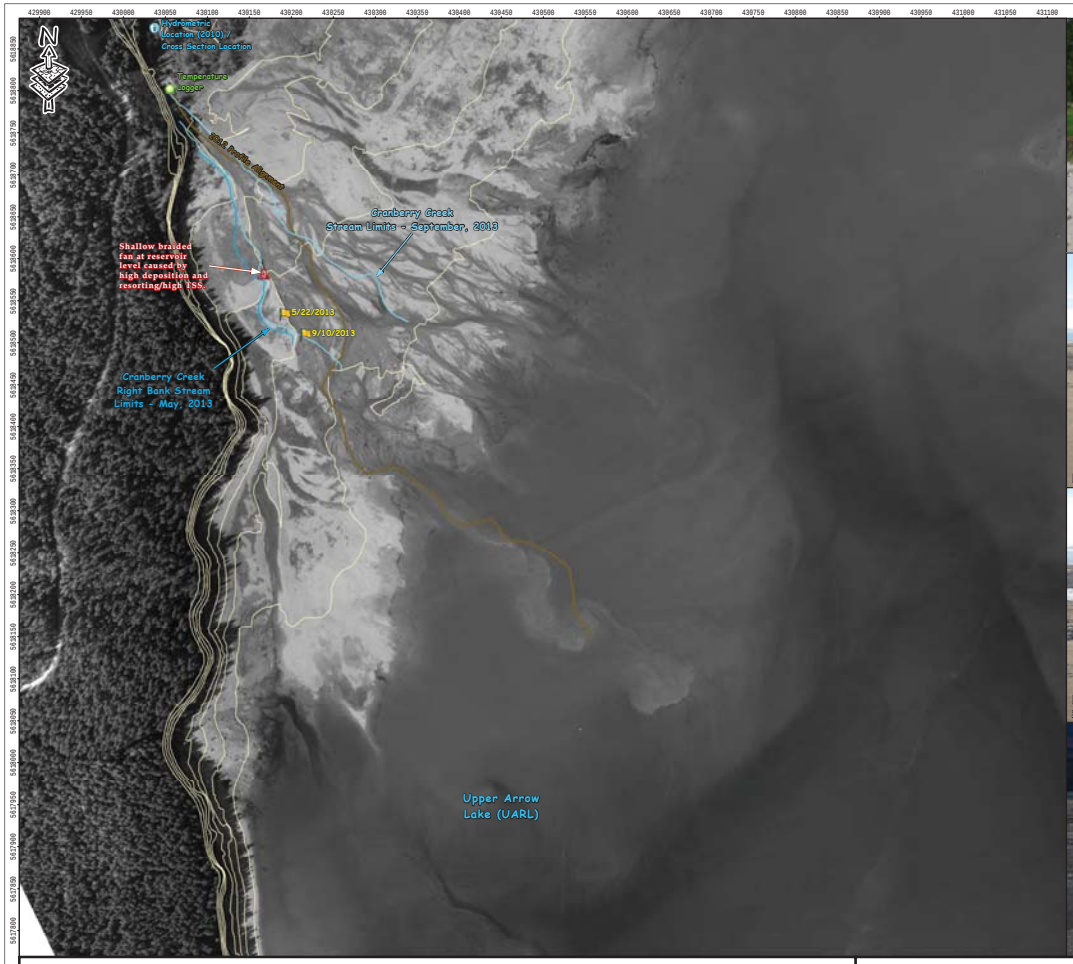



Photo: P1110811 - Photo taken looking upstream (May 22, 2013).


Photo: P1110813 - Photo taken looking downstream (May 22, 2013).


Photo: P1130874 - Photo taken looking downstream (September 10, 2013).


Photo: P1130877 - Photo taken looking downstream showing braiding over the lower extents of the drawdown zone (September 10, 2013).


Photo: PDSCN0605 - Photo taken looking downstream (October 9, 2013).


Photo: PDSCN0610 - Photo taken looking upstream from reservoir wetted level (October 9, 2013).

Legend

- Fish Habitat
- Obstruction
- Erosion
- Reservoir Elevation Level
- Hydrometric Location (2010) / Cross Section Location
- Temperature Logger
- Stream Limits (May, 2013)
- Stream Limits (September, 2013)
- 2012 Profile Alignment
- 2 Metre Contours

In the spring of 2009, flows were too high to sample or observe rainbow trout. Nevertheless, with these flows, tributary access through the drawdown zone was not a concern. In lower section of the drawdown zone, rooted stumps and partially embedded large woody debris, are influencing scour and channelization through fine substrates, thereby maintaining a more defined and passable channel and at the same time providing cover and structure for fish. Recent management recommendations have resulted in establishment of a minimum flow for Cranberry Creek; where the diversion of flows has typically left 12 km of lower reaches dewatered (Andrusak and Slarey, 2004; Spence et al, 2005). Despite this, very low stream flows were observed on September 9, 2009, which were of concern for kokanee access and migration. Only 52 kokanee were counted upstream of the drawdown zone in a small residual pool within 100m of the reservoir high water level.

2013 Observations:

May 22, 2013 – There were no passage concerns with high stream flows.

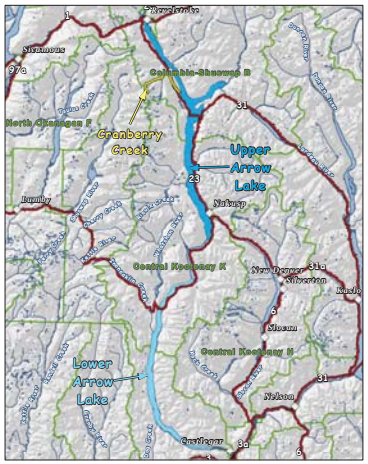
September 10, 2013 – The mainstem channel had no passage concerns at the documented flows. However, braided secondary channel had passage concerns.

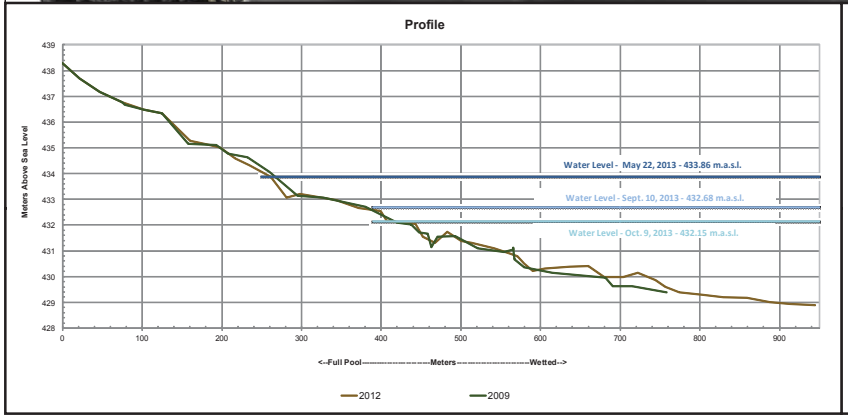
October 9, 2013 – The mainstem channel had no passage concerns at the documented flows. However, braided secondary channel had passage concerns.

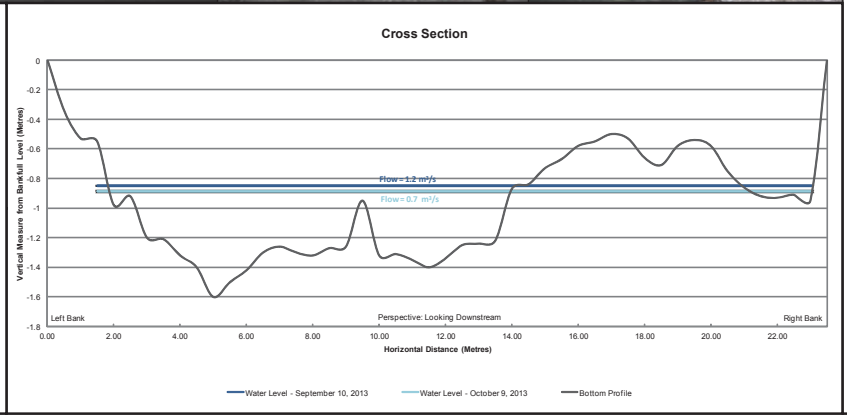
50 25 0 50 100 150 200 250 300
Meters
1 : 2 , 7 5 0

BC hydro

ECOSCAPE Environmental Consultants Ltd.







Crawford Creek

Year 6 (2013) Fish Migration Passage Monitoring Reference: CLBMON– 32A

Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program

Location:	Arrow Lakes
Project No.:	08-249
Prepared for:	BC Hydro and Power Authority
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	July, 2014
Survey Date:	May 28, September 9, October 9, 2013

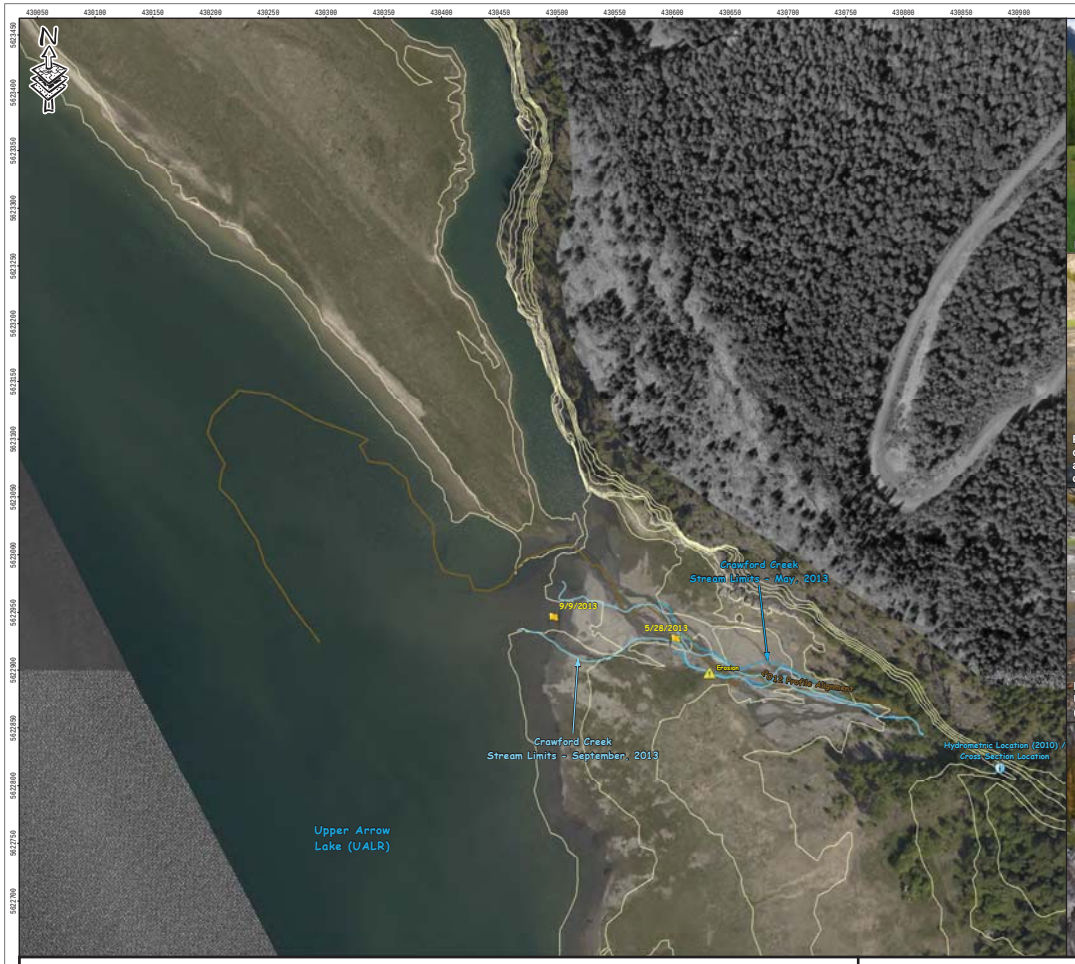



Photo: Panorama taken from right bank looking over drawdown zone towards UARL (May 28, 2013).

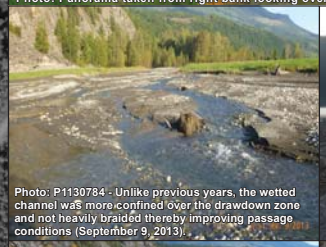


Photo: P1130784 - Unlike previous years, the wetted channel was more confined over the drawdown zone and not heavily braided thereby improving passage conditions (September 9, 2013).


Photo: P1130816 - Photo taken looking downstream (September 9, 2013).


Photo: DSCN0461 - Looking upstream from UARL wetted level; no passage concerns (October 9, 2013).


Photo: DSCN0471 - Taken from left bank looking upstream (October 9, 2013).


Photo:Photo: Panorama taken from right bank looking over drawdown zone towards UARL (October 9, 2013).

Legend

- Fish Habitat
- Obstruction
- Erosion
- Reservoir Elevation Level
- Hydrometric Location (2010) / Cross Section Location
- Temperature Logger
- 2012 Profile Alignment
- Stream Limits (May, 2013)
- Stream Limits (September, 2013)
- 2 Metre Contours

Crawford Creek was not documented as having any access problems due to reservoir elevation. However, stream depth and braiding in the drawdown zone may impede fish access at low reservoir levels (Anonymous 2002).

During the spring 2009survey period, potential low flow barriers included two braided sections. Even at moderate flows, channel braiding and shallow depths may partially inhibit tributary access to rainbow trout. Substrates within the drawdown zone consist predominantly of fines, with coarser material being highly embedded. Thus, the drawdown zone is not suitable for spawning. In 2009, upstream access by kokanee was confirmed by visual observations. It was noted that the channel forms over highly unstable braided sections provided access this year, which was likely supported by increased stream flows brought about by moderate to heavy rainfall over the days that preceded the survey. However, this channel instability may also function to restrict access depending on how the channel re-sorts and develops when the reservoir levels drop.

2013 Observations:

May 28, 2013 – Fish passage was considered marginal due to very high TSS at current flows from erosion of fines over the drawdown zone. However, high flows maintain good depths for passage.

September 9, 2013 – Passage condition improved over previous years since there was less braiding over the drawdown zone and the channel was more confined. The stream was passable Kokanee were observed upstream of the drawdown zone.

October 9, 2013 – There were no passage concerns at the existing flows and reservoir levels.

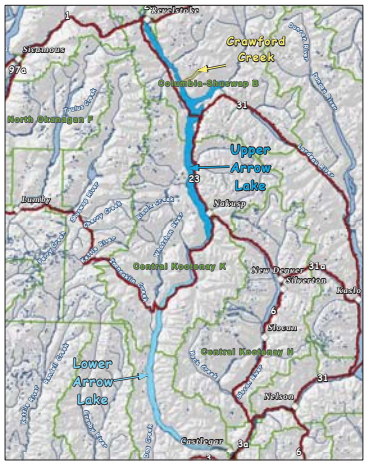
40 20 0 40 80 120 160 200

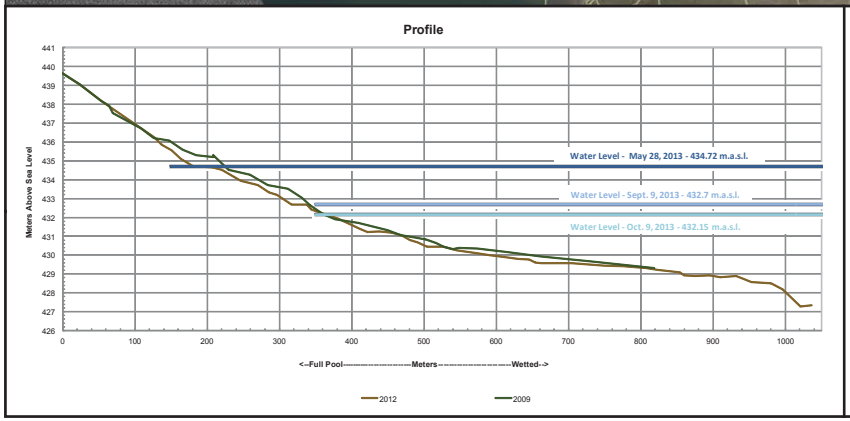
Meters

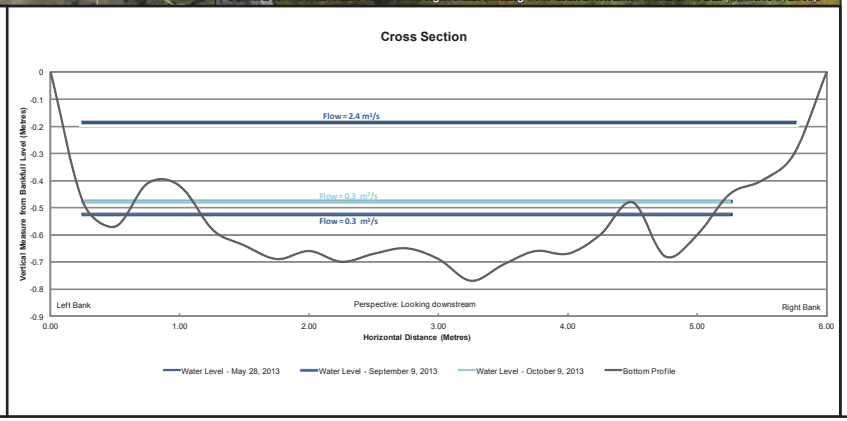
1 : 2 , 0 0 0

BC hydro

ECOSCAPE Environmental Consultants Ltd.







Deer Creek

Year 6 (2013) Fish Migration Passage Monitoring Reference: CLBMON– 32A

Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program

Location:	Arrow Lakes
Project No.:	08-249
Prepared for:	BC Hydro and Power Authority
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	July, 2014
Survey Date:	May 23, September 12, October 8, 2013


Photo: P1110872 - Photo taken of Deer Creek looking upstream in the mid to upper portion of the drawdown zone where channel braiding occurs (May 23, 2013).


Photo: P1110871 - Photo taken looking upstream (May 23, 2013).

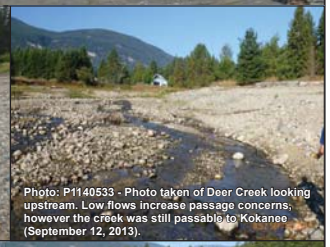


Photo: P1140533 - Photo taken of Deer Creek looking upstream. Low flows increase passage concerns, however the creek was still passable to Kokanee (September 12, 2013).


Photo: P1140518 - Photo taken looking over Deer Creek (September 12, 2013).


Photo: DSCN0315 - Photo taken of Deer Creek looking upstream (October 8, 2013).


Photo: DSCN0324 - Photo taken of Deer Creek looking downstream (October 8, 2013).

Legend

- Fish Habitat
- Obstruction
- Erosion
- Reservoir Elevation Level
- Hydrometric Location (2010) / Cross Section Location
- Temperature Logger
- Stream Limits (September, 2013)
- 2 Metre Contours
- 2012 Profile Alignment

Deer Creek has high spawning and rearing potential for both kokanee and bull trout and moderate/high adult holding potential for the respective species (RL & L Environmental Services Ltd, 1997). There is currently 2 km of Deer Creek available for kokanee spawning, but a series of log jams prevent further upstream access (Zimmer, 2007), although 2.7 km is apparently accessible to adfluvial rainbow trout (Sebastian et al, 2000; Andrusak and Slaney, 2004). Resident rainbow trout were observed to occur upstream of the falls at 2.7 km (Bayes and Olmstead, 1997).

During the spring drawdown survey (April 7, 2009), minor passage concerns were identified from the mid elevation of the drawdown zone to the wetted level of the reservoir (429.5 m.a.s.l.). These concerns were associated with channel braiding in the mid-level of the drawdown zone and high instability (active bank sloughing) in the lower lengths of the drawdown zone. However, based on the increasing flows, rainbow trout access and migration was not assessed as a problem. Kokanee access assessments, conducted on September 11 2009, identified good stream flows and no passage concerns – supported by counts of up to 200 fish/10 linear meter upstream of the drawdown zone.

2013 Observations:

May 23, 2013 – There were no passage concerns; with high stream flows mitigating any potential effect of the current LARL wetted level.

September 12, 2013 – There were no passage concerns at the existing flows and reservoir levels.

October 8, 2013 – There were no passage concerns at the existing flows and reservoir levels.

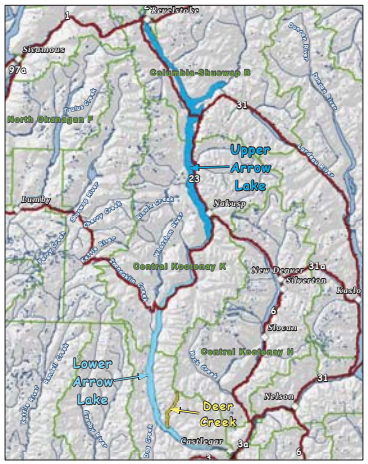
30 15 0 30 60 90

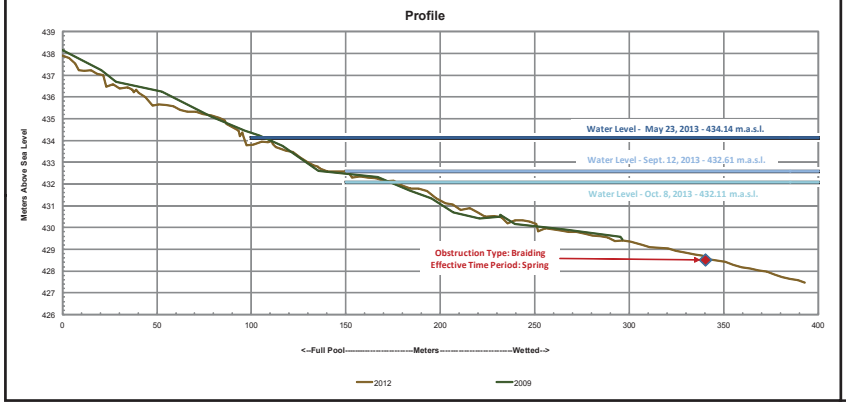
Meters

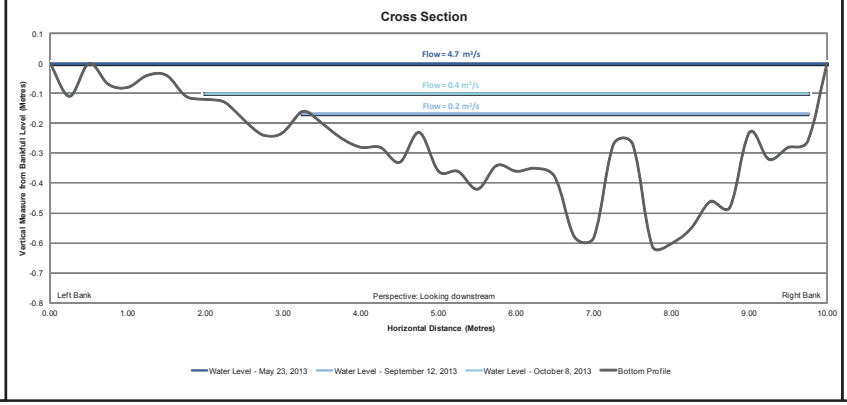
1 : 1 , 0 0 0

BC hydro

ECOSCAPE Environmental Consultants Ltd.







Dog Creek (Lower Arrow)

Year 6 (2013) Fish Migration Passage Monitoring Reference: CLBMON– 32A

Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program

Location:	Arrow Lakes
Project No.:	08-249
Prepared for:	BC Hydro and Power Authority
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	July, 2014
Survey Date:	May 23, September 12, October 7, 2013

Legend

- Fish Habitat
- Obstruction
- Erosion
- Reservoir Elevation Level
- Hydrometric Location (2010) / Cross Section Location
- Temperature Logger
- Stream Limits (September, 2013)
- 2012 Profile Alignment - P1
- 2012 Profile Alignment - P2
- 2 Metre Contours

Dog Creek has been stocked with Gerrard rainbow trout; 7,509 Gerrard rainbow trout from the Kootenay Hatchery were released within both Dog and Deer creek in 1986 (Lindsay, 1986). The drawdown zone is described as primarily riffle with limited pools and runs (Canadian Columbia River Inter-Tribal Fisheries Commission, 2006). Low flows and channel braiding within the drawdown zone may also reduce fish access to Dog Creek (Anonymous 2002) and ongoing stream monitoring and truck and transport techniques have been suggested to improve access.

During the spring 2009 assessments, Dog Creek was assessed as passable at current flows with a potential low flow barrier occurring over the lower (braided) section of the drawdown zone when the reservoir is at low levels. Kokanee were observed above the drawdown zone on September 11, 2009 and although flows were low, upstream access was possible.

2013 Observations:

May 23, 2013 – There were no passage concerns; with high stream flows mitigating any potential effect of the current LARL wetted level.

September 12, 2013 – Flows were low and the right channel was dry. Low flows resulted in marginal to impassable conditions for Kokanee.

October 7, 2013 – Increased flows measured in October improve passage conditions for fish. Although Bull Trout do not frequent Dog Creek, the October inspection provided observation of stream passage conditions at different flow and reservoir levels.

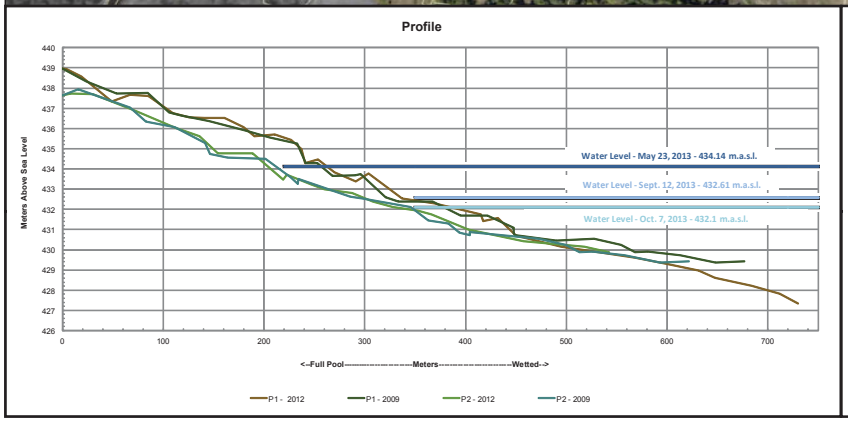
40 20 0 40 80 120 160 200

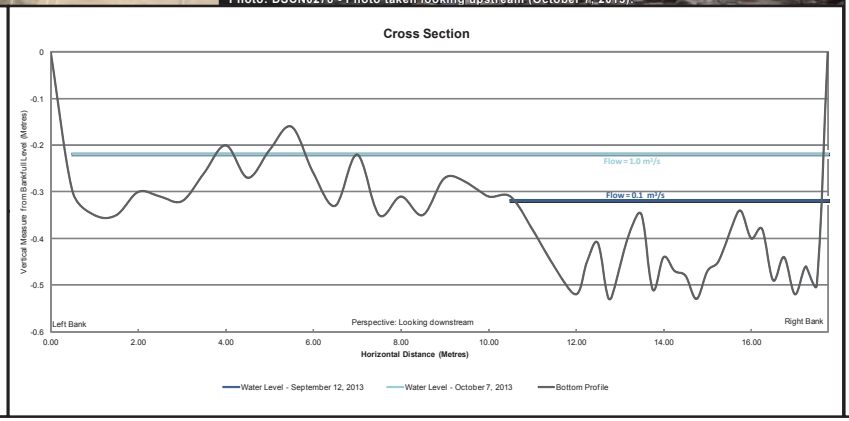
Meters

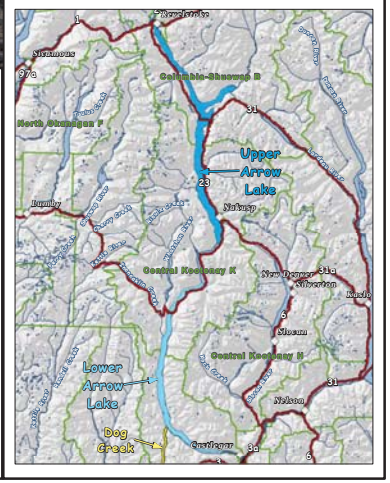
1 : 2 , 0 0 0

BC hydro

ECOSCAPE Environmental Consultants Ltd.







Drimmie Creek

Year 6 (2013) Fish Migration Passage Monitoring Reference: CLBMON– 32A

Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program

Location:	Arrow Lakes
Project No.:	08-249
Prepared for:	BC Hydro and Power Authority
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	July, 2014
Survey Date:	May 28, September 9, October 10, 2013

Photo: P1120085 - Photo taken looking upstream from the old road. (May 28, 2013).

Photo: P1120086 - Photo taken looking downstream from the old road. (May 28, 2013).

Photo: P1130712 - Photo taken looking upstream from the old road. (September 9, 2013).

Photo: P1130668 - Photo taken looking upstream from the reservoir level (432.7 m). At low flows, Drimmie Creek was still passage to Kokanee at levels 1.3 m below the soft constraint (434 m). (September 9, 2013).

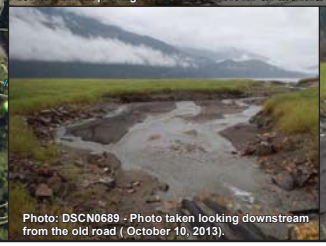


Photo: DSCN0689 - Photo taken looking downstream from the old road (October 10, 2013).

Photo: DSCN0691 - Photo taken looking upstream from the old road. Adult Bull Trout were observed in the creek upstream of the drawdown zone. (October 10, 2013).

Legend

- Fish Habitat
- Obstruction
- Erosion
- Reservoir Elevation Level
- Hydrometric Location (2010) / Cross Section Location
- Temperature Logger
- Stream Limits (May, 2013)
- Stream Limits (September, 2013)
- 2 Metre Contours
- 2012 Profile Alignment

Access issues from the reservoir are not considered a problem and low reservoir elevations were thought to provide improved spawning conditions with exposure of suitable gravels (BC Hydro, 1992). However, a meandering braided channel was described for the drawdown area, consistent with high freshet flows (BC Hydro, 1992). Accessible habitat was approximately 1 km before a natural access barrier (BC Hydro, 1992; Andrusak and Slaney, 2004). Other authors have indicated that bull trout and kokanee may have 3 km of access, while rainbow trout were noted to have 1.4 km (Sebastian et al., 2000).

During the spring 2009 survey, potential passage impediments were associated with low flows over the braided channel occurring at the downstream end (430.4 m asl) of the drawdown zone during low reservoir levels. Moving upstream, the channel becomes more confined by high banks, and woody debris embedded in the channel helps to maintain scour pools and improve complexity and instream cover. Kokanee fry were captured upstream of the culvert in the spring (May 26, 2009). Kokanee migration during 2009 assessments was unimpeded - supported by adequate stream flows. Spawning behaviour was observed over suitable substrates occurring in the drawdown zone upstream of the culvert.

2013 Observations:

May 28, 2013 – There were no passage concerns with moderate to high stream flows.

September 9, 2013 – No passage concerns at the documented flows. A split channel, instead of braiding, maintained improved passage conditions (i.e. deeper more confined channels) for Kokanee.

October 10, 2013 – There were no passage concerns at low to moderate flows. Adult Bull Trout observed upstream of the drawdown zone.

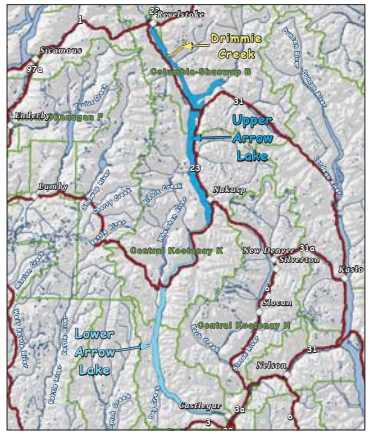
50 25 0 50 100 150 200 250

Meters

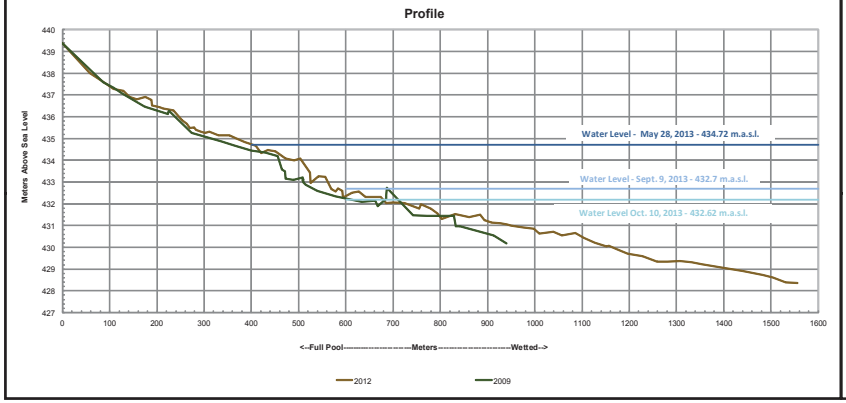
1 : 2 , 5 0 0

BC hydro

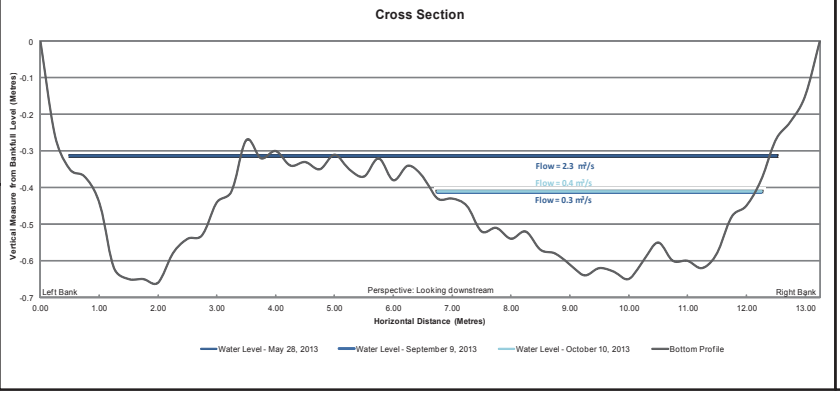
ECOSCAPE Environmental Consultants Ltd.



Profile



Cross Section



Eagle Creek

Year 6 (2013) Fish Migration Passage Monitoring Reference: CLBMON– 32A

Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program

Location:	Arrow Lakes
Project No.:	08-249
Prepared for:	BC Hydro and Power Authority
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	July, 2014
Survey Date:	May 23, September 11, October 8, 2013

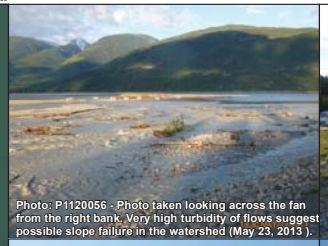


Photo: P1120056 - Photo taken looking across the fan from the right bank. Very high turbidity of flows suggest possible slope failure in the watershed (May 23, 2013).


Photo: P1120059 - Photo taken looking upstream from the right bank (May 23, 2013).


Photo: P1140151 - Photo taken looking downstream from the left bank. Very low flows and braided channel form present passage barriers for Kokanee in the lower drawdown zone (September 11, 2013).

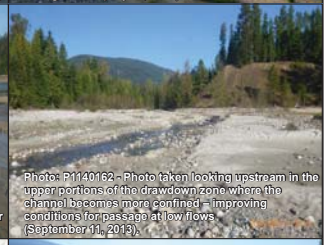


Photo: P1140162 - Photo taken looking upstream in the upper portions of the drawdown zone where the channel becomes more confined – improving conditions for passage at low flows (September 11, 2013).


Photo: P1140170 - Photo taken showing Kokanee that have managed to migrate upstream through braided and very shallow conditions presented at very low flows over the drawdown zone (September 11, 2013).


Photo: P1140203 - Photo taken looking downstream showing very low flows, with intermittent dry stream bed (September 11, 2013).


Photo: DSCN0388 - Photo taken looking upstream from the reservoir level showing low flows (October 8, 2013).


Photo: DSCN0393 - Photo taken looking upstream (October 8, 2013).

Legend

- Fish Habitat
- Obstruction
- Erosion
- Temperature Logger
- Hydrometric Location (2010) / Cross Section Location
- Reservoir Elevation Level
- Stream Limits (September, 2013)
- 2012 Profile Alignment
- 2 Metre Contours

Eagle Creek is thought to have a high overall fisheries value, as there is good spawning potential both upstream and downstream of the high water level (Bayes and Olmstead, 1997). Fish have access to 4.3 km of Eagle Creek before an approximately 2 m chute blocks further passage for kokanee (Seaton, 1978). It is thought that bull trout may be able to navigate the barrier depending on discharge levels (Seaton, 1978), and bull trout are documented as spawning in Eagle Creek (Sebastian et al, 2000). Adfluvial rainbow trout spawning has also been documented in Eagle Creek (Seaton, 1978; Toth and Tsumara, 1996). A waterfall that occurs approximately 9.2 km from the confluence blocks all fish passage (Seaton, 1978, Lindsay and Seaton, 1978).

Water levels appear to fluctuate on an annual basis, as fisheries values were reported to be high, but Eagle Creek had one report of being dry in autumn (Andrusak and Slaney, 2004) and was observed to go subsurface approximately 500 m upstream of the reservoir confluence in 2005 (Canadian Columbia River Inter-Tribal Fisheries Commission, 2006) and dry at 583 m in 1998 (Miller, 1998). Several reports cited low flows and shallow water levels in the fall, as well as channel braiding (BC Hydro, 1992; Bayes and Olmstead, 1997; Miller, 1998; Andrusak and Slaney, 2004 and Canadian Columbia River Inter-Tribal Fisheries Commission, 2006). During kokanee spawning surveys in 1998, temperature levels were 22.5°C at the mouth, approaching lethal levels for kokanee; spawning occurred in remnant pools with heavy bird predation (Miller, 1998). Heavy bird predation was also documented in 1996 (Bayes and Olmstead, 1997).

Eagle Creek was added to the tributary field sampling program for 2010 due to severe aggrading and low flow impediments to kokanee access observed in September 2009.

2013 Observations:

May 23, 2013 – High flows provided sufficiently deep wetted channels for fish passage. Very high turbidity of flows suggest possible slope failure in the watershed.

September 11, 2013 – Very low flows and braided channel form present passage barriers for Kokanee in the lower drawdown zone.

October 8, 2013 – Increased flows improved conditions for fish passage.

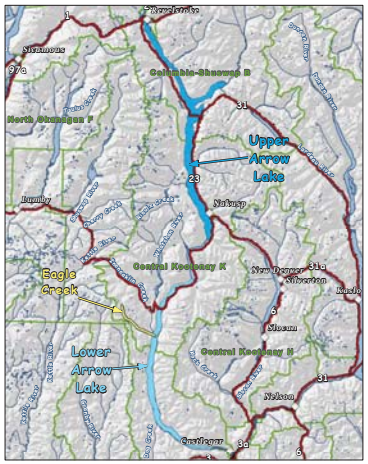
50 25 0 50 100 150 200 250

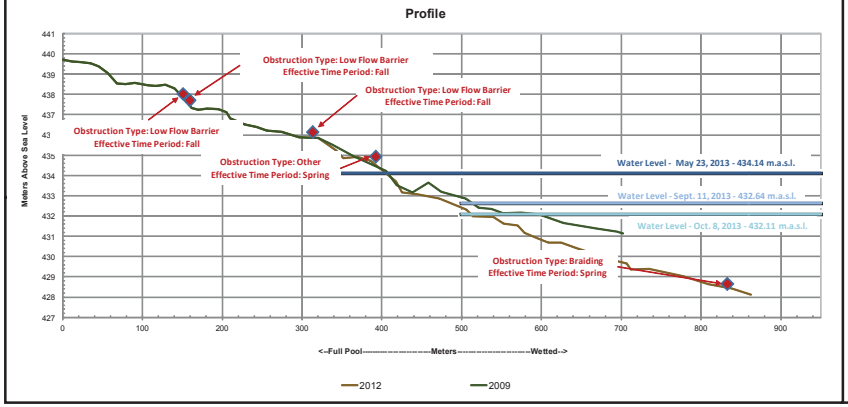
Meters

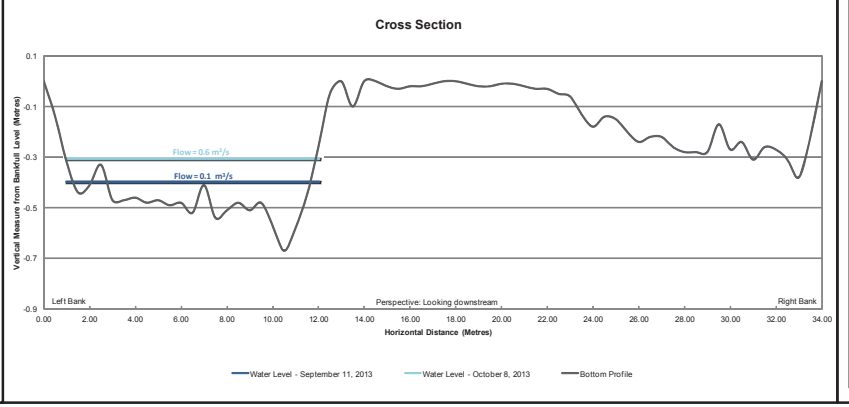
1 : 2 , 2 5 0

BC hydro

ECOSCAPE Environmental Consultants Ltd.







Johnston Creek

Year 6 (2013) Fish Migration Passage Monitoring Reference: CLBMON– 32A

Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program

Location:	Arrow Lakes
Project No.:	08-249
Prepared for:	BC Hydro and Power Authority
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	July, 2014
Survey Date:	May 23, September 11, October 7, 2013

Legend

- Fish Habitat
- Obstruction
- Erosion
- Reservoir Elevation Level
- Hydrometric Location (2010) / Cross Section Location
- Temperature Logger
- Stream Limits (September, 2013)
- 2 Metre Contours
- 2012 Profile Alignment

Johnston Creek supports kokanee and rainbow trout spawning. Previous assessments did not identify impediments to fish migration in the drawdown zone. Adfluvial access extends about 360 m upstream of the reservoir where there is a 2.5 m waterfall (Bayes and Olmstead, 1997; Gebhart, 1999). The drawdown zone has good gradients and hydraulic structures with pockets of spawning gravel and the riparian zone exhibits some rearing and spawning potential (Bayes and Olmstead, 1997).

Johnston Creek was assessed as passable during 2009 passage monitoring for rainbow trout and kokanee, supported by adequate spring and late summer stream flows. On September 11, 2009 it was estimated that between 500 -1000 kokanee were staging at the confluence and about 50 kokanee were counted over a 30m length of stream above the drawdown zone.

2013 Observations:

May 23, 2013 – There were no passage concerns identified during high stream discharges.

September 11, 2012 – There were no passage concerns observed. Kokanee were observed spawning in upper limits of drawdown zone in gravel pockets among boulders.

October 7, 2013 - There were no passage concerns observed at current stream flows and reservoir level.

40 20 0 40 80

Meters

1 : 1 , 0 0 0


Photo: P1110928 - Photo taken looking downstream over the drawdown zone (May 23, 2013).


Photo: P1110930 - Photo taken looking upstream over the drawdown zone (May 23, 2013).

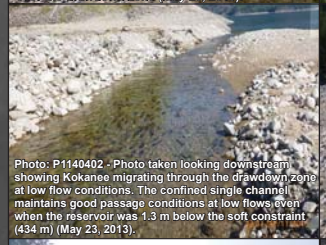


Photo: P1140402 - Photo taken looking downstream showing Kokanee migrating through the drawdown zone at low flow conditions. The confined single channel maintains good passage conditions at low flows even when the reservoir was 1.3 m below the soft constraint (434 m) (May 23, 2013).

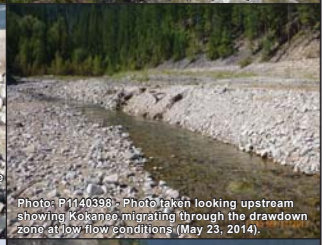
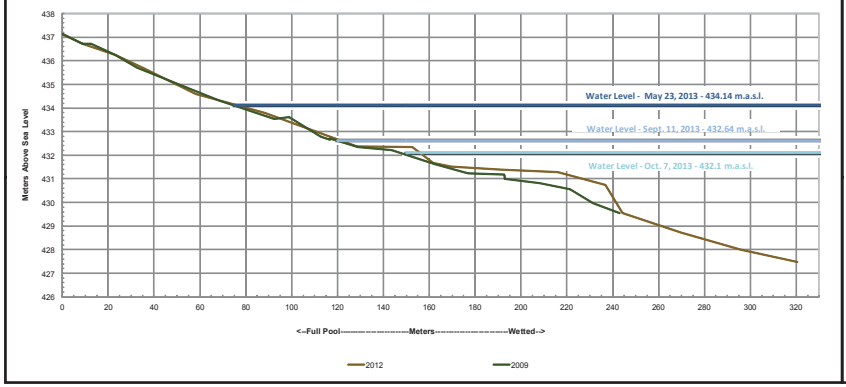
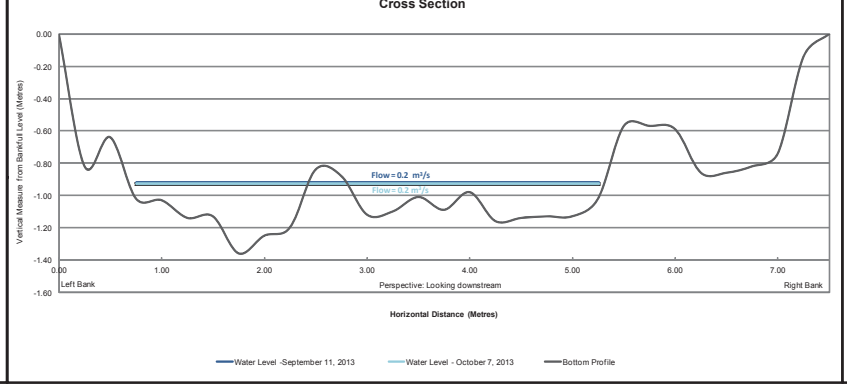


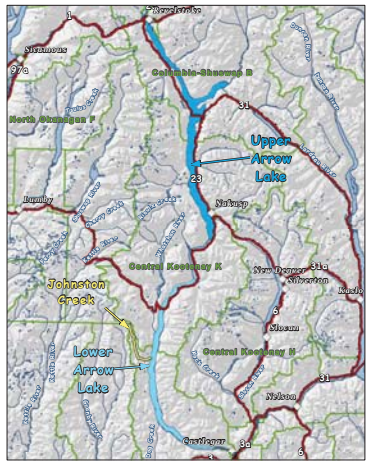
Photo: P1140398 - Photo taken looking upstream showing Kokanee migrating through the drawdown zone at low flow conditions (May 23, 2014).


Photo: DSCN0210 - Photo taken looking upstream (October 7, 2013).


Photo: DSCN0207 - Photo taken looking downstream (October 7, 2013).





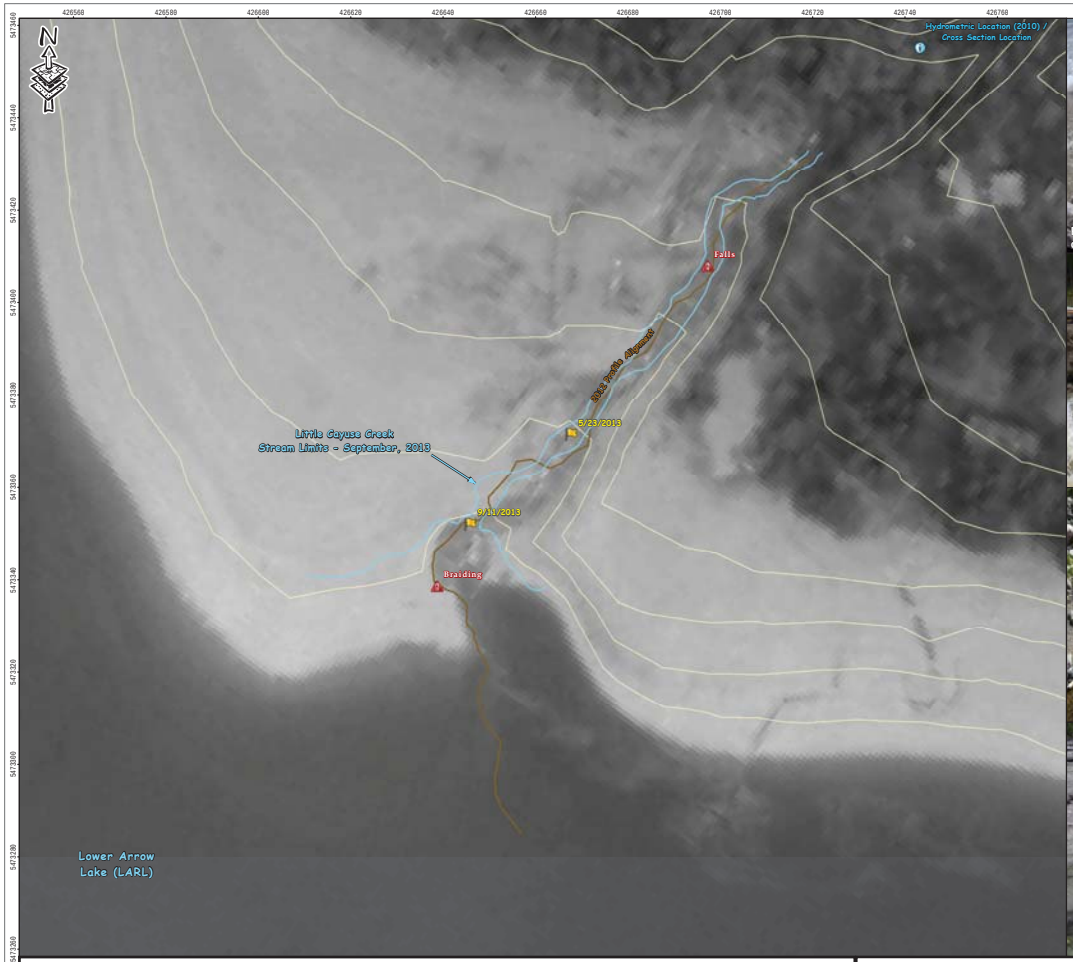


Little Cayuse Creek

Year 6 (2013) Fish Migration Passage Monitoring Reference: CLBMON– 32A

Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program

Location:	Arrow Lakes
Project No.:	08-249
Prepared for:	BC Hydro and Power Authority
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	July, 2014
Survey Date:	May 23, September 11, October 8, 2013



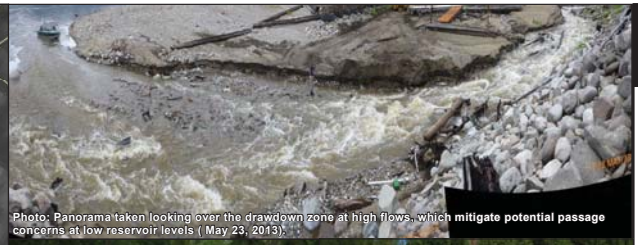


Photo: Panorama taken looking over the drawdown zone at high flows, which mitigate potential passage concerns at low reservoir levels (May 23, 2013).


Photo: P1110856 - Photo taken looking upstream (May 23, 2013).


Photo: P1140460 - Photo taken looking upstream from the reservoir level (September 11, 2013).


Photo: P1140472 - Photo taken looking downstream (September 11, 2013).


Photo: P1140461 - Photo taken looking downstream at the lake confluence (September 11, 2013).


Photo: DSCN0293 - Photo taken looking upstream (October 8, 2013).


Photo: DSCN0296 - Photo taken looking downstream (October 8, 2013).

Legend

- Fish Habitat
- Obstruction
- Erosion
- Reservoir Elevation Level
- Hydrometric Location (2010) / Cross Section Location
- Temperature Logger
- Stream Limits (September, 2013)
- 2 Metre Contours
- 2012 Profile Alignment

In 1992 it was noted that there were no access problems in relation to reservoir elevation (BC Hydro 1992). A 1996 assessment concluded that the overall fisheries value of Little Cayuse Creek was high, with more than 1600 kokanee documented up to 400m upstream of the reservoir and over 1000 in 1995 (Bayes and Olmstead, 1997). Rainbow trout and long nose dace were also documented (Bayes & Olmstead 1997). The only obstruction noted in the 1996 assessment was a 4 m high fall that occurs approximately 400 m upstream of the reservoir (Bayes & Olmstead 1997).

In 2009, spring flows likely accommodated upstream rainbow trout migrations with little concern. However, low stream flow conditions during fall kokanee migrations were identified as a potential barrier. During the September 11, 2009 assessment only five (5) kokanee were observed holding (almost stranded) in small residual pools at the upper limits of the drawdown zone. This year's observations on Little Cayuse suggest that upstream migration barriers are more a function of low stream flows rather than reservoir elevations.

2013 Observations:

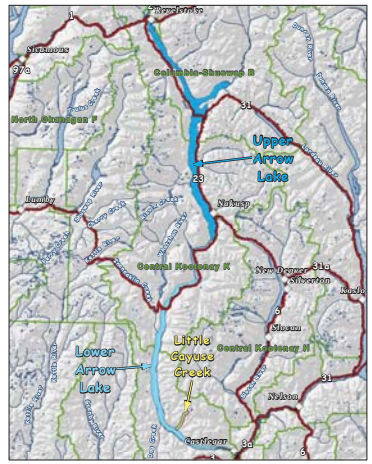
May 23, 2013 – There were no passage concerns observed during the May inspection; with high relative discharges providing adequately deep water to support fish migration and to provide instream cover.

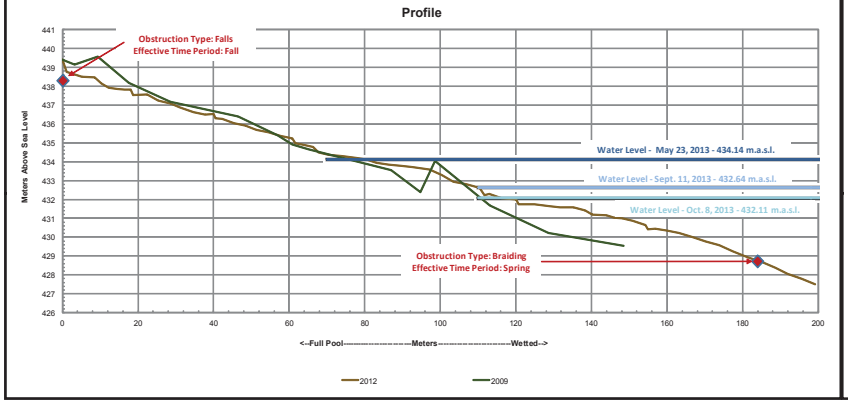
September 11, 2013 – Passage conditions were marginal just above the reservoir wetted level (432.6 m) but improved upstream above the approximate 434 m soft constraint elevation. Kokanee were still able to migrate upstream with fish recorded above the drawdown zone.

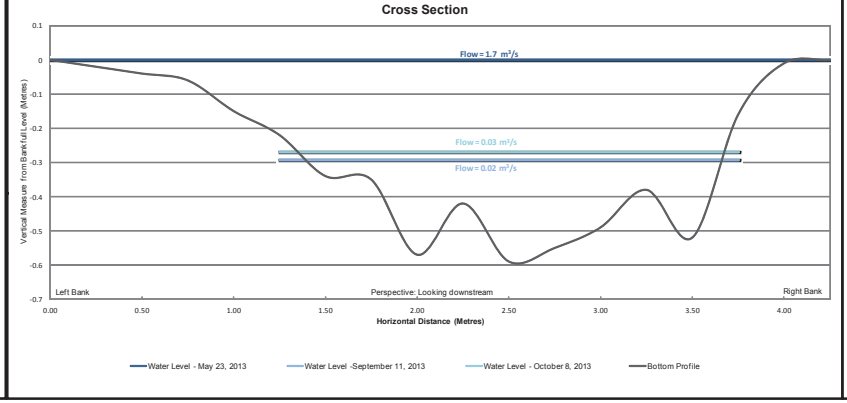
10 5 0 10 20 30 40 50
Meters
1 : 5 0 0

BC hydro

ECOSCAPE Environmental Consultants Ltd.







Mackenzie Creek

Year 6 (2013) Fish Migration Passage Monitoring Reference: CLBMON– 32A

Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program

Location:	Arrow Lakes
Project No.:	08-249
Prepared for:	BC Hydro and Power Authority
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	July, 2014
Survey Date:	May 22, September 10, October 9, 2013

Legend

- Fish Habitat
- Obstruction
- Reservoir Elevation Level
- Hydrometric Location (2010) / Cross Section Location
- Temperature Logger
- Stream Limits (May, 2013)
- Stream Limits (September, 2013)
- 2 Metre Contours
- 2012 Profile Alignment

Mackenzie Creek is known to support rainbow trout, kokanee, and bull trout spawning (Decker et al, 2005; Lindsay, 1976). Earlier reports indicate that passage through the drawdown zone is not an issue (BC Hydro, 2002; den Biesen and Ord, 2002; Sebastian et al, 2000; Andrusak and Slaney, 2004), but upstream barriers to all fish species likely occur approximately 4 km upstream (Lindsay, 1976; Sebastian et al, 2002).

During the 2009 surveys (spring and fall) there were no impediments to upstream migration through the drawdown zone identified. Bull trout fry, kokanee, and rainbow were all sampled / observed within the drawdown zone in 2009. Moderate to high stream flows observed in the spring 2009 would support rainbow passage regardless of reservoir elevations. Large woody debris embedded throughout the channel likely influences channel definition and scour, providing instream cover and resting habitat for fish.

2013 Observations:

May 22, 2013 – There were no passage concerns observed at the observed streamflows and reservoir levels.

September 10, 2013 – There were no Kokanee passage concerns identified. The well-defined channel provides good passage conditions for fish even at low flows.

October 9, 2013 - There were no fall passage concerns identified. The well-defined channel provides good passage conditions for fish at low flows.

20 10 0 20 40 60 80

Meters

1 : 7 5 0

Photo: P1110773 - Photo taken looking upstream from the reservoir level (May 22, 2013).

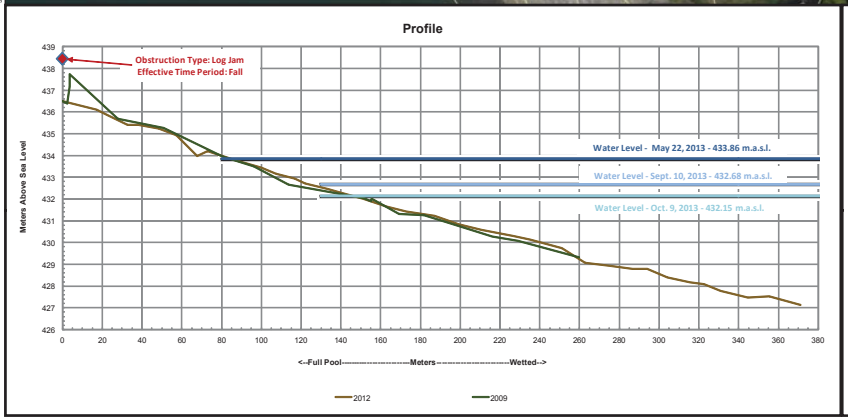
Photo: P1110774 - Photo taken looking downstream (May 22, 2013).

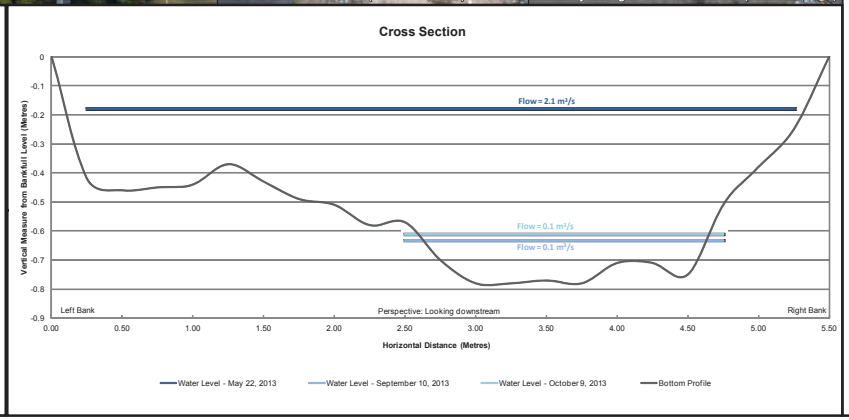
Photo: P1130895 - Photo taken looking upstream from the reservoir level (September 10, 2013).

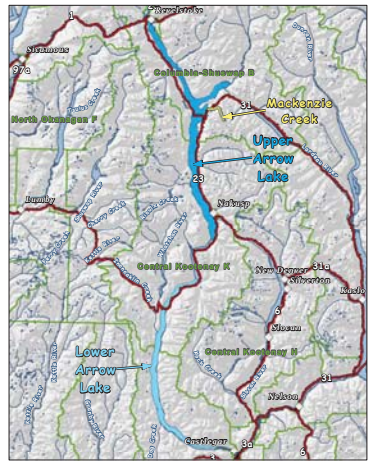
Photo: P1130939 -Photo taken looking downstream. Although split in the lower drawdown zone, the generally confined channel maintains passable conditions at low flows when the reservoir was about 1.3 m below the soft constraint (September 10, 2013).

Photo: DSCN0499 - Photo taken looking upstream from the reservoir level (October 9, 2013).

Photo: DSCN0501 - Photo taken looking upstream mid-way through the drawdown zone (October 9, 2013).







Nacillewaet Creek

Year 6 (2013) Fish Migration Passage Monitoring Reference: CLBMON– 32A

Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program

Location:	Arrow Lakes
Project No.:	08-249
Prepared for:	BC Hydro and Power Authority
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	July, 2014
Survey Date:	May 22, September 10, October 9, 2013

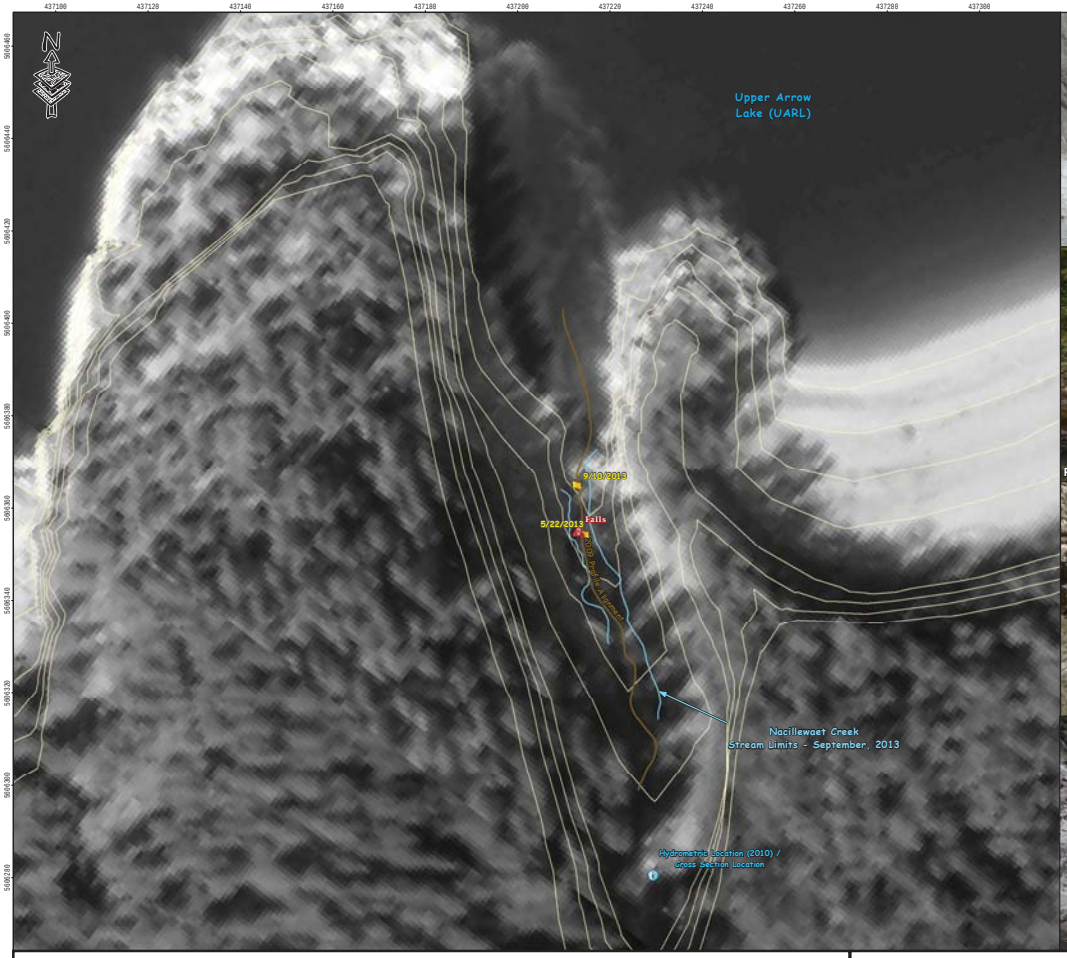



Photo: P1110789 - Photo taken showing drawdown zone from reservoir level (May 22, 2013).


Photo: P1110793 - Photo taken looking downstream from full pool reservoir level (May 22, 2013).


Photo: 314 - Photo taken showing potential passage impediments to Kokanee (September 10, 2013).


Photo: 308 - Photo taken looking downstream over the drawdown zone (September 10, 2013).


Photo: DSCN0559 - Photo taken looking upstream from the reservoir level (October 9, 2013).


Photo: DSCN0565 - Photo taken looking upstream (October 9, 2013).

Legend

- Fish Habitat
- Obstruction
- Erosion
- Reservoir Elevation Level
- Hydrometric Location (2010) / Cross Section Location
- Temperature Logger
- 2 Metre Contours
- 2009 Profile Alignment
- Stream Limits (September, 2013)

Nacillewaet Creek has been described as having good bull trout habitat characteristics (den Biesen and Ord, 2002). Access issues have been identified within the drawdown zone, particularly during low flows, and they are attributed to high quantities of large woody debris and high gradients (den Biesen and Ord, 2002; Gebhart, 1999; RL & L Environmental Services, 1997). A large set of 3 m falls are located approximately 140 m upstream of the reservoir and form complete barrier to fish migration and this, along with steep gradients, large substrate and cascade chute complexes, may reduce use of the stream by resident lake populations (RL & L Environmental Services, 1997).

The 2009 observations were consistent with previous assessments in regards to potential drawdown zone barriers. Rainbow trout and kokanee access above the drawdown zone is likely restricted by persistent woody debris falls and low flows. Above the full pool reservoir level, the stream gradient increases to 20%, which would inhibit rainbow trout and kokanee migration further upstream. However, the step-pool morphology may be suitable for bull trout production. Gravel substrates occur in the drawdown zone, stabilized by embedded large woody debris and bedrock outcrops, which may be suitable for spawning. Juvenile rainbow trout were captured (May 2009) upstream of the reservoir within the drawdown zone. However, no kokanee were observed staging or migrating in early September.

2013 Observations:

May 22, 2013 - High stream flows improve passage conditions up the drawdown zone.

September 10, 2013 - Resorted LWD and boulders reduced fall passage conditions from those observed in previous years. Plunge heights over the LWD and boulders were increased with reduced pool depths observed at the bases of these features.

October 9, 2013 – Impassable due to resorted LWD, excessive waterfall heights with inadequate plunge pool depths.

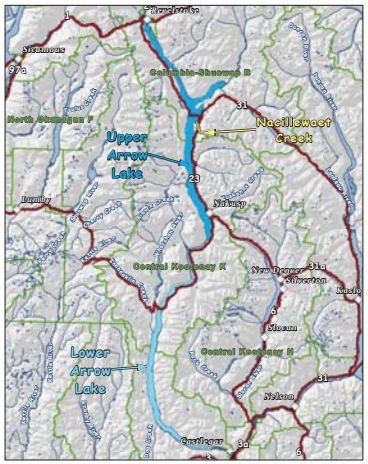
10 5 0 10 20 30 40 50

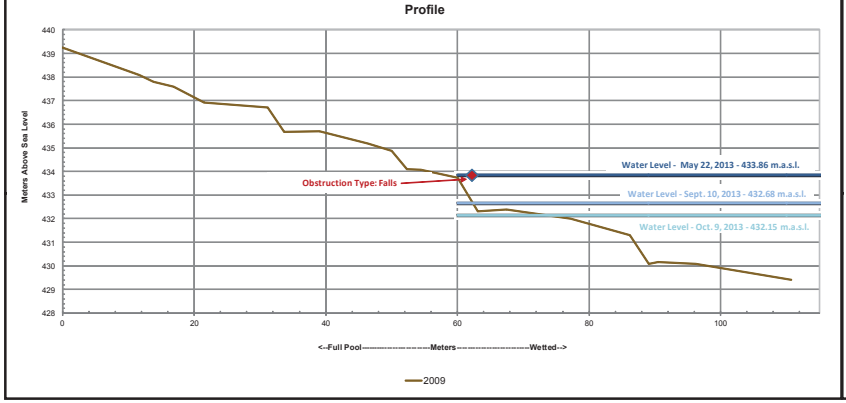
Meters

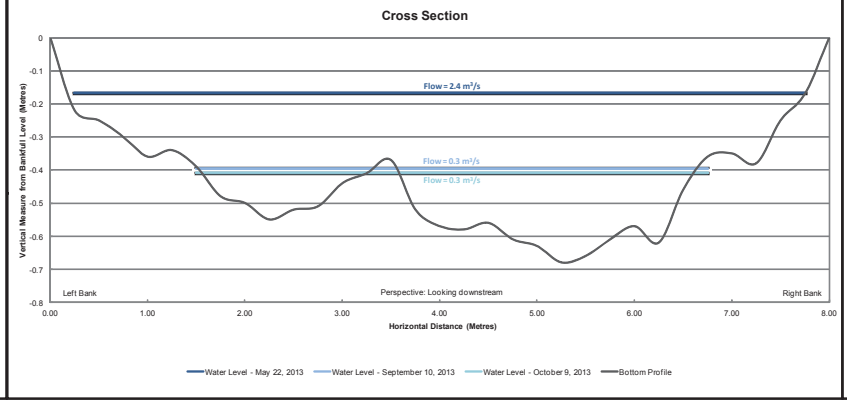
1 : 5 0 0

BC hydro

ECOSCAPE Environmental Consultants Ltd.







Octopus Creek

Year 6 (2013) Fish Migration Passage Monitoring Reference: CLBMON– 32A

Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program

Location:	Arrow Lakes
Project No.:	08-249
Prepared for:	BC Hydro and Power Authority
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	July, 2014
Survey Date:	May 23, September 11, October 8, 2013

Legend

- Fish Habitat
- Obstruction
- Temperature Logger
- Hydrometric Location (2010) / Cross Section Location
- Reservoir Elevation Level
- Stream Limits (May, 2013)
- Stream Limits (September, 2013)
- 2 Metre Contours
- 2012 Profile Alignment

Rainbow trout and kokanee utilize Octopus Creek from the reservoir upstream about 0.5 km to a waterfall (Andrusak and Slaney, 1994; Sebastian et al, 2000). Previous assessments identified no obstructions in the drawdown zone (Gebhart, 1999; Canadian Columbia River Inner-Tribal Fisheries Commission, 2006; BC Hydro, 1992).

During the 2009 spring surveys, braiding over the lower fan (~432.3 m.a.s.l.) of the drawdown zone was recorded as a potential barrier at low to moderate stream stages. However, with increasing flows leading into freshet and subsequent rainbow trout migration periods, improved channel definition resulted over the lower drawdown zone fan and rainbow trout access was not impeded. This was supported by the capture of an affluvial adult rainbow about 20 m upstream of the bridge during the spring survey period. There were no impediments to kokanee access in 2009. The reservoir levels were above the lower fan braiding and stream flows were sufficient for migration and spawning.

2013 Observations:

May 23, 2013 – High channel mobility persisted after the 2012 debris flow as the fan continues to resort. Channel restoration carried out over the fan in 2012 had unravelled. Fish passage was considered marginal due to very high TSS at current flows.

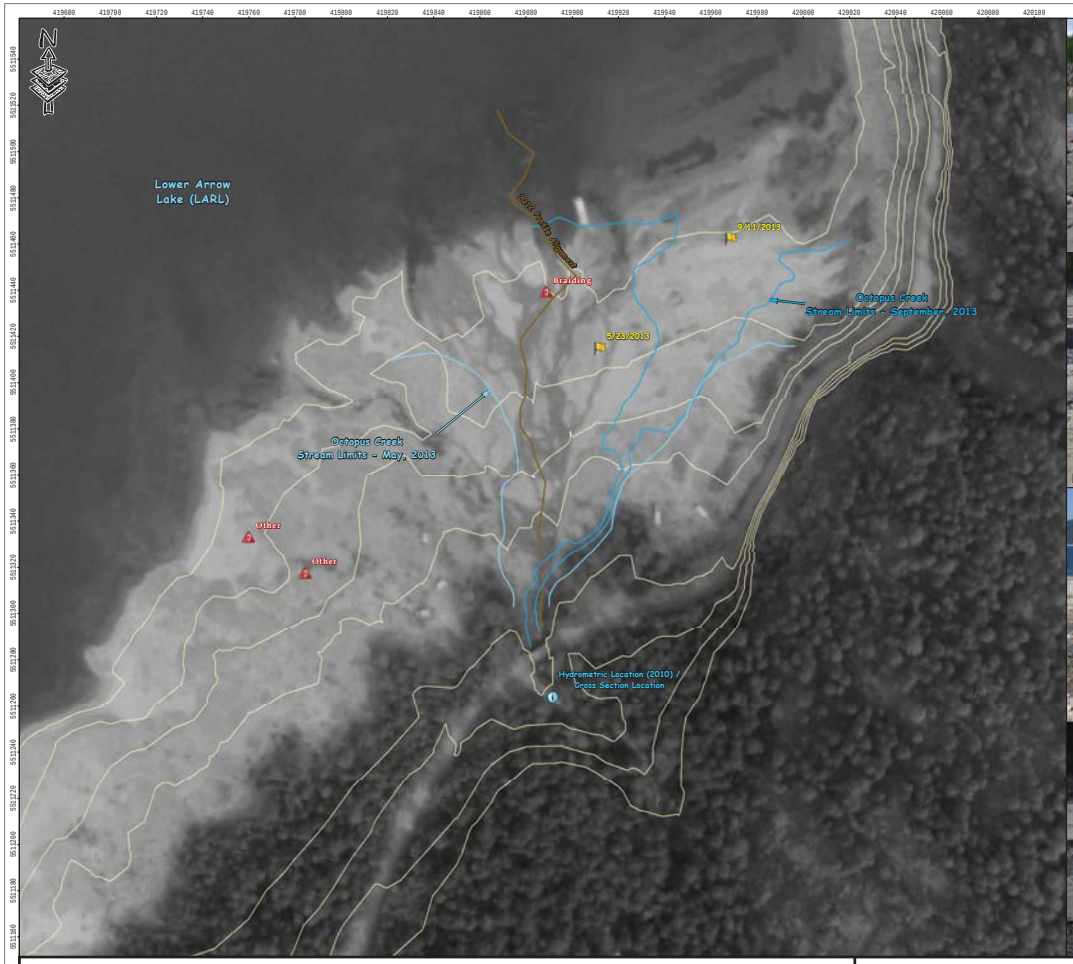
September 11, 2013 – Marginal passage conditions just above the reservoir wetted level (432.64 m) up to above 435 m, and improving further up the drawdown zone.

October 8, 2013 - Marginal passage conditions just above the reservoir wetted level (432.11 m) up to above 435 m, and improving further up the drawdown zone.

30 15 0 30 60 90

Meters

1 : 1,000



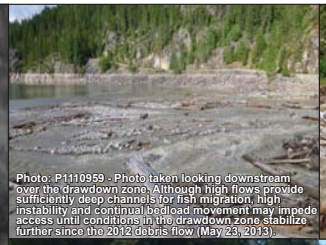


Photo: P1110959 - Photo taken looking downstream over the drawdown zone. Although high flows provide sufficiently deep channels for fish migration, high instability and continual bedload movement may impede access until conditions in the drawdown zone stabilize further since the 2012 debris flow (May 23, 2013).

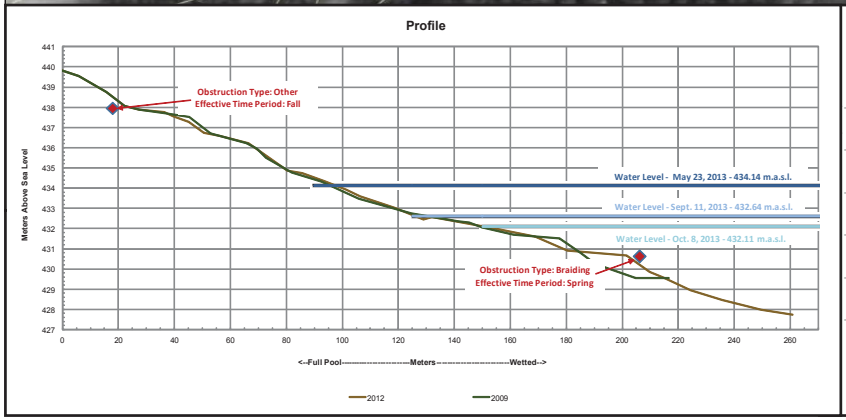

Photo: P1110971 - Photo taken looking upstream toward the new bridge (since 2012 debris flow) (May 23, 2013).

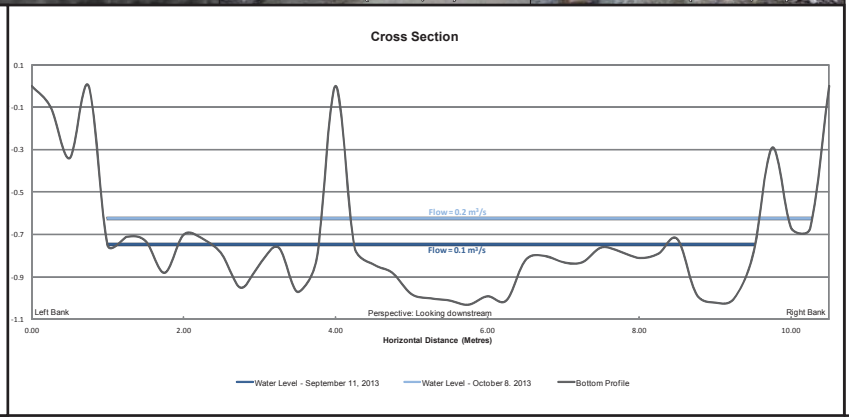

Photo: P1140320 - Photo taken looking upstream over the drawdown zone (September 11, 2013).

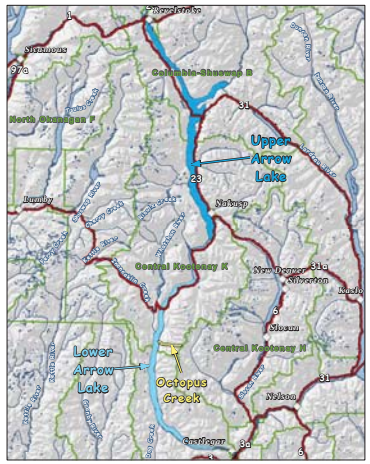

Photo: P1140365 - Photo taken looking downstream over the drawdown zone (September 11, 2013).


Photo: DSCN0333 - Photo taken looking upstream over the drawdown zone (October 8, 2013).


Photo: DSCN0338 - Photo taken looking upstream over the drawdown zone (October 8, 2013).







Payne Creek

Year 6 (2013) Fish Migration Passage Monitoring Reference: CLBMON– 32A

Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program

Location:	Arrow Lakes
Project No.:	08-249
Prepared for:	BC Hydro and Power Authority
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	July, 2014
Survey Date:	May 22, September 10, October 9, 2013


Photo: P1110825 - Photo taken looking upstream over the drawdown zone (May 22, 2013).


Photo: P1110828 - Photo taken looking upstream over the drawdown zone (May 22, 2013).


Photo: 373 - Photo taken looking upstream over the drawdown zone (September 10, 2013).


Photo: 374 - Photo taken looking downstream (September 10, 2013).


Photo: DSCN0523 - Photo taken looking upstream over the drawdown zone (October 9, 2013).


Photo: DSCN0528 - Photo taken looking downstream over the drawdown zone (October 9, 2013).

Legend

- Fish Habitat
- Obstruction
- Erosion
- Temperature Logger
- Hydrometric Location (2010) / Cross Section Location
- Reservoir Elevation Level
- Stream Limits (September, 2013)
- 2 Metre Contours
- 2012 Profile Alignment

Payne Creek is known to contain spawning habitat for kokanee and bull trout (RL & L Environmental Services, 1997). However, only about 60 m of Payne Creek are accessible upstream from the reservoir full pool level; where a 10 m high waterfall occurs. Access through the drawdown zone may be impeded by highly erodible substrates and persistent woody debris (den Biesen and Ord, 2002; Gebhart, 1999) although some assessors have suggested that access is not a problem (BC Hydro, 1992). Due to barriers just upstream of the reservoir, habitat values within the stream are considered to be low to moderate (den Biesen and Ord, 2002; RL & L Environmental Services, 1997).

During the 2009 survey period, the drawdown zone of Payne Creek was accessed as passable both in the spring (rainbow trout) and late summer to fall period (kokanee and bull trout). Although substrates are highly erodible, the channel was well defined and abundant instream woody debris helped to maintain resting pools and cover.

2013 Observations:

May 22, 2013 – There were no passage concerns at the observed relative moderate flows and reservoir wetted levels.

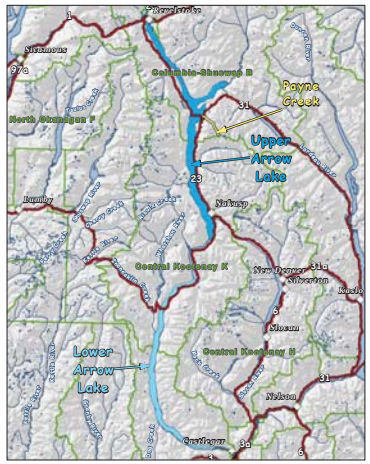
September 10, 2013 – The creek was passable and kokanee were observed upstream to the waterfall.

October 9, 2013 – No passage concerns at current flow and reservoir levels. Kokanee were still observed spawning into early October.

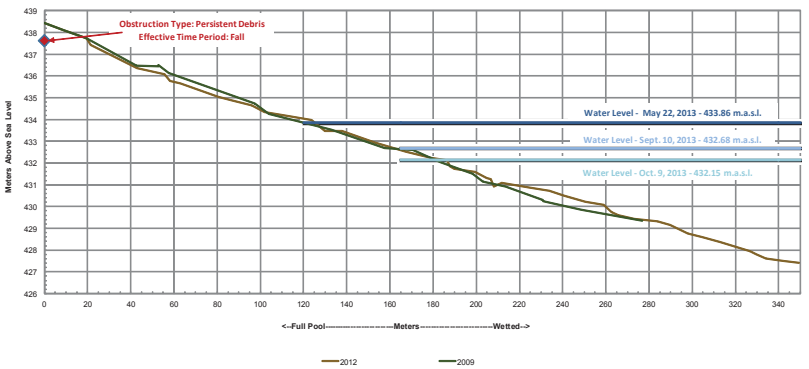
20 10 0 20 40 60 80
Meters
1 : 7 5 0

BC hydro

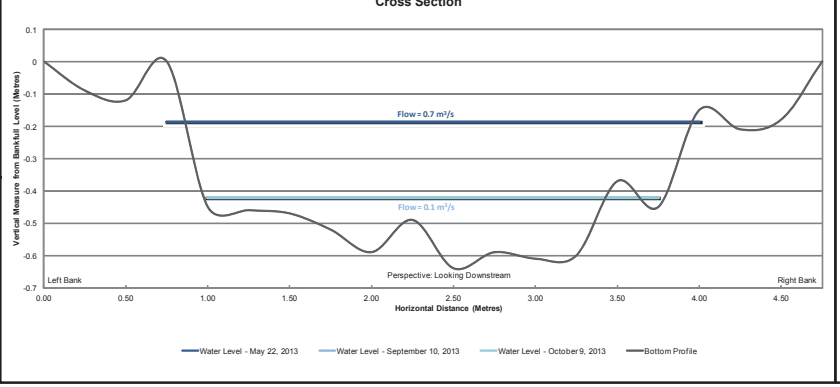
ECOSCAPE Environmental Consultants Ltd.



Profile



Cross Section



Renata Creek

Year 6 (2013) Fish Migration Passage Monitoring Reference: CLBMON– 32A

Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program

Location:	Arrow Lakes
Project No.:	08-249
Prepared for:	BC Hydro and Power Authority
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	July, 2014
Survey Date:	May 23, September 12, October 7, 2013


Photo: P1110907 - Photo taken looking upstream (March 30, 2012).


Photo: P1110908 - Photo taken looking downstream (March 30, 2012).


Photo: P1140626 - Photo taken looking upstream showing dry streambed over the drawdown zone (September 12, 2013).


Photo: P1140654 - Photo taken looking upstream showing intermittently wetted streambed of the mid drawdown zone. (September 12, 2013).


Photo: P1140665 - Photo taken looking upstream showing very low stream flows upstream of the drawdown zone (September 12, 2013).


Photo: DSCN0261 - Photo taken looking upstream at the reservoir full pool elevation (October 7, 2013).


Photo: DSCN0237 - Photo taken looking upstream showing a wetted streambed extending through the drawdown zone to Arrow Reservoir (October 7, 2013).

Legend

- Fish Habitat
- Obstruction
- Erosion
- Temperature Logger
- Hydrometric Location (2010) / Cross Section Location
- Reservoir Elevation Level
- Stream Limits (September, 2013)
- 2 Metre Contours
- 2012 Profile Alignment

Bayes and Olmstead (1997) report the overall fisheries value of Renata Creek as medium, with diverse habitat and areas of good spawning potential in the drawdown zone, as well as excellent salmonid spawning and rearing potential. Previous assessments (Gebhart 1999) found no obstructions in the drawdown zone. The flows of Renata Creek appear to be highly variable (RL & L Environmental Services Ltd 1997), while other studies indicate no flows/no access at the time of assessment (BC Hydro 1992).

Spring rainbow trout access was not impeded by the observed flows during the 2009 survey. The greatest potential for low flow barriers likely occur when the reservoir levels are below an elevation of 431m above mean sea level; where extensive channel braiding was documented. On September 11, 2009 no surface flows were present over the aggraded drawdown zone between the wetted level of the reservoir extending upstream to nearly full pool level. At about the reservoir full pool level, discontinuous surface flows were documented. Thus, kokanee access and spawning in Renata Creek was restricted in 2009.

2013 Observations:

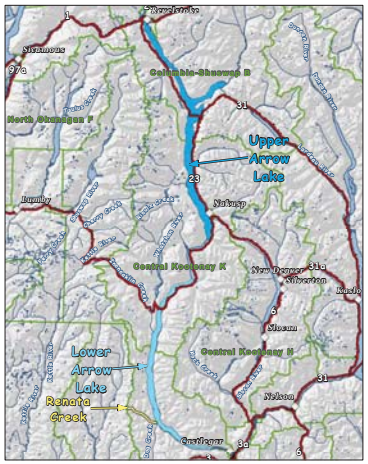
May 23, 2013 – There were no passage concerns at high flows.

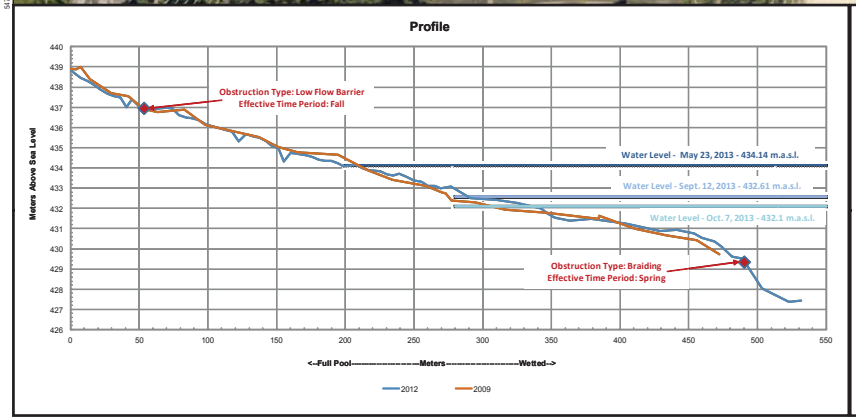
September 12, 2013 – Fall kokanee passage was restricted by very low stream flows and dry creek bed over the lower drawdown zone.
October 7, 2013 – Increased stream flows maintaining wetted channel to reservoir level and passage conditions have improved from impassable to marginal.

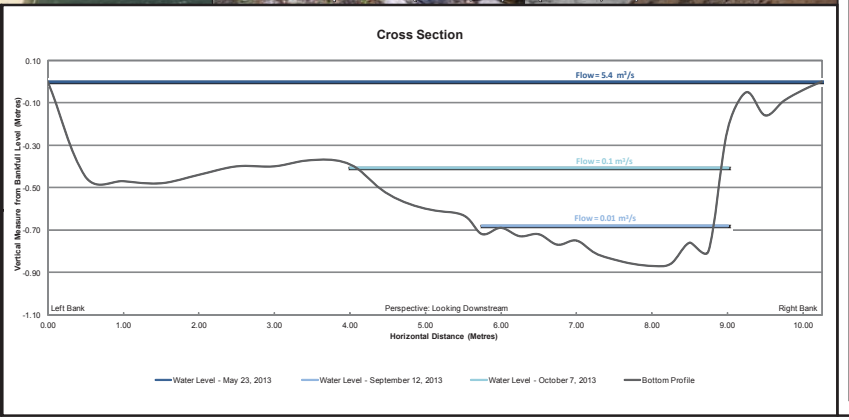
20 10 0 20 40 60 80 100
Meters
1 : 1 , 0 0 0

BC hydro

ECOSCAPE Environmental Consultants Ltd.







Taite Creek

Year 6 (2013) Fish Migration Passage Monitoring Reference: CLBMON– 32A

Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program

Location:	Arrow Lakes
Project No.:	08-249
Prepared for:	BC Hydro and Power Authority
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Robert Wagner
Checked by:	Kyle Hawes
Projection:	NAD83-UTM Zone 11
Date:	July, 2014
Survey Date:	May 23, September 11, October 8, 2013

Legend

- Fish Habitat
- Obstruction
- Erosion
- Temperature Logger
- Hydrometric Location (2010) / Cross Section Location
- Reservoir Elevation Level
- Stream Limits (May, 2013)
- Right Bank Stream Limit (September, 2013)
- 2012 Profile Alignment
- 2 Metre Contours


Photo: P1120026 - Photo taken looking upstream from the reservoir full pool level (May 23, 2013).


Photo: P1120036 - Photo taken looking downstream over the drawdown zone showing flows now following the left bank extents of the fan (May 23, 2013).


Photo: P1140261 - Photo taken looking downstream (September 11, 2013).


Photo: P1140303 - Photo taken looking upstream from the reservoir level (September 11, 2013).


Photo: DSCN0361 - Photo taken looking upstream from the reservoir level (October 8, 2013).


Photo: DSCN0366 - Photo taken looking upstream through the drawdown zone (October 8, 2013).

The drawdown zone of Taite Creek was assessed as passable in the spring 2009 for rainbow trout. Main stem channels were well defined and substrates were fouled with periphyton - indicating increased channel stability in the mid to upper levels of the drawdown zone. At low reservoir levels, access to Taite Creek may be restricted by channel braiding that was documented in the bottom 30 m of the drawdown zone. Good channel definition and stream flows supported kokanee migration and access in September 2009. Side channels that occur periodically along length of Taite Creek were documented providing high value spawning and rearing habitat for salmonids and may provide passage around log jams.

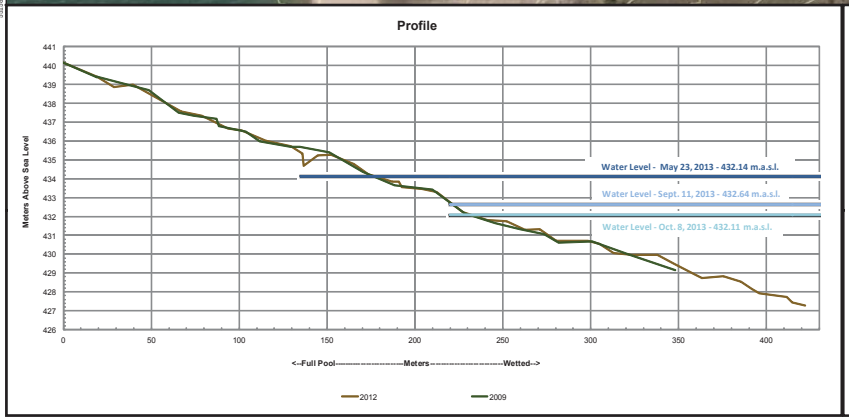
2013 Observations:

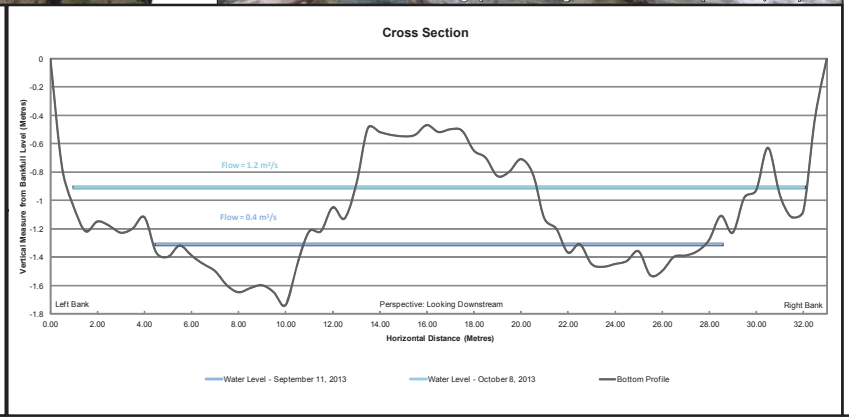
May 23, 2013 – There were no passage concerns observed. The raised riffle that formed in 2012, causing passage concerns for Kokanee, had unravelled during high flows resulting in improved channel conditions for fish passage.

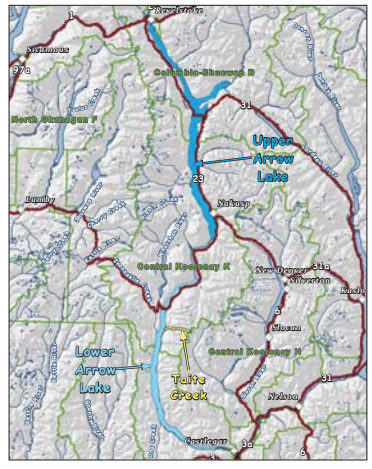
September 11, 2013 – There were no concerns with fish passage at current stream flows and reservoir elevation.

October 8, 2013 - There were no concerns with fish passage at current stream flows and reservoir elevation.

20 10 0 20 40 60 80 100 120
Meters
1 : 1,000







APPENDIX A
Tributary Summaries

Akolkolex River

The Akolkolex River has a natural barrier at the high water level of the reservoir (BC Hydro, 1992). Sebastian et al (2000) noted that there was potentially one km of habitat accessible for spawning by Bull Trout, Rainbow Trout, and Kokanee downstream of the falls. Kokanee have been observed using the stream up to the natural barrier within the drawdown zone for spawning (BC Hydro, 1992) and access for Kokanee may be reduced due to low water levels and braiding that has been documented at the stream mouth during extreme low water years (Anonymous 2002).

During the 2009 survey period low spring reservoir elevations revealed the suitable spawning substrates that exist in the upper 100 – 200 m of river below the waterfall. While suitable for salmonid spawning, these substrates were inundated by the reservoir before the end of May, with inundation preceding typical Rainbow Trout incubation and emergence periods. In addition, these substrates were not available to Kokanee in the fall 2009, as the reservoir level flooded these substrates extending to the waterfall.

2010 Observations:

April 22, 2010 - No fish sampling completed. At current reservoir levels, there is spawning suitability in the upper limits of the drawdown zone downstream of the falls for adfluvial rainbow; however, these substrates will likely soon be inundated.

May 24, 2010 - No fish sampling completed. All suitable spawning substrates in the drawdown zone are submerged at current reservoir elevations.

2011 Observations:

April 12, 2011- No passage due to falls. Potential for RB spawning in DDZ; none observed.

July 11, 2011- The drawdown zone is inundated. No passage due to falls.

2012 Observations:

The Akolkolex River was not surveyed in 2012.

2013 Observations:

The Akolkolex River was not surveyed in 2013.

Bannock Creek

Bannock Creek is a known Rainbow Trout, Bull Trout, and Kokanee spawning stream (RL & L Environmental Services, 1997; Andrusak and Slaney, 2004). The stream has been classified as a low value stream (den Biesen and Ord, 2002), possibly due to the high level of siltation noted and potential barriers that occur with a debris jam approximately 0.66 km upstream (RL & L Environmental Services, 1997). Aside from the potential barriers, spawning habitats within the stream may be limited by the depth of pools and siltation due to upstream forestry practices (den Biesen and Ord, 2002; RL & L Environmental Services, 1997). Spawning habitats for Kokanee and Bull Trout were rated as moderate to high for approximately 1 km upstream of the reservoir.

The 2009 survey identified the rock apron downstream of the culvert as a potential upstream migration barrier at both low reservoir levels and stream flows. However, spring flows were suitable for allowing passage over this structure. Kokanee access through the drawdown zone was not an issue in 2009, as the reservoir level was above the rock apron and baffles through the culvert enable passage above. However, no Kokanee were observed staging or migrating during September surveys, despite suitable stream temperatures.

2010 Observations:

April 27, 2010 - A log barrier marked in 2009 is just below wetted level of UARL. The rock apron is also passable at current flows and reservoir level. Cover includes pools associated with culvert baffles and large woody debris, which is collecting, but dynamic.

May 24, 2010 – There were no fish passage concerns at current stream flows and reservoir elevation.

September 9, 2010 - At the current reservoir levels, the reservoir is backwatered into the culvert. Levels have been higher, as large woody debris is washed into the culvert from the reservoir and is located near the culvert inlet. There is an accumulation of fines downstream of the culvert, eroding from the banks during high water levels. No Kokanee were observed although passage is not a problem at current reservoir elevation and stream flows.

2011 Observations:

April 13, 2011-There are no passage concerns at current flows and reservoir elevation. Substrates appear unchanged from previous years. HOBO temperature data logger launched along right bank upstream of culvert (#3198_Bannock).

July 12, 2011-There are no passage concerns at current stream flow and reservoir level. Stream flows moderate-higher in April. HOBO data logger inundated with reservoir level, and not located. RB and MW observed in culvert. UARL is backwatered upstream of road crossing by approximately 15-20 m.

September 9, 2011-There are no concerns with fish passage at current reservoir levels and stream flow; KO observed u/s of culvert. UARL backwatered in culvert approximately 8 m downstream of inlet. HOBO data logger was not located and a replacement was not installed in 2011.

2012 Observations:

April 3, 2012 – There were no passage concerns observed. Passage conditions appeared to have improved over previous years.

May 15, 2012 – There were no passage concerns at the existing flows and reservoir levels.

September 9, 2012 – There were no passage concerns at the existing flows and reservoir levels.

2013 Observations:

May 22, 2013 – There were no passage concerns observed.

September 9, 2013 – There were no passage concerns at the existing flows and reservoir levels in spite of levels being about 1-m below the 434 m soft constraint.

October 9, 2013 – There were no passage concerns at the existing flows and reservoir levels.

Blanket Creek

Blanket Creek is not considered to have significant access issues. A set of falls occur 1.5 km upstream from the reservoir high water level. However, spawning habitat for Kokanee and Bull Trout was only estimated at 1 km of habitat (Sebastian et al, 2000).

During the 2009 survey period, no passage concerns were noted during both spring and fall migration periods – primarily attributed to adequate stream flows - maintaining sufficient residual pool depth and passage over lower braided sections within the drawdown zone.

2010 Observations:

April 23, 2010 - No fish sampling. Fish passage is not an issue at current flows and reservoir elevation. A black cottonwood has fallen across the channel upstream of the cross-section location; a large scour pool has resulted and there is potential to alter downstream morphology.

May 25, 2010 - There are no fish passage concerns at current flows and reservoir level.

September 9, 2010 - Spawning Kokanee and redds observed throughout drawdown zone, including just upstream of the UARL wetted level. Pockets of spawning among cobbles and boulders in gravel and laterally along channel in small 1/2-1" gravels. No passage concerns were noted over the drawdown zone of the main stem; however, low flows were observed along the left channel and some Kokanee that have passed through are unable to ascend up to main stem. Kokanee were observed to have spawned in mixed sand/gravel towards the upstream end of the left channel.

2011 Observations:

April 12, 2011-There are no fish passage concerns at current flows and reservoir level. Launched HOBO temperature data logger (Tag #055, serial #9893911). Snow along both banks prevented completion of bankfull cross-section. Along the left bank, increased erosion occurs towards reservoir wetted level along the drawdown zone.

July 11, 2011-There are no passage concerns at current stream flows and reservoir elevation. The wetted width and velocities were highest observed during monitoring program, and it appeared that the stream had been flowing approximately 0.2 m higher. The side channel along the right bank was wetted at the cross-section location. A black cottonwood has fallen along the right bank within the DDZ downstream of the deep pool. The stream was too swift to complete cross-section or sampling.

September 9, 2011-There is no concern with fish passage; DDZ is inundated and stream flow is moderate. UARL level ~437 m asl. Data retrieved from HOBO logger; logger came off tag/rock- tag replaced with Tag #010 and logger secured with rebar. Debris jam downstream of cross-section appears smaller. Well-defined, deep channel throughout DDZ-no recommendations for enhancement.

2012 Observations:

April 4, 2012 – During low flow and low reservoir levels the mainstem channel was assessed as passable. However, the right bank channel passage condition was assessed as marginal. The right bank secondary channel and associated shallow braided channels showed some passage concerns.

May 16, 2012 – No passage concerns with moderate to high flows.

September 8, 2012 – Passage concerns were not observed at the UARL wetted level. Sculpin and salmonid stranding was observed in an isolated pool where a barrier beach had formed as a result of very high stream flows occurring simultaneously with high reservoir levels. The right bank channel was nearly dry due to creek flows being diverted to the left channel as a result of beach deposition. There appeared to be greater flows through the left bank side channel with the possibility of a future avulsion as the debris jam, situated at the left channel inlet, is deteriorating. No Kokanee or redds were observed until upstream of the drawdown

zone - in spite of the extensive gravel recruitment and deposition documented in the drawdown zone.

2013 Observations:

May 28, 2012 – There were no passage concerns at the existing flows and reservoir levels.

September 9, 2013 – There were no passage concerns at the existing flows and reservoir levels. Sustained higher flows from high elevation snow packs and glacial meltwater maintain good passage conditions at all reservoir levels.

October 9, 2013 – There were no passage concerns at the existing flows and reservoir levels.

Burton Creek

The limiting factors for Kokanee and Bull Trout production include: limited overhead cover, limited low velocity habitat (pools) for adult staging, and limited suitable substrate for salmonid spawning during fall low flow periods (RL and L Environmental Services Ltd, 1997).

No obstructions were noted in the drawdown zone during the 2009 survey period. While the fan downstream of the Highway 6 Bridge is wide and heavily braided at low reservoir levels, the spring creek flows maintained good channelization and depth and no access problems were noted. During Kokanee staging and migration periods, the reservoir levels reached upstream of the bridge and, combined with adequate stream flows, Kokanee access through the drawdown zone was not impeded. While overall the lack of instream cover/structure relative to the magnitude of the drawdown zone/fan was of concern, the deep pool beneath the Highway 6 Bridge provides significant cover for staging fish.

2010 Observations:

April 22, 2010 - No fish sampling. Moderate flows during site visit with no passage concerns at current flows and reservoir level. Good large woody debris and channel complexity at cross section location.

May 23, 2010 - Reservoir wetted to upstream of bridge; side channel temperature along highway is 8.8°C, and there are no passage concerns at current flows and reservoir elevation. Electrofishing efforts upstream of drawdown zone at cross-section location in key habitat areas among LWD jams, deep pools, and in high quality side channels; large fish (RB/MW) observed in deep pools that were too deep to shock.

September 11, 2010 - Reservoir backwatered upstream of bridge crossing; no apparent concerns with passage at current reservoir levels and flows. The HOBO data logger, ECO_3, TAG 097 was launched at 15:20.

2011 Observations:

April 14, 2011-No concerns with fish passage at current flows (low to moderate); downstream of the bridge, two main channels have good flow volumes and depths for fish passage with combined flows from Caribou and Burton Creeks. HOBO data logger installed in Sept 2010 was lost over winter-tag still in place, but logger gone. New data logger installed along the right bank. Large cottonwood along the right bank at cross-section has had further beaver damage; could alter channel when falls. Instream cover includes LWD and associated scour, as well as deep water cover downstream of the highway bridge.

July 8, 2011-There are no passage concerns with high stream flows and high reservoir levels. The reservoir level extends nearly to the Caribou Creek cross-section location. Burton Creek is too swift to cross or sample.

September 13, 2011-There are no concerns with fish passage at current stream flows and reservoir level; the DDZ is inundated. Flows are low, but appear to be seasonally higher than in previous years. The HOBO data logger was located and data retrieved.

2012 Observations:

April 2, 2012 – The creek was passable within a well-defined channel.

May 12, 2012 – Passage concerns were not observed at the moderate to high flows.

September 10, 2012 – Large sediment deposition and beach formations were observed as a result of very high stream flows occurring simultaneously as full pool reservoir levels. Flood-stage flows resulted in substantial gravel recruitment from upstream sources, which was deposited just above and below the full pool reservoir levels. KO were observed spawning within the upper level of the drawdown zone. Beach substrates and sand/gravel bars had formed up to 2 m in depth over coarser streambed substrates. Expectations are that severe resorting will occur during the 2013 spring freshet. Both the right and left banks at the cross-section location had eroded and the channel widened. A new cross-section location was established approximately 50 m upstream of the previous cross section location. High Kokanee spawning use was observed throughout observed reaches from the reservoir level up to the cross section.

2013 Observations:

May 21, 2013 – There were no passage concerns at the existing flows and reservoir levels.

September 10, 2013 - There were no passage concerns at the existing flows and reservoir levels. Sustained higher flows from high elevation snow packs maintain good passage

conditions. However, low instream cover over the drawdown zone may expose Kokanee to increased predation.

October 8, 2013 - There were no passage concerns at the existing flows and reservoir levels.

Burton Creek and Caribou Creek Confluence

The limiting factors for Kokanee and Bull Trout production include: limited overhead cover, limited low velocity habitat (pools) for adult staging, and limited suitable substrate for salmonid spawning during fall low flow periods (RL and L Environmental Services Ltd, 1997).

No obstructions were noted in the drawdown zone during the 2009 survey period. While the fan downstream of the Highway 6 Bridge is wide and heavily braided at low reservoir levels, the spring creek flows maintained good channelization and depth and no access problems were noted. During Kokanee staging and migration periods, the reservoir levels reached upstream of the bridge and, combined with adequate stream flows, Kokanee access through the drawdown zone was not impeded. While overall the lack of instream cover/structure relative to the magnitude of the drawdown zone/fan was of concern, the deep pool beneath the Highway 6 Bridge provides significant cover for staging fish.

2010 Observations:

On September 10, 2009 more than 10,000 staging Kokanee were observed in this pool along with at least four (4) adult Bull Trout (observations made during snorkel surveys). There were no obstructions documented during the 2010 field monitoring, and both Caribou and Burton Creeks were passable at the reservoir elevations and stream flows observed during key migration periods for Kokanee, Rainbow Trout and Bull Trout.

2011 Observations:

April 14, 2011 - No concerns with fish passage at current flows (low to moderate); downstream of the bridge, two main channels have good flow volumes and depths for fish passage with combined flows from Caribou and Burton Creeks.

July 8, 2011 - The drawdown zone was inundated nearly to full pool during the site assessment and there were no concerns with fish passage.

September 13, 2011 - Contrary to previous years when large numbers of salmonids were observed staging in the deep pool upstream of the highway bridge, much of the drawdown zone remained inundated and this area was within the reservoir/lacustrine environment. There were no passage concerns and Kokanee were observed upstream of the Burton and Caribou cross-section locations.

2012 Observations:

April 2, 2012 – The channel was deemed passable but conditions were marginal. Braided channels were of sufficient depth but channel cover was very low. Shallow water was observed sheeting over the channel bottom in braided segments and substrate erosion was high in the lower reaches of the drawdown zone. While passage was possible throughout the mainstem channel and right bank secondary channel, turbidity from bank erosion was high, which may deter fish migration upstream. Flows became clearer as substrates transitioned upstream from fines to gravel.

May 15, 2012 – The confluence was passable at the observed flows.

September 2012 - The reservoir level extended upstream beneath the Highway 6 Bridge beyond the confluence of Burton and Caribou Creeks. There were no passage concerns noted.

2013 Observations:

May 21, 2013 – There were no passage concerns at the existing flows and reservoir levels.

September 10, 2013 - There were no passage concerns at the existing flows and reservoir levels in spite of the reservoir being about 1.3 m below the 434 m soft constraint. Sustained higher flows from high elevation snow packs maintain good passage conditions.

October 8, 2013 – There were no passage concerns at the existing flows and reservoir levels.

Caribou Creek

The limiting factors for Kokanee and Bull Trout production include: limited overhead cover, limited low velocity habitat (pools) for adult staging, and limited suitable substrate for salmonid spawning during fall low flow periods (RL and L Environmental Services Ltd, 1997).

No obstructions were noted in the drawdown zone during the 2009 survey period. While the fan downstream of the Highway 6 Bridge is wide and heavily braided at low reservoir levels, the spring creek flows maintained good channelization and depth and no access problems were noted. During Kokanee staging and migration periods, the reservoir levels reached upstream of the bridge and, combined with adequate stream flows, Kokanee access through the drawdown zone was not impeded. While overall the lack of instream cover/structure relative to the magnitude of the drawdown zone/fan was of concern, the deep pool beneath the Highway 6 Bridge provides significant cover for staging fish.

2010 Observations:

April 22, 2010 - No fish sampling completed. There are no passage concerns at current flows and reservoir elevation; Caribou is in early stages of freshet, just starting to cloud. A complete cross-section was not possible due to depth and swift water.

May 23, 2010 - No fish sampling completed. There are no passage concerns at current flows and reservoir elevation. Flows too high at cross-section location to measure.
September 11, 2010 - There are no passage concerns at current flows and reservoir elevation. Kokanee were observed spawning in small pockets of gravels at the cross-section location; substrates were noted to be coarser than at Burton cross section. The left bank of the cross-section is tied into stump at downstream side.

2011 Observations:

April 14, 2011-Upstream of the highway bridge there are no passage concerns at current flows (low to moderate); downstream of the bridge, two main channels have good flow volumes and depths for fish passage with combined flows from Caribou and Burton Creeks. HOBO temperature data logger (6972_Caribou) installed u/s of cross-section using t-post driven into stream bed with tag and logger attached using galvanized wire. Instream cover includes LWD and associated scour, as well as deep water cover downstream of the highway bridge.

July 8, 2011-There are no passage concerns with high stream flows and high reservoir levels. The reservoir level extends nearly to the Caribou Creek cross-section location. Stream flows are too swift to complete cross-section. Water chemistry data was collected upstream of the McCormick Rd bridge.

September 12, 2011-There are no concerns with fish passage at current stream flows and reservoir elevation; the DDZ is inundated. KO observed u/s of cross-section. YOY fish were observed in isolated wet areas along the right bank u/s of the highway crossing amongst reed canary grass. Stranding and desiccation may occur in these areas as the reservoir level recedes. The HOBO data logger was located downstream of the installation point and data was retrieved; the logger was reinstalled at the left bank cross-section stump.

2012 Observations:

April 2, 2012 – No passage concerns with a defined channel present upstream of the Highway 6 Bridge and adequate stream flows.

May 5, 2012 – Passage concerns were not observed at the moderate to high flows.

September 10, 2012 – The former mainstem channel had been plugged with sand/gravel deposited as a result of very high stream flows occurring simultaneously as full pool reservoir levels. Alluvial deposits at the reservoir high water level had caused flows to divert to the left bank channel. The former right mainstem that followed the right bank was plugged and dry. The flows present were sufficient for passage but the channel appeared unstable due to the re-sorting of substrates caused by the high rate of reservoir recession (i.e., 10 cm per day).

2013 Observations:

May 21, 2013 – There were no passage concerns at the existing flows and reservoir levels.

September 10, 2013 - There were no passage concerns at the existing flows and reservoir levels. Sustained higher flows from high elevation snow packs maintain good passage conditions. However, low instream cover over the drawdown zone may expose Kokanee to increased predation.

October 8, 2013 - There were no passage concerns at the existing flows and reservoir levels.

Cranberry Creek

In the spring of 2009, flows were too high to sample or observe Rainbow Trout. Nevertheless, with these flows, tributary access through the drawdown zone was not a concern. In lower section of the drawdown zone, rooted stumps and partially embedded large woody debris, are influencing scour and channelization through fine substrates, thereby maintaining a more defined and passable channel and at the same time providing cover and structure for fish. Recent management recommendations have resulted in establishment of a minimum flow for Cranberry Creek; where the diversion of flows has typically left 12 km of lower reaches dewatered (Andrusak and Slaney, 2004; Spence et al, 2005). Despite this, very low stream flows were observed on September 9, 2009, which were of concern for Kokanee access and migration. Only 52 Kokanee were counted upstream of the drawdown zone in a small residual pool within 100m of the reservoir high water level.

2010 Observations:

April 27, 2010 - No fish sampling completed. The left channel is the same as last year in terms of spatial extents; flows were notably higher in previous week as evidenced by recently de-watered channels over braided fan. Stream flow appears to be lower than 2009, although no fish passage concerns are noted along the mainstem channel. Lateral side channels of the braided fan are shallow and may impede passage during upstream Rainbow Trout migration. The majority of woody debris marked in 2009 surveys as cover and beneficial for passage is already inundated by reservoir. De-watering may strand fish in smaller side channels. Cover includes reservoir cover, root wads, and some boulders in drawdown zone; increasing boulder cover and pools upstream.

May 25, 2010 - No passage concerns at current flows and reservoir level; reservoir wetted up to point where creek is just two well defined channels, all braided portions of fan inundated by reservoir. Spawning longnose suckers were observed during electrofishing efforts.

September 10, 2010 - There are no passage concerns at current flows and reservoir elevation. Kokanee observed to be spawning in upper limits of drawdown zone. The HOBO data logger ECO 2_096 was deployed at 15:07 and is located downstream of the cross-section location on the downstream side of the 3m mid-channel boulder.

2011 Observations:

April 13, 2011-Left and right primary channels are passable at current flows; however, braiding in the centre of the fan presents passage concerns. The HOBO data logger deployed in 2010 was not retrieved and may have been buried in fines following increased slide activity along the right bank. A new data logger was relocated upstream of the slide at left bank of cross-section to reduce the risk of being buried if the slope experiences further erosion. LWD and stumps are maintaining scour and improving passage and providing instream cover within the DDZ over the fan.

July 12, 2011-There are no passage concerns when UARL is at or near full pool and creeks are at high stage. Flows are too high to conduct cross-section or locate data logger.

September 10, 2011-There are no concerns with fish passage at the current UARL level and stream flow; spawning KO observed upstream of UARL and drawdown zone braiding is inundated, resulting in one mainstem. The landslide/bank sloughing along the right bank and high reservoir level has resulted in increased deposition of fines throughout drawdown zone. The HOBO data logger deployed in April was not located; substrate movement at the sampler location was evident. Rebar and galvanized wire was used in deployment of another data logger along the left bank at cross-section location.

2012 Observations:

April 5, 2012 – The reservoir wetted level at the Cranberry Creek outlet was 427.5 m. Upstream passage in the lower reaches of the drawdown zone were assessed as marginal. While the wetted depths appeared to be sufficient for passage (in spite of braiding), the severe substrate erosion and high levels of Total Suspended Solids (TSS) may restrict migration of spawning fish such as rainbow. As the substrates transition to gravels upstream, the turbidity decreases and passage conditions are improved with support of large woody debris that is embedded in the channel.

May 16, 2012 – There were no passage concerns with high stream flows although channel braiding was extensive.

September 9, 2012 - Beach substrate accumulation from high summer flows and full pool reservoir levels had dramatically altered the character of the fan. The passage conditions were marginal to good for fall conditions, but KO were not observed upstream of the reservoir, possibly due to warm stream temperatures (11.4°C). Significant gravel recruitment from landslide activity had deposited along the creek channel during high reservoir levels. The gravel recruitment had improved spawning substrates for Kokanee. The creek dispersed into a shallow braided fan at the reservoir level created by substrate deposition/resorting and high TSS. Erosion and channel migration was observed along the left bank.

2013 Observations:

May 22, 2013 – There were no passage concerns with high stream flows.

September 10, 2013 – The mainstem channel had no passage concerns at the documented flows. However, braided secondary channel had passage concerns.

October 9, 2013 – The mainstem channel had no passage concerns at the documented flows. However, braided secondary channel had passage concerns.

Crawford Creek

Crawford Creek was not documented as having any access problems due to reservoir elevation. However, stream depth and braiding in the drawdown zone may impede fish access at low reservoir levels (Anonymous 2002).

During the spring 2009survey period, potential low flow barriers included two braided sections. Even at moderate flows, channel braiding and shallow depths may partially inhibit tributary access to Rainbow Trout. Substrates within the drawdown zone consist predominantly of fines, with coarser material being highly embedded. Thus, the drawdown zone is not suitable for spawning. In 2009, upstream access by Kokanee was confirmed by visual observations. It was noted that the channel forms over highly unstable braided sections provided access this year, which was likely supported by increased stream flows brought about by moderate to heavy rainfall over the days that preceded the survey. However, this channel instability may also function to restrict access depending on how the channel re-sorts and develops when the reservoir levels drop.

2010 Observations:

April 23, 2010 - There are no passage concerns at current flows and reservoir elevation. Drawdown zone cover includes root wads in channel and associated scour pools and gravels.

May 24, 2010 - There are no passage concerns at current flow and reservoir levels. Kokanee fry were observed rearing and schooling below the reservoir level where backwatering occurs over grasses and sedges. Some deep pools associated with root wads in the drawdown zone, although erosion and deposition of fines is occurring along the left bank within the drawdown zone.

September 9, 2010 - The main stem of Crawford Creek is passable at current flows and reservoir levels. Kokanee and redds observed in drawdown zone. A grizzly bear was feeding in the drawdown zone and fled as the boat approached.

2011 Observations:

April 13, 2011-No passage concerns at current flows. Creek is notably more confined and less braided, maintaining a deeper channel compared to previous 2 yrs. of sampling when braiding was more dramatic and passage more of a concern in spring before freshet. HOBO temperature data logger deployed downstream of cross-section. Crawford has a highly unstable fan and changes each year as reservoir levels rise and fall.

July 11, 2011-There are no passage concerns with seasonally high stream flows and high UARL elevation. The HOBO data logger was not located due to swift, turbid, turbulent water.

September 9, 2011-There were no passage concerns at current reservoir level and stream flows; KO observed u/s of cross-section. Braiding was noted above the UARL wetted level and the stream was flowing along the left bank extents. Unable to locate data logger- deposition of substrates beneath the log may have buried logger, or it may have been lost with freshet. HOBO logger was re-launched and moved downstream along right bank. Cross-section location relocated 2 m downstream of data logger.

2012 Observations:

April 4, 2012 – In downstream reaches the channel becomes deep cut with very high turbidity from erosion, which may restrict fish passage upstream from the reservoir. Braiding over mid reaches of the drawdown zone was not as severe as previous years. The left bank channel was passable but marginal because of shallow depths and high erosion leading to turbid conditions. However, the upper limit of the drawdown zone was assessed impassable due to a combination of channel braiding and low flows.

May 16, 2012 – High channel mobility was observed. Fish passage was considered marginal due to very high TSS at current flows.

September 8, 2012 – The stream was passable but sediment deposition had occurred at the high water level, forming a large sand and gravel bar. As a result, the mainstem was tightly confined along the right bank with only a small secondary left bank channel. Kokanee were observed upstream of the drawdown zone, but in very small numbers.

2013 Observations:

May 28, 2013 – Fish passage was considered marginal due to very high TSS at current flows from erosion of fines over the drawdown zone. However, high flows maintain good depths for passage.

September 9, 2013 – Passage condition improved over previous years since there was less braiding over the drawdown zone and the channel was more confined. The stream was passable Kokanee were observed upstream of the drawdown zone.

October 9, 2013 – There were no passage concerns at the existing flows and reservoir levels.

Deer Creek

Deer Creek has high spawning and rearing potential for both Kokanee and Bull Trout and moderate/high adult holding potential for the respective species (RL & L Environmental Services Ltd, 1997). There is currently 2 km of Deer Creek available for Kokanee spawning, but a series of log jams prevent further upstream access (Zimmer, 2007), although 2.7 km is apparently accessible to adfluvial Rainbow Trout (Sebastian et al, 2000; Andrusak and Slaney, 2004). Resident Rainbow Trout were observed to occur upstream of the falls at 2.7 km (Bayes and Olmstead, 1997).

During the spring drawdown survey (April 7, 2009), minor passage concerns were identified from the mid elevation of the drawdown zone to the wetted level of the reservoir (429.5 m.a.s.l.). These concerns were associated with channel braiding in the mid-level of the drawdown zone and high instability (active bank sloughing) in the lower lengths of the drawdown zone. However, based on the increasing flows, Rainbow Trout access and migration was not assessed as a problem. Kokanee access assessments, conducted on September 11 2009, identified good stream flows and no passage concerns – supported by counts of up to 200 fish/10 linear meter upstream of the drawdown zone.

2010 Observations:

April 20, 2010 - There are no passage concerns at current flows and reservoir levels. Lower braided sections observed in April 2009 are inundated in spring 2010. No fish sampling was completed.

May 22, 2010 - There are no passage concerns at current flows and reservoir levels.

September 13, 2010 - Kokanee spawning, no passage issues up main channel at current flows and reservoir levels; drawdown zone spawning observed. Observed common mergansers, osprey, bald eagle, common raven, American crow, common loon and gulls. The HOBO data logger, ECO_4, TAG 098, was installed downstream of boulder in center of channel approx. 8m upstream of cross-section-data point collected.

2011 Observations:

March 17, 2011-There are no passage concerns at current flow and reservoir levels. Secondary channels may not be passable. HOBO data from Eco_4 was retrieved.

July 7, 2011-There are no fish passage concerns; high reservoir level and seasonally high stream flows. High velocity and turbidity making it too difficult to retrieve data from HOBO logger. RSC and NSC observed within DDZ and LARL wetted level confluence.

September 14, 2011-There are no concerns with fish passage at current stream flows and reservoir level; KO observed u/s of cross-section. The left bank may have experienced erosion u/s of the LARL wetted level at young ponderosa pine and Douglas fir. The rock with epoxy and tag were located; however, the HOBO data logger was gone and wire snapped. A logger (Tag#035; Logger #6874) was re-launched along the right bank.

2012 Observations:

March 30, 2012 – The exposed (by low reservoir levels) lower reach of the drawdown zone (428 m) was assessed as impassable as low flows sheeted over a braided channel. Flows were sufficient for passage in the upper defined segments of the fan with boulder/cobble substrates and a wetted width of approximately 3 m.

May 14, 2012 – There were no passage concerns; with high stream flows mitigating any potential effect of the current LARL wetted level.

September 11, 2012 – The channel appeared to be more braided but there were no passage concerns observed at the LARL wetted level and at the observed flows.

2013 Observations:

May 23, 2013 – There were no passage concerns; with high stream flows mitigating any potential effect of the current LARL wetted level.

September 12, 2013 – There were no passage concerns at the existing flows and reservoir levels.

October 8, 2013 – There were no passage concerns at the existing flows and reservoir levels.

Dog Creek (Lower Arrow)

Dog Creek has been stocked with Gerrard Rainbow Trout; 7,509 Gerrard Rainbow Trout from the Kootenay Hatchery were released within both Dog and Deer creek in 1986 (Lindsay, 1986). The drawdown zone is described as primarily riffle with limited pools and runs (Canadian Columbia River Inter-Tribal Fisheries Commission, 2006). Low flows and channel braiding within the drawdown zone may also reduce fish access to Dog Creek (Anonymous 2002) and ongoing stream monitoring and truck and transport techniques have been suggested to improve access.

During the spring 2009 assessments, Dog Creek was assessed as passable at current flows with a potential low flow barrier occurring over the lower (braided) section of the drawdown zone

when the reservoir is at low levels. Kokanee were observed above the drawdown zone on September 11, 2009 and although flows were low, upstream access was possible.

2010 Observations:

April 20, 2010 - There are no concerns with fish passage at current flows and reservoir levels. No fish sampling occurred. Freshet has begun. A local resident indicated that rainbow could be seen in the creek in late May, early June, following freshet. The beaver dam along the right bank above the drawdown zone is now approx. 11 m wide by 1 m deep, and is likely currently obstructing fish passage along the right side channel.

May 23, 2010 - There are no concerns with fish passage at current flows and reservoir levels. Water was too cold to electrofish and too swift and deep to complete a detailed cross section or fish sampling.

September 13, 2010 - Although there was insufficient flow along right bank channel to facilitate fish passage (wetted for approximately 40m), the main stem was passable at current flows and reservoir elevation. Flows appeared to be higher than in 2009 September visit. Kokanee spawning was confirmed in the drawdown zone with presence of redds and eggs.

2011 Observations:

March 17, 2011-There are no passage concerns at current stream flow and reservoir levels. HOBO temperature data logger installed (Tag #52, part #9893919).

July 7, 2011-There are no passage concerns at current reservoir level and stream flows. HOBO data logger located in an area that was too swift and deep for data retrieval. Several CSU observed near confluence and several cyprinids among reed canary grass within inundated DDZ. High reservoir levels providing productive rearing habitat, resulting in extensive cover along right bank including instream vegetation, SWD and LWD.

September 14, 2011-Although stream flows are low, KO are moving upstream of the DDZ with the current high reservoir level. KO observed u/s of the cross-section. RB fry also noted near cross-section location and a dead torrent sculpin was located amongst the rocks within the DDZ. The HOBO temperature data logger was not located.

2012 Observations:

March 31, 2012 – Passage concerns were not observed at the moderate stream flows. The channel remained narrow and well-defined to the low reservoir wetted level.

May 14, 2012 – There were no passage concerns through the drawdown zone of Dog Creek at the observed LARL wetted levels and high stream flows.

September 11, 2012 – Flows were low and the right channel was nearly dry, but fish passage appeared to be possible through the left channel - albeit marginal. However, the

predominantly large cobble substrates provide some cover for small-bodied Kokanee migrating upstream during this period.

2013 Observations:

May 23, 2013 – There were no passage concerns; with high stream flows mitigating any potential effect of the current LARL wetted level.

September 12, 2013 – Flows were low and the right channel was dry. Low flows resulted in marginal to impassable conditions for Kokanee.

October 7, 2013 – Increased flows measured in October improve passage conditions for fish. Although Bull Trout do not frequent Dog Creek, the October inspection provided observation of stream passage conditions at different flow and reservoir levels.

Drimmie Creek

Access issues from the reservoir are not considered a problem and low reservoir elevations were thought to provide improved spawning conditions with exposure of suitable gravels (BC Hydro, 1992). However, a meandering braided channel was described for the drawdown area, consistent with high freshet flows (BC Hydro, 1992). Accessible habitat was approximately 1 km before a natural access barrier (BC Hydro, 1992; Andrusak and Slaney, 2004). Other authors have indicated that Bull Trout and Kokanee may have 3 km of access, while Rainbow Trout were noted to have 1.4 km (Sebastian et al., 2000).

During the spring 2009 survey, potential passage impediments were associated with low flows over the braided channel occurring at the downstream end (430.4 m asl) of the drawdown zone during low reservoir levels. Moving upstream, the channel becomes more confined by high banks, and woody debris embedded in the channel helps to maintain scour pools and improve complexity and instream cover. Kokanee fry were captured upstream of the culvert in the spring (May 26, 2009). Kokanee migration during 2009 assessments was unimpeded - supported by adequate stream flows. Spawning behaviour was observed over suitable substrates occurring in the drawdown zone upstream of the culvert.

2010 Observations:

April 27, 2010 - There are no concerns with fish passage at current flows and reservoir level. Cover includes root wads in drawdown zone, overhanging grasses and undercut banks upstream of the culvert/road crossing and boulder cover associated with culvert armouring.

May 25, 2010 - UARL wetted to culvert crossing; passage not of concern at current flows and reservoir level. Abundant spawning habitat occurs throughout the drawdown zone.

September 9, 2010 - Drimmie is passable, but could benefit from channel confinement and enhancement structures as a case study for structural works. Kokanee migration primarily along left limits of braided channel where channel is more defined with increased wetted depth. Kokanee are migrating upstream; however, there is shallow braiding over the drawdown zone and with much lower flows a barrier to passage may occur. With few dead fish observed and numerous fish staging in pools, it was estimated that Kokanee are at the beginning of the main run. Spawning redds were observed within the drawdown zone and in sandy gravel substrates.

2011 Observations:

April 12, 2011-Temperature data retrieved from HOBO data logger. Upstream of road crossing and multiple outlets, cover is limited to <1%, provided by LWD, small pools and undercut banks. Braiding upstream of culvert creates low flow concerns and very low cover; cover largely limited to undercut banks where reed canary grass present and riprap associated with left bank armouring/road. Both banks 100% eroding downstream of culvert crossing; however, channel is confined and increased cover noted due to LWD and associated scour. Downstream of culvert to UARL wetted level- no passage concerns. Below current wetted level, braiding and low flow barriers exist (from Yr 1 sampling). Construct berms to constrict channel and decrease braiding; this will also add cover within the DDZ. No shoal spawning or coarse shoreline areas.

July 11, 2011-There are no passage concerns at current stream flows and reservoir level. The DDZ is inundated-able to drive boat across road with 1.9 m clearance at nearest depth. Moved data logger from right bank to log along left bank approximately 8 m u/s.

September 9, 2011-No concerns with KO passage at current reservoir level and stream flows. The UARL is backwatered throughout most of DDZ; therefore, DDZ spawning and subsequent stranding is not a concern. Stream flow exclusively along left bank, rather than splitting near the HWL; some flow (1-3 m wide and <10 cm deep) along right bank extents with KO spawning. Sorting of substrates with the high reservoir level has resulted in an accumulation of sand and gravel along the right bank along previous right channel-may improve passage in spring. Data retrieved from the HOBO logger; no concerns with wire connection-galvanized wire used.

2012 Observations:

April 5, 2012 – Flows were following a single channel along the left extent of the fan upstream of the road and culvert crossing. All previous inspections had identified a braided channel over this section of fan. As a result, passage conditions were improved upstream of the culvert during the spring 2012. New evidence of erosion was observed along the right bank downstream of the culvert. In areas where severe bank and channel erosion was occurring high turbidity was observed, which may deter upstream fish migration.

September 8, 2012 – Channel aggrading from high 2012 summer reservoir levels and simultaneous stream discharges resulted in a new channel form over the braided fan occurring upstream of the culvert. The mainstem flows were following the right bank extents of the fan and the former left bank mainstem channel had been filled with sediment and appeared impassable at the current flows.

2013 Observations:

May 28, 2013 – There were no passage concerns with moderate to high stream flows.

September 9, 2013 – No passage concerns at the documented flows. A split channel, instead of braiding, maintained improved passage conditions (i.e. deeper more confined channels) for Kokanee.

October 10, 2013 – There were no passage concerns at low to moderate flows. Adult Bull Trout observed upstream of the drawdown zone.

Eagle Creek

Eagle Creek is thought to have a high overall fisheries value, as there is good spawning potential both upstream and downstream of the high water level (Bayes and Olmstead, 1997). Fish have access to 4.3 km of Eagle Creek before an approximately 2 m chute blocks further passage for Kokanee (Seaton, 1978). It is thought that Bull Trout may be able to navigate the barrier depending on discharge levels (Seaton, 1978), and Bull Trout are documented as spawning in Eagle Creek (Sebastian et al, 2000). Adfluvial Rainbow Trout spawning has also been documented in Eagle Creek (Seaton, 1978; Toth and Tsumara, 1996). A waterfall that occurs approximately 9.2 km from the confluence blocks all fish passage (Seaton, 1978; Lindsay and Seaton, 1978).

Water levels appear to fluctuate on an annual basis, as fisheries values were reported to be high, but Eagle Creek had one report of being dry in autumn (Andrusak and Slaney, 2004) and was observed to go subsurface approximately 500 m upstream of the reservoir confluence in 2005 (Canadian Columbia River Inter-Tribal Fisheries Commission, 2006) and dry at 583 m in 1998 (Miller, 1998). Several reports cited low flows and shallow water levels in the fall, as well as channel braiding (BC Hydro, 1992; Bayes and Olmstead, 1997; Miller, 1998; Andrusak and Slaney, 2004 and Canadian Columbia River Inter-Tribal Fisheries Commission, 2006). During Kokanee spawning surveys in 1998, temperature levels were 22.5°C at the mouth, approaching lethal levels for Kokanee; spawning occurred in remnant pools with heavy bird predation (Miller, 1998). Heavy bird predation was also documented in 1996 (Bayes and Olmstead, 1997).

Eagle Creek was added to the tributary field sampling program for 2010 due to severe aggrading and low flow impediments to Kokanee access observed in September 2009.

2010 Observations:

April 24, 2010- The stream is marginally passable at current flows, due to severe braiding, with some channels more passable than others. Depth throughout drawdown zone was noted to be less than 0.1 m to 0.25 m at the deepest segment closest to the right bank. Access from the drawdown zone to the mainstem is somewhat perched above the left bank side channel.

May 21, 2010- There are no passage concerns with the current flow and reservoir level. Flows and channel extents were consistent with those observed in April. The stream temperature was colder than on April 21, 2010. No fish sampling was completed.

September 14, 2010- Kokanee spawning observed (<25) downstream of left bank riprap armouring. However, low stream flows and braiding are a passage concern; braiding present and would be more severe at lower reservoir levels. Placements of one temperature data logger downstream of the left bank riprap and one other upstream where riparian vegetation is present are recommended for temperature comparisons in 2011.

2011 Observations:

March 18, 2011-Marginal passage conditions were noted along the Eagle Creek fan on March 18, 2011, with some sections of braiding towards the left and right bank wetted extents noted to be impassable at the current stream flows. HOBO temperature data logger was installed along the left bank amongst riprap (Tag #54, part #9893912). An EB was noted in a shallow pool in a side channel/backwater area along the right bank wetted extents.

July 8, 2011-There are no passage concerns at current reservoir level and high seasonal stream flows; DDZ is inundated. HOBO data logger located, data retrieved, and placement reinforced with T-bar for additional stability. It appears that Didymo (*Didymosphenia geminata*) is established within the Eagle Creek side channel along the left bank.

September 14, 2011-Eagle Creek does not appear to be passable, regardless of high reservoir levels. However, KO have migrated u/s above the DDZ and cross-section, possibly when the LARL and/or stream flows were higher. The mainstem typically flows along the left bank; however, flows are insufficient and subsurface along the left bank with most of flow along right bank. The HOBO data logger was located, but had been pulled out of the water around September 10 and placed on the riprap, based on temperature data. Logger was reinstalled with rebar.

2012 Observations:

April 1, 2012 – The right channel formed a shallow riffle at the observed flows and appeared likely to unravel at increased flows. The lower reaches of the fan had passage concerns due to extensive braiding and subsequent very shallow wetted depths. Progressing upstream, the channels became more well-defined and passage conditions improved. Previous inspections identified mainstem flows occurring more central and to the left (looking downstream) of the

fan. In the spring 2012 the mainstem flows and shifted and were being conveyed along the right extents of the fan.

May 14, 2012 - High stream discharge prevented hydrologic measurements. As a result of the flows and deep wetted depths, there were no passage concerns identified in May.
September 10, 2012 – Passage concerns were identified at the confluence of Eagle Creek with the wetted reservoir level as a result of low stream flows. The creek was not braided at the outlet so the impediment was not a function of the reservoir in this instance and was rather a function of low stream flows. Although passage conditions were marginal, Kokanee were observed migrating upstream beyond the full pool level of the reservoir.

2013 Observations:

May 23, 2013 – High flows provided sufficiently deep wetted channels for fish passage. Very high turbidity of flows suggest possible slope failure in the watershed.

September 11, 2013 – Very low flows and braided channel form present passage barriers for Kokanee in the lower drawdown zone.

October 8, 2013 – Increased flows improved conditions for fish passage.

Johnston Creek

Johnston Creek supports Kokanee and Rainbow Trout spawning. Previous assessments did not identify impediments to fish migration in the drawdown zone. Adfluvial access extends about 360 m upstream of the reservoir where there is a 2.5 m waterfall (Bayes and Olmstead, 1997; Gebhart, 1999). The drawdown zone has good gradients and hydraulic structures with pockets of spawning gravel and the riparian zone exhibits some rearing and spawning potential (Bayes and Olmstead, 1997).

Johnston Creek was assessed as passable during 2009 passage monitoring for Rainbow Trout and Kokanee, supported by adequate spring and late summer stream flows. On September 11, 2009 it was estimated that between 500 -1000 Kokanee were staging at the confluence and about 50 Kokanee were counted over a 30m length of stream above the drawdown zone.

2010 Observations:

April 21, 2010 - There are no passage concerns at current flow and reservoir elevation. The creek is passable throughout the fan and is well-defined. Flows were too high to complete full cross-section. Fish sampling did not occur during this site visit. Freshet appears to be earlier in this lower watershed system, similar to Dog and Renata Creeks.

May 22, 2010 - There are no passage concerns at current flow and reservoir elevation. Flows lower than April 21, 2010.

September 14, 2010 - There are no passage concerns at current flows and reservoir elevation- the well-defined channel and large substrates assist with passage over the fan. Kokanee were observed to be spawning in the drawdown zone. Five bald eagles were observed at the confluence with LARL. The HOBO data logger Eco_05 Tag099 was installed with data point logged.

2011 Observations:

March 16, 2011-There are no passage concerns at current stream flow and reservoir elevation. Temperature data was retrieved from HOBO data logger Eco_05. Fish sampling was not conducted.

July 7, 2011-There are no passage concerns at the current reservoir level and stream flow. Moderate stream flow. Previous cross-section location inundated with LARL; therefore, moved upstream. HOBO data logger not located; substrates appear to have resorted and visibility was difficult with depths and white water in plunge pools.

September 13, 2011-There are no concerns with KO passage at current reservoir levels and stream flows; KO u/s of cross-section and eggs noted. The HOBO data logger was not located. There appears to have been a shift in substrates following freshet.

2012 Observations:

March 31, 2012 – There were no passage concerns observed and the creek channel was well-defined over nearly the entire drawdown zone length to the wetted level of the reservoir (427.54 m).

May 14, 2012 – There were no passage concerns identified during high stream discharges.

September 11, 2012 – There were no passage concerns observed. Very high spring - early summer discharges resulted in movement of large channel substrates (i.e., boulders). Kokanee were observed spawning in upper limits of drawdown zone in gravel pockets among boulders.

2013 Observations:

May 23, 2013 – There were no passage concerns identified during high stream discharges.

September 11, 2012 – There were no passage concerns observed. Kokanee were observed spawning in upper limits of drawdown zone in gravel pockets among boulders.

October 7, 2013 - There were no passage concerns observed at current stream flows and reservoir level.

Little Cayuse Creek

In 1992 it was noted that there were no access problems in relation to reservoir elevation (BC Hydro 1992). A 1996 assessment concluded that the overall fisheries value of Little Cayuse Creek was high, with more than 1600 Kokanee documented up to 400m upstream of the reservoir and over 1000 in 1995 (Bayes and Olmstead, 1997). Rainbow Trout and long nose dace were also documented (Bayes & Olmstead 1997). The only obstruction noted in the 1996 assessment was a 4 m high fall that occurs approximately 400 m upstream of the reservoir (Bayes & Olmstead 1997).

In 2009, spring flows likely accommodated upstream Rainbow Trout migrations with little concern. However, low stream flow conditions during fall Kokanee migrations were identified as a potential barrier. During the September 11, 2009 assessment only five (5) Kokanee were observed holding (almost stranded) in small residual pools at the upper limits of the drawdown zone. This year's observations on Little Cayuse suggest that upstream migration barriers are more a function of low stream flows rather than reservoir elevations.

2010 Observations:

April 19, 2010 - There are no concerns with passage at current flows and reservoir elevation. No fish sampling was completed.

May 22, 2010 - There are no concerns with passage at current flows and reservoir elevation. A potential barrier occurs immediately upstream of the cross section where a cascade may impede passage at low flows.

September 13, 2010 - There are passage concerns with low flows, although Kokanee were observed to be upstream of the cross-section beyond the cascade that was thought to be a potential barrier.

2011 Observations:

March 17, 2011 – Passage concerns identified at lower 50 cm of creek elevation above the LARL wetted level. HOBO data logger installed (tag# 50, Part #9893913).

July 7, 2011-There are no passage concerns with current LARL level and stream flows. Two adult RB in DDZ; hundreds of RSC visible. HOBO data logger had stopped logging temperature on May 14, 2011; rock with the logger had moved downstream and impact to the logger was visible. New HOBO launched (Tag #064, #9906862) ~4-5 m upstream of cross-section; flagged with orange along both banks.

September 14, 2011-There are no concerns with fish passage at current reservoir level and stream flows; KO u/s of DDZ and cross-section. Bird predation noted u/s of cross-section. The HOBO data logger was located and data downloaded.

2012 Observations:

March 30, 2012 – Little Cayuse Creek was inaccessible to upstream migrating fish based on observed braiding and very low streamflows during the March inspection. The barrier was observed from the wetted reservoir level (427.6 m) upstream to about 430 m. Upstream from this elevation, passage conditions improved as the channel became more defined and stable with small boulder and cobble substrates.

May 14, 2012 – There were no passage concerns observed during the May inspection; with high relative discharges providing adequately deep water to support fish migration and to provide instream cover.

September 11, 2012 – Little Cayuse Creek was impassable to Kokanee over a new steep-faced gravel fan that had formed at the upper level of the drawdown zone. One Kokanee was observed downstream of the obstruction in the drawdown zone.

2013 Observations:

May 23, 2013 – There were no passage concerns observed during the May inspection; with high relative discharges providing adequately deep water to support fish migration and to provide instream cover.

September 11, 2013 – Passage conditions were marginal just above the reservoir wetted level (432.6 m) but improved upstream above the approximate 434 m soft constraint elevation. Kokanee were still able to migrate upstream with fish recorded above the drawdown zone.

Mackenzie Creek

Mackenzie Creek is known to support Rainbow Trout, Kokanee, and Bull Trout spawning (Decker et al, 2005; Lindsay, 1976). Earlier reports indicate that passage through the drawdown zone is not an issue (BC Hydro, 2002; den Biesen and Ord, 2002; Sebastian et al, 2000; Andrusak and Slaney, 2004), but upstream barriers to all fish species likely occur approximately 4 km upstream (Lindsay, 1976; Sebastian et al, 2000).

During the 2009 surveys (spring and fall) there were no impediments to upstream migration through the drawdown zone identified. Bull Trout fry, Kokanee, and rainbow were all sampled / observed within the drawdown zone in 2009. Moderate to high stream flows observed in the spring 2009 would support rainbow passage regardless of reservoir elevations. Large woody debris embedded throughout the channel likely influences channel definition and scour, providing instream cover and resting habitat for fish.

2010 Observations:

April 22, 2010 - There are no passage concerns at current flows and reservoir elevation. There is a well-defined channel throughout the drawdown zone with abundant woody debris. The left bank has migrated from bank erosion just downstream of the microturbine inlet channel, although it does not appear to be a direct result of the inlet channel. No fish sampling was completed in April.

May 24, 2010 - There are no passage concerns at current flows and reservoir elevation. The channel is well-defined to the current reservoir level.

September 10, 2010 - There are no passage concerns at current flows and reservoir elevation. A single defined channel occurs over the upper fan to upstream of the lake HWL. One Kokanee was observed at the lake level with no staging Kokanee observed at the confluence with the reservoir. The left bank is noticeably more eroded than in spring.

2011 Observations:

April 13, 2011-There are no passage concerns at current flows and reservoir elevation. HOBO temperature data logger installed along left bank (3196_MACKENZIE).

July 12, 2011-There are no passage concerns at current reservoir levels and stream flows. THE UARL wetted level is upstream of the established cross-section point; therefore, cross-section was moved u/s. HOBO data logger also inundated.

September 10, 2011-There are no concerns with fish passage with current stream flows and reservoir level; KO observed upstream of the UARL wetted level. Temperature data was retrieved from the HOBO data logger.

2012 Observations:

April 3, 2012 – There were no passage concerns during the early April inspection. With the exception of a short (~10 m - long) braided section of stream immediately above the wetted reservoir level (427.54m), the channel was well-defined with occasional LWD providing instream cover.

May 15, 2012 – There were no passage concerns observed at the observed streamflows and reservoir levels.

September 9, 2012 – There were no fall passage concerns identified. The summer high reservoir levels reached upstream beyond the cross-section location and rafted a new large woody debris jam at the full pool elevation. In addition, the high reservoir levels resulted in the deposition of sediments at about 440 m elevation creating a new gravel bar - expected to scour out during subsequent 2013 freshet flows.

2013 Observations:

May 22, 2013 – There were no passage concerns observed at the observed streamflows and reservoir levels.

September 10, 2013 – There were no Kokanee passage concerns identified. The well-defined channel provides good passage conditions for fish even at low flows.

October 9, 2013 - There were no fall passage concerns identified. The well-defined channel provides good passage conditions for fish at low flows.

Nacillewaet Creek

Nacillewaet Creek has been described as having good Bull Trout habitat characteristics (den Biesen and Ord, 2002). Access issues have been identified within the drawdown zone, particularly during low flows, and they are attributed to high quantities of large woody debris and high gradients (den Biesen and Ord, 2002; Gebhart, 1999; RL & L Environmental Services, 1997). A large set of 3 m falls are located approximately 140 m upstream of the reservoir and form complete barrier to fish migration and this, along with steep gradients, large substrate and cascade chute complexes, may reduce use of the stream by resident lake populations (RL & L Environmental Services, 1997).

The 2009 observations were consistent with previous assessments in regards to potential drawdown zone barriers. Rainbow Trout and Kokanee access above the drawdown zone is likely restricted by persistent woody debris falls and low flows. Above the full pool reservoir level, the stream gradient increases to 20%, which would inhibit Rainbow Trout and Kokanee migration further upstream. However, the step-pool morphology may be suitable for Bull Trout production. Gravel substrates occur in the drawdown zone, stabilized by embedded large woody debris and bedrock outcrops, which may be suitable for spawning. Juvenile Rainbow Trout were captured (May 2009) upstream of the reservoir within the drawdown zone. However, no Kokanee were observed staging or migrating in early September.

2010 Observations:

April 23, 2010 - No fish sampling completed.

May 24, 2010 - Stream may be passable at current flows and reservoir elevation, although large woody debris and step-pool morphology may be potential structural impediments. Rainbow Trout juveniles and fry were captured within drawdown zone. Good potential for Bull Trout.

September 10, 2010 - Kokanee observed staging and spawning from wetted level of lake upstream to steep cascade pool; redds observed. Large numbers (~ 400-500) staging at reservoir confluence - while some Kokanee were observed above what may be considered a physical obstruction, not all staging fish may be able to ascend, which may result in shoal

spawning at reservoir level or just above. Redds identified in about 1m wetted depth within present lake inundation; concern that fish spawning on small features presently inundated by reservoir may have eggs stranded or washed away as reservoir levels drop. Kokanee were able to ascend above the cross-section location, with ~20 m before a steep cascade-pool.

2011 Observations:

April 13, 2011-Flows are moderate to high with increased turbidity; step pools are still passable at current flows and reservoir elevation. Snow along both banks during the site survey. Channel extents remain unchanged from previous surveys. The stream has abundant woody debris and associated pockets of spawning gravel. HOBO data logger installed (03905_Nacillewaet) approximately 10 m downstream of cross-section along right bank.

July 12, 2011-There are no passage concerns at current flows and reservoir elevation; DDZ is inundated. Right bank erosion along the DDZ resulting in deposition of fines. HOBO data logger not located due to flows, water depth and turbulence.

September 10, 2011-There are no concerns with fish passage at current stream flows and reservoir level. KO were observed spawning in gravel pockets, primarily along the stream banks. The HOBO data logger was buried in gravel and cobble, but data was retrieved.

2012 Observations:

April 3, 2012 - Moderate flows over the step pools of the drawdown zone were observed to have passable routes. The stream has abundant woody debris and associated pockets of spawning gravel.

May 15, 2012 - High stream flows improved passage conditions up the drawdown zone from the April inspections.

September 9, 2012 - Resorted LWD and boulders reduced fall passage conditions from those observed in previous years. Plunge heights over the LWD and boulders were increased with reduced pool depths observed at the bases of these features - impairing the potential for Kokanee to migrate into the drawdown zone and spawn (as observed in 2011).

2013 Observations:

May 22, 2013 - High stream flows improve passage conditions up the drawdown zone.

September 10, 2013 - Resorted LWD and boulders reduced fall passage conditions from those observed in previous years. Plunge heights over the LWD and boulders were increased with reduced pool depths observed at the bases of these features.

October 9, 2013 – Impassable due to resorted LWD, excessive waterfall heights with inadequate plunge pool depths.

Octopus Creek

Rainbow Trout and Kokanee utilize Octopus Creek from the reservoir upstream about 0.5 km to a waterfall (Andrusak and Slaney, 1994; Sebastian et al, 2000). Previous assessments identified no obstructions in the drawdown zone (Gebhart, 1999; Canadian Columbia River Inner-Tribal Fisheries Commission, 2006; BC Hydro, 1992).

During the 2009 spring surveys, braiding over the lower fan (~432.3 m.a.s.l.) of the drawdown zone was recorded as a potential barrier at low to moderate stream stages. However, with increasing flows leading into freshet and subsequent Rainbow Trout migration periods, improved channel definition resulted over the lower drawdown zone fan and Rainbow Trout access was not impeded. This was supported by the capture of an adfluvial adult rainbow about 20 m upstream of the bridge during the spring survey period. There were no impediments to Kokanee access in 2009. The reservoir levels were above the lower fan braiding and stream flows were sufficient for migration and spawning.

2010 Observations:

April 21, 2010 - There are no concerns with passage at current flows and reservoir elevation. The reservoir level is up approximately 2 m from 2009 April site visit. No fish sampling took place, as temperatures were too cold (4.1°C). Octopus Creek water temperatures have decreased over the past two days with increased flows due to snow melt; the creek temperature on April 19 was 5.6°C. Increased braiding was noted along the right bank, which could pose a potential barrier at low flows.

May 21, 2010 - There are no concerns with passage at current flows and reservoir elevation. Water temperature was down to 4.8°C, with snow at higher elevations and too cold to electrofish; therefore, no sampling completed. Mean water depth has increased by approximately 5 cm.

September 14, 2010 - Octopus Creek was passable at current flows and reservoir level. Spawning Kokanee were observed throughout the drawdown zone to current reservoir level. Octopus Creek was at a low stage. The right bank at the cross-section location was becoming severely undercut; mature birch and fir may collapse in next high flow period. There could be a risk of blocking bridge if the two trees fall instream.

2011 Observations:

March 17, 2011-There are no concerns with passage at current flows and reservoir elevation. HOBO temperature data logger installed along left bank at bridge crossing (Tag #53, part #9893914).
July 8, 2011-There are no passage concerns at high LARL reservoir level and moderate to high stream flows. DDZ is inundated. HOBO data logger located and data retrieved.

September 13, 2011-There are no concerns with fish passage at current reservoir level and stream flows; KO observed u/s of cross-section. The HOBO temperature logger was located and data was retrieved.

2012 Observations:

April 1, 2012 – The creek was not passable due to low flows, channel braiding, and low reservoir levels. Upstream migration was deemed inaccessible from the wetted reservoir level (427.5m) upstream to about 430 m elevation. Upstream from this point, the channel become well-defined and passable at the observed lower flows.

May 13, 2012 – There were no passage concerns at the observed streamflows and reservoir levels.

September 10, 2012 – A large debris flow occurred during summer 2013 flood-stage discharges. As a result, the creek avulsed and established a new alignment westward over the fan. The new channel was not passable as it was spilling over the steep-sided edge of the debris fan. The new channel appeared to be highly unstable and showed signs of unravelling between the wetted reservoir level to near the full pool elevation. Construction activities were underway to restore the former channel alignment and to reconstruct the bridge, which sustained damage during the debris flow event.

2013 Observations:

May 23, 2013 – High channel mobility persisted after the 2012 debris flow as the fan continues to resort. Channel restoration carried out over the fan in 2012 had unravelled. Fish passage was considered marginal due to very high TSS at current flows.

September 11, 2013 – Marginal passage conditions just above the reservoir wetted level (432.64 m) up to above 435 m, and improving further up the drawdown zone.

October 8, 2013 - Marginal passage conditions just above the reservoir wetted level (432.11 m) up to above 435 m, and improving further up the drawdown zone.

Payne Creek

Payne Creek is known to contain spawning habitat for Kokanee and Bull Trout (RL & L Environmental Services, 1997). However, only about 60 m of Payne Creek are accessible upstream from the reservoir full pool level; where a 10 m high waterfall occurs. Access through the drawdown zone may be impeded by highly erodible substrates and persistent woody debris (den Biesen and Ord, 2002; Gebhart, 1999) although some assessors have suggested that access is not a problem (BC Hydro, 1992). Due to barriers just upstream of the reservoir,

habitat values within the stream are considered to be low to moderate (den Biesen and Ord, 2002; RL & L Environmental Services, 1997).
During the 2009 survey period, the drawdown zone of Payne Creek was accessed as passable both in the spring (Rainbow Trout) and late summer to fall period (Kokanee and Bull Trout). Although substrates are highly erodible, the channel was well defined and abundant instream woody debris helped to maintain resting pools and cover.

2010 Observations:

April 23, 2010 - There are no concerns with passage at current flows and reservoir elevation

May 24, 2010 - There are no concerns with passage through the drawdown zone at current flows and reservoir elevation.

September 10, 2010 - Approximately 400-500 Kokanee are staging at confluence of creek and reservoir. Kokanee are spawning up to the falls in gravel pockets and beneath the abundance of large woody debris. Large woody debris occurs throughout the drawdown zone. Approximately 220 Kokanee counted instream in addition to those staging at the mouth. The eroding right bank downstream of the falls is resulting in deposition of fines and accumulation of clay instream.

2011 Observations:

April 13, 2011-There are no passage issues at current flow and reservoir levels. Channel is relatively defined throughout the DDZ, with some lateral and mid-channel gravel bars with associated erosion. LWD is not presenting an issue to fish passage. HOBO temperature data logger was launched within the LWD along the right bank downstream of cross-section.

July 12, 2011-There are no concerns with passage at current reservoir level and stream flow. LWD throughout DDZ is not impeding passage. HOBO data logger nailed to log in spring-not located at current DDZ inundation and associated water depth.

September 10, 2011-There are no concerns with fish passage at current stream flows and reservoir level; DDZ is inundated. KO staging in UARL and KO observed upstream of UARL wetted level and LWD. The LWD is not obstructing fish passage, and provides instream cover. HOBO logger located and temperature data retrieved.

2012 Observations:

April 3, 2012 – Embedded instream large woody debris helps to maintain a well-defined channel, which mitigates passage concerns during low flow and low reservoir levels.

May 15, 2012 – There were no passage concerns at the observed relative moderate flows and reservoir wetted levels.

September 9, 2012 – The creek was passable and Kokanee were observed upstream to the waterfall. The summer high reservoir levels had re-sorted the LWD jam situated at about 439 m elevation. Field observations noted potential passage impairments as a result of the resorted LWD jam. However, the presence of Kokanee upstream of the feature indicates that passage was still possible - with the jam itself providing extensive cover for fish.

2013 Observations:

May 22, 2013 – There were no passage concerns at the observed relative moderate flows and reservoir wetted levels.

September 10, 2013 – The creek was passable and Kokanee were observed upstream to the waterfall.

October 9, 2013 – No passage concerns at current flow and reservoir levels. Kokanee were still observed spawning into early October.

Renata Creek

Bayes and Olmstead (1997) report the overall fisheries value of Renata Creek as medium, with diverse habitat and areas of good spawning potential in the drawdown zone, as well as excellent salmonid spawning and rearing potential. Previous assessments (Gebhart 1999) found no obstructions in the drawdown zone. The flows of Renata Creek appear to be highly variable (RL & L Environmental Services Ltd 1997), while other studies indicate no flows/no access at the time of assessment (BC Hydro 1992).

Spring Rainbow Trout access was not impeded by the observed flows during the 2009 survey. The greatest potential for low flow barriers likely occur when the reservoir levels are below an elevation of 431m above mean sea level; where extensive channel braiding was documented. On September 11, 2009 no surface flows were present over the aggraded drawdown zone between the wetted level of the reservoir extending upstream to nearly full pool level. At about the reservoir full pool level, discontinuous surface flows were documented. Thus, Kokanee access and spawning in Renata Creek was restricted in 2009.

2010 Observations:

April 20, 2010 - There are no concerns with passage at current flows and reservoir elevation-flows are moderate to high and still running clear. No fish sampling was completed.

May 23, 2010 - There are no concerns with passage at current flows and reservoir elevation. Flows appear lower than April 20 site visit; however, wetted levels had likely recently been around 15 cm higher. The large wasting right bank along the drawdown zone appears to have sloughed more since April, 2010.

September 13, 2010 - There are insufficient flows and residual pools to allow stream access from reservoir through drawdown zone for spawning Kokanee. The creek is flowing now with recent rain and cooler temperatures. Several dead Rainbow Trout fry, longnose dace and sculpins were found throughout the drawdown zone. Rainbow fry were observed live within a pool upstream of the cross-section location.

2011 Observations:

March 17, 2011 – Installed HOBO temperature data logger (Tag #51, part #9893915); no passage concerns at current stream flow and reservoir levels.

July 7, 2011 – There are no concerns with fish passage; DDZ is inundated, with high reservoir level just downstream of the log crossing. Main flows are along the right bank at the cross-section, resulting in increased scour. YOY cyprinids along RB in DDZ. Not able to locate HOBO data logger for data retrieval. Fine material from drawdown zone right bank sloughing into reservoir during site visit.

September 14, 2011 – Stream has very low flows; however, with the current high reservoir level, some KO may be able to ascend. During the site visit, the stream appeared impassable across much of the channel width; however, KO were observed u/s of the cross-section location. Quad use through the creek channel appears frequent, with essentially a road crossing the channel downstream of the cross-section. A rock line has also been built up across the channel downstream of cross-section, but KO are passing upstream. The location where the HOBO data logger was placed has been altered and the logger was not located.

2012 Observations:

March 30, 2012 – The lower reaches of the drawdown zone (427.6 m - 429.3 m elevation) were not passable, in spite of the moderate stage flows, due to channel braiding and a steep-faced alluvial fan over which the shallow flows were cascading.

May 14, 2012 – There were no passage concerns as the lower reaches of the drawdown zone were now inundated by the wetted reservoir level and flows were high.

September 11, 2012 – Consistent with September inspections in previous years, fall Kokanee passage was restricted by low stream flows with intermittent sections of dry channel bed occurring in the drawdown zone.

2013 Observations:

May 23, 2013 – There were no passage concerns at high flows.

September 12, 2013 – Fall Kokanee passage was restricted by very low stream flows and dry creek bed over the lower drawdown zone.

October 7, 2013 – Increased stream flows maintaining wetted channel to reservoir level and passage conditions have improved from impassable to marginal.

Taite Creek

The drawdown zone of Taite Creek was assessed as passable in the spring 2009 for Rainbow Trout. Main stem channels were well defined and substrates were fouled with periphyton - indicating increased channel stability in the mid to upper levels of the drawdown zone. At low reservoir levels, access to Taite Creek may be restricted by channel braiding that was documented in the bottom 30 m of the drawdown zone. Good channel definition and stream flows supported Kokanee migration and access in September 2009. Side channels that occur periodically along length of Taite Creek were documented providing high value spawning and rearing habitat for salmonids and may provide passage around log jams.

2010 Observations:

April 21, 2010 - There are no passage concerns at current flows and reservoir elevation. Creek is in early runoff and still running clear. The side channel along the left bank above the drawdown zone provides spawning habitat with overhanging riparian vegetation, large woody debris and gravels as the dominant substrate. No fish sampling occurred.

May 23, 2010 - There are no passage concerns at current flows and reservoir elevation. The creek had recently overtopped banks and flows through the left bank flood channel are evident - the wetted level would have been approximately 25 cm higher than today. No fish sampling was completed.

September 14, 2010 - There are no passage concerns with current flows and reservoir elevation. Kokanee spawning upstream of the reservoir level throughout the drawdown zone and creek; approximately 65 were observed along the right bank off mainstem flow. High numbers of Kokanee are concentrated in side channel along the left bank, downstream of debris jam. The HOBO data logger ECO_6, TAG100 was launched mid-channel approximately 5m upstream of the cross-section location.

2011 Observations:

March 18, 2011 – There are no passage concerns at current flows and reservoir elevation. Temperature data was retrieved from HOBO data logger Eco_06.

July 7, 2011 – There are no passage concerns at current flows and reservoir level; DDZ is inundated and LARL appears close to full pool elevation. Taite Creek is too high to electrofish, retrieve data logger or complete cross-section.

September 13, 2011 – There are no concerns with fish passage at current stream flows and reservoir elevation; KO observed to be spawning u/s of cross-section and DDZ. Taite Creek

has a well-defined main stem. The HOBO data logger rock was located with tag and epoxy still intact; however, the logger was gone. A new data logger (#6871_Taite) was installed along the left bank side channel u/s of the cross-section and downstream of the debris jam.

2012 Observations:

April 1, 2012 – The creek appeared passable within the two well-defined channels.

May 14, 2012 – There were no passage concerns observed and flows were high.

September 10, 2012 – High summer steam discharge, resulting in marked channel resorting and widening, during full pool reservoir levels resulted in the complete plugging (with sand and gravel) of the right bank mainstem channel. As a result, all flows were diverted into the secondary left bank channel, which is more poorly defined and has reduced habitat value. Passage concerns were noted where flows were cascading over a steeper section of the channel; however, Kokanee were observed upstream of this feature beyond the cross-section location (above the drawdown zone).

2013 Observations:

May 23, 2013 – There were no passage concerns observed. The raised riffle that formed in 2012, causing passage concerns for Kokanee, had unravelled during high flows resulting in improved channel conditions for fish passage.

September 11, 2013 – There were no concerns with fish passage at current stream flows and reservoir elevation.

October 8, 2013 - There were no concerns with fish passage at current stream flows and reservoir elevation.