BC hydro

# Columbia River Project Water Use Plan

# YEAR 5 (2012) FISH MIGRATION PASSAGE MONITORING SUMMARY REPORT

**Reference: CLBMON– 32A**

***Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program***

**Survey Period: 2012**

**Ecoscape Environmental Consultants Ltd.**
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**Kelowna, BC**
**V1V 2M2**

April 2013

PROGRAM NO. CLBMON-32A

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| CLBMON 32A STATUS OF OBJECTIVES MANAGEMENT QUESTIONS AND HYPOTHESES AFTER YEAR 5 | | | |
|---|---|---|---|
| **Objectives** | **Management Hypotheses** | **Management Questions** | **Year 5 (2012) Status** |
| 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.<br>Does the operation of the Arrow Lakes Reservoir block or reduce upstream migration of focal fish populations in tributary streams? | A.1.<br>The operations of the Arrow Lakes Reservoir can block or reduce upstream migration of fish populations in tributary streams. The high vertical fluctuations of the reservoir contribute to channel instability, aggrading and braiding, in some tributary fans. 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 around the onset of Kokanee migration and spawning in early September. 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. This reduced access is a result of low to very low stream flows and wider, more poorly defined channels that are prevalent over the drawdown zone in some tributaries.<br><br>Opportunities to improve fish passage in tributaries with expansive fans and drawdown zone braiding are presented within this report. |
| | | Q.2.<br>Are there significant reservoir elevation thresholds below which spawner access is impacted? | A.2.<br>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 – 0.05. At a passage score of 0.05, about half of the tributaries will have migration barriers in the drawdown zone. Below 0.03, there is a high risk that tributaries will not be accessible to fish. During Kokanee migration and spawning, the current soft operating constraint of 434 m represents a key elevational threshold. The observed very low stream flows that occur late August – early September results in passage scores of about 0.03 when Arrow Reservoir is at 434 m.<br><br>Reservoir elevation passage thresholds are dependent on stream flows that occur during the same point in time. The 2010-2012 stream temperature monitoring suggests that spring Rainbow Trout migrations may not occur until mid-April. 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 Migrations were initiated in late March to early April when flows are still low to very low. |
| | | Q.3.<br>Do high stream flows in tributaries in the spring mitigate impacts of low reservoir elevations? | A.3.<br>Spring surveys in 2012 were mostly completed prior to Rainbow Trout migration when stream temperatures were approaching 5°C and stream stages were still low. Passage concerns were noted in March/April in 8 of the 18 creeks at mean reservoir elevations of 427.5 m. Between mid-April and late May, when tributaries were consistently reaching 5°C, the mean daily reservoir elevations climbed from 427.7 to about 432 m. Stream flows were also increasing accordingly with spring runoff. The effect of increased stream flows was demonstrated in the passage matrix in 2012, where a sharp increase in the relative discharge of reference creeks resulted in passage scores jumping from the low passage threshold of 0.03 to over 0.1 in under three days between April 23 – 26. This was also observed on tributaries that experience earlier seasonal runoff and increased flows such as Mackenzie Creek, which had moderate flows occurring by the beginning of April and a passage score of 0.09 – with no passage concerns identified. Therefore, consistent with observations from previous years, high stream flows in tributaries in the spring can mitigate 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 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). 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) 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?**

2. **Are there significant reservoir elevation thresholds below which spawner access is impacted?**

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

During Year 1 of the CLBMON-32 program, we 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 2012, spring surveys to evaluate low reservoir elevations and low flow passage conditions were conducted from March 30-April 5. Subsequent passage assessments, timed with Rainbow Trout migration and spawning, were completed from May 13-16, and Kokanee access monitoring was carried out from September 8–11, 2012.

Upon the commencement of the late March – early April surveys, the reservoir level was around 427.5 m, just under 2 m higher than the mean elevation of the reservoir between 1984 and 2008. The reservoir level climbed slowly to about 428 m by the end of April. At the beginning of May, levels began to increase sharply, paralleling the rate of increase exhibited over the period of record.

At the beginning of May, levels were increasing at a rate of about 5 cm/day and gradually increased to 20 cm/day by the end of the month. September reservoir elevations were approximately 1.5 m higher than the 434 m asl (Above Sea Level) soft operating constraint.

During the spring low reservoir-low flow survey period (March 30-April 5), 10 tributaries were assessed as passable and 8 were noted as inaccessible or having passage concerns. The rainbow migration and spawning passage assessments (May 13-16) identified no passage concerns when stream flows were at moderate stages and the reservoir was at about 430 m. September Kokanee passage assessments identified 6 of the 18 tributaries as having passage concerns. This number is up from previous years, with factors attributed to a combination of low flows and channel alterations from flood stage discharges and high reservoir levels (summer 2012). On many tributaries, new sand/gravel fans were formed at the upper limit of the drawdown zone. As the reservoir levels and stream flows subsequently receded, new upstream migration barriers were evident in some of the smaller tributaries. Of the six tributaries identified as being impassable in September 2012, none are known to be frequented by Bull Trout. None of the surveyed tributaries with reported Bull Trout use had passage concerns at the reservoir elevations experienced into November.

While one of the prominent observations during the September surveys was the negative effect that summer high flows and reservoir levels had on fall passage, the potential positive effect of gravel recruitment for improved spawning habitat condition was less apparent. This was documented in Burton Creek, where large volumes gravel (outwash) was deposited at full pool reservoir levels. High numbers of Kokanee were observed spawning in Burton Creek at the upper elevation of the drawdown zone in new gravels, which had previously been predominantly more coarse-textured substrates with higher compaction.

Consistent with 2009 observations, tributaries containing rooted stumps and other anchored structures through the drawdown zone fan (e.g., Cranberry Creek) tended to have good channel definition and scour around these features. As a result, such structures may help improve passage conditions over tributary fans and also provide increased cover and improved fish habitat. The design and placement/anchoring of structures through the unstable drawdown zone, by emulating the function of rooted tree stumps and rootwads, may function to reduce channel braiding and help to maintain a more defined thalweg, thereby improving passage conditions. It is thought that Drimmie Creek in Upper Arrow and Eagle Creek in Lower Arrow may provide suitable pilot sites for instream enhancement works.

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# 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 (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 (soft constraint) 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.

# 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 2005a).

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 2005a).

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 2005a; 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.*" (CRWUPCC 2005a – 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?**

2. **Are there significant reservoir elevation thresholds below which spawner access is impacted?**

3. **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 2005a). 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 tributaries monitored 2012, as well as presence of drawdown zone barriers. The location of these watercourses along the Arrow Lakes Reservoir is shown in Figure 1.

**Table 1.** Key tributaries monitored in 2012 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.

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# FIGURE 1

Year 5 (2012) Fish Migration Passage Monitoring Key Streams

| | |
|---|---|
| Project: | Fish Migration Access Assessment and Monitoring |
| 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: | March, 2013 |

## LEGEND

- City
- Major Highway
- Streams and Rivers
- Surveyed Streams
- Municipal Boundary
- Lake
- Lower Arrow Lake
- Upper Arrow Lake

5 2.5 0 5 10 15 20 Kilometers

N

Revelstoke
Sicamous
Lumby
Nakusp
Slocan
Silverton
Castlegar
Upper Arrow Reservoir
Lower Arrow Reservoir
The Narrows
Mabel Lake
Sugar Lake
Slocan Lake
Drimmie Creek
Blanket Creek
Crawford Creek
Cranberry Creek
Mackenzie Creek
Bannock Creek
Nacillewaet Creek
Payne Creek
Burton Creek
Eagle Creek
Taite Creek
Octopus Creek
Johnston Creek
Deer Creek
Renata Creek
Little Cayuse Creek
Caribou Creek
Dog Creek (Lower Reservoir)
Columbia-Shuswap B
North Okanagan F
North Okanagan E
Central Kootenay K
Central Kootenay H
Central Kootenay J
Central Kootenay I
Central Kootenay D
Central Kootenay G
1
23
97A
6
31
22
360000 370000 380000 390000 400000 410000 420000 430000 440000 450000 460000 470000 480000
5650000 5640000 5630000 5620000 5610000 5600000 5590000 5580000 5570000 5560000 5550000 5540000 5530000 5520000 5510000 5500000 5490000 5480000 5470000 5460000

# 3.0 METHODS-YEAR 5 (2012) TRIBUTARY PASSAGE ASSESSMENTS/MONITORING

Inventory and study elements were designed to investigate spawning distribution and assess tributary access. The timing of biophysical and topographic surveys of tributary fans focused on periods of combined low stream flow and low reservoir operating levels to optimize field inventory and mapping and identify passage barriers to Rainbow Trout, which may otherwise not be apparent during higher reservoir levels. Field surveys were also timed to coincide with Rainbow Trout, Kokanee and Bull Trout staging and spawning activities.

## 3.1 Timing of Field Activities

Rainbow Trout migration typically begins as water levels increase with spring freshets and when stream temperatures reach 5°C (Ford et al. 1995). This period generally coincides with low reservoir levels, which occur over March and April. In 2012, minimum reservoir levels occurred from late March through to early May, with the lowest daily mean recorded at 427.52 m, occurring from April 7-9, 2012. Late March - early April tributary surveys occurred over the low reservoir period. Tributary surveys in the spring commenced at the south end of the Lower Arrow Reservoir and progressed northward. Surveys were initiated in the south because the combined effect of lower watershed elevations (lower topographic relief) and warmer climatic conditions at the south end of the reservoir usually result in earlier snow melt and stream freshet than at the north end.

Three (3) assessment periods (early spring, mid spring and fall) were completed during the fourth year of passage assessments. Drawdown surveys and evaluation of fish passage potential at low stream flow and reservoir levels were conducted from March 30 - April 5. Rainbow migration passage condition assessments were carried May 13 - 16. Kokanee and Bull Trout passage condition assessments were carried out from September 8–11, working from north to south, with temperatures in the UARL tributaries expected to drop sooner than in the LARL. September surveys were consistent with previous years and coincided with Kokanee spawning throughout the study area.

## 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 are Marine Emergency Duty (MEDA3) certified and the principal biologist, Kyle Hawes, is a certified operator with the Small Vessel Operators Proficiency (SVOP) training. Prior to initiating the field program, it was ensured that all crew members had current first aid and spinal immobilization and transportation endorsement certification. Additionally, in August 2010, all crew members completed Swiftwater Flood Rescue Technician Level II training and certification.

Access and launch sites utilized in 2012 were:

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

Road access was utilized during periods of inclement weather or where logistically practical. Major routes included:

- Highway 6 to Edgewood and Nakusp
- Highways 97, 97A, 97B and 1 to Revelstoke
- Highway 23 from Nakusp to Revelstoke

## 3.3 Habitat Assessments

Physical, biological, and hydrological characteristics were re-surveyed in 2012 during low reservoir levels (March 30 - April 5, 2012) with the intent on comparing channel and topographic character with information first gathered during the 2009 surveys. Access to each of the tributaries was by boat, with the exception Burton Creek and Caribou Creek. These ground surveys aimed to identify and measure potential barriers that occur in tributaries between the average upper and lower operational reservoir levels.

Biophysical surveys of the tributary fans adapted 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. In March and April surveys, segments were again stratified along the drawdown zones where different attributes or biophysical characteristics occurred, with subsequent collection of GPS point and line features (Table 2) with descriptions of features such as substrates, braiding, riparian condition, bank stability and representative photos.

| **Table 2.** 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 Topographic Survey and Hydrological Review

In 2012, the thalweg profile over the drawdown zone and channel cross sections were surveyed using a real time kinematic (RTK) survey system (Photo Plate 1). A minimum of two cross sections were recorded for smaller tributary fans with up to five cross sections measured on larger fans. In addition, known or potential barriers were surveyed with the total station and linked to the GIS data base (entered into the Trimble GPS). The hydraulic character of the drawdown zone of respective tributaries was described within the detailed cross sections and channel widths, braiding form, and depths were recorded. Attributes recorded include spatial extents and depths of residual pools and staging areas downstream adjacent potential barriers.

Elevations were corrected to geodetic levels (meters above mean sea level) using the daily geodetic reservoir elevation datum from BC Hydro. The survey data was processed and illustrated on comprehensive annotated map sheets for each tributary, which included a plan view, channel profiles, cross sections, and representative photos. The elevational position of key instream habitats (e.g., spawning) and potential barriers were included on profile drawings to assess the impact of changing reservoir levels on drawdown zone passage and potential spawning utilization.

**Photo Plate 1:** Conducting topographic surveys with RTK system on Blanket Creek (*left*) and Cranberry Creek (*right*).

## 3.5 Stream Hydrologic Monitoring

Detailed cross section surveys were completed during all three (3) field sampling periods in 2012. 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 (capable of 0.3 m accuracy) and Hurricane antennae. GPS points were recorded at the stream centreline (midpoint of bankfull width). Cross section locations were also marked in the field with flagging tape and either galvanized spikes or rebar along the left and right banks.

Table 3 lists the location coordinates of the detailed cross sections for the 18 streams surveyed during the 2012 monitoring program.

**Table 3.** Detailed cross section locations established for each of the 18 watercourses surveyed during the 2012 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 2012 monitoring visits, as well as ice coverage over a portion of the channel in late March and early April. 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 flexible 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.

Velocity and depths 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; however, when water depths exceeded 1 m, it was recommended that the 2 point system be used in which the 2/10 and 8/10 velocity measurements were recorded to calculate mean velocity (BC MoE, 2009). When the water was between 0.75 and 1.0 m, the method employed was at the operator's discretion (BC MoE, 2009). In the interest of crew safety, all velocity measurements were taken using the 1 point 6/10 method, as maintaining a static position while wading in depths of over 1 m was challenging, and the measurement had to be taken as quickly as possible.

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 2012 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).

The depths collected and distances across the channel were used to calculate the area of each section, based on the formula of the area of a trapezoid. The sum of discharges of all segments of the cross section provided a measure of discharge for the cross section. Discharges were calculated for each stream cross section in March, April, May, and September and are found in Table 5 in Section 4.0 Results. Data tables and calculations are presented in Appendix A-1.

## 3.6 Stream Temperature Monitoring

In September 2010, a total of six (6) Onset HOBO Pendant Temperature/Light data loggers (UA-002-64) were installed in six (6) of the 18 tributaries (Table 4). 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 on the balance of tributaries during the 2011 survey period and maintained during the 2012 monitoring period (discussed below).

**Table 4.** Location coordinates of HOBO pendant temperature/light data loggers launched in 2010 and 2011 and maintained during the 2012 monitoring period.

| Tributary | HOBO data logger ID | Date of Deployment | Location (UTM Coordinates) |
|---|---|---|---|
| Drimmie Creek | Eco_01 Tag_095 | September 10, 2010;<br>moved upstream ~ 8m<br>to LB July 11, 2011 | 5634759 N 422861 E<br><br>5634739 N 422834 E |
| Blanket Creek | 3911_BLANKET Tag_055<br>replaced with 010<br>September 9, 2011 | April 12, 2011 | 5632334 N 423318 E |
| Cranberry Creek | Eco_02 Tag_096 | September 10, 2010<br>April 13, 2011<br>September 10, 2011 | 5618802 N 430056 E<br>5618871 N 430042 E<br>5618871 N 430042 E |
| Crawford Creek | Tag_042 | April 13, 2011<br>September 9, 2011 | 5622831 N 430852 E<br>5622832 N 430844 E |
| Bannock Creek | 3198_Bannock | April 13, 2011 | 5609319 N 433505 E |
| MacKenzie Creek | 3196_MACKENZIE | April 13, 2011 | 5611568 N 440367 E |
| Payne Creek | 3908_Payne | April 13, 2011 | 5608846 N 438913 E |
| Nacillewaet Creek | 3905_NACILLEWAET | April 13, 2011 | 5606306 N 437228 E |
| Caribou Creek | 6972_CARIBOU | April 14, 2011<br>September 12, 2011 | 5536657 N 436662 E<br>5536684 N 436678 E |
| Burton Creek | Eco_03 Tag_097<br>6878_Burton | September 11, 2010<br>April 14, 2011 | 5536231 N 436019 E<br>5536223 N 436051 E |
| Taite Creek | Eco_06 Tag_100<br>6871_TAITE | September 14, 2010<br>September 13, 2011 | 5516145 N 421840 E<br>5516139 N 421847 E |
| Eagle Creek | Tag_054<br>3912_Eagle | March 18, 2011<br>July 8, 2011 | 5514187 N 417753 E<br>5514177 N 417761 E |
| Octopus Creek | Tag_053<br>3914_Octopus | March 18, 2011 | 5511281 N 419892 E |
| Johnston Creek | Eco_05 Tag_099 | September 14, 2010 | 5503921 N 416388 E |
| Renata Creek | Tag_051 3915_Renata | March 17, 2011 | 5476331 N 419777 E |
| Dog Creek | Tag_052 3919_Dog | March 17, 2011 | 5475717 N 420139 E |
| Deer Creek | Eco_04 Tag_098<br>Tag_035 6874_Deer | September 13, 2010<br>September 14, 2011 | 5474280 N 424843 E<br>5474276 N 424860 E |
| Little Cayuse Creek | Tag_050<br>Tag_064 6862_Little Cayuse | March 17, 2011<br>July 7, 2011 | 5473457 N 426749 E<br>5473457 N 426749 E |

Installation of data loggers was adapted from methods outlined in Isaak and Horan (2010).

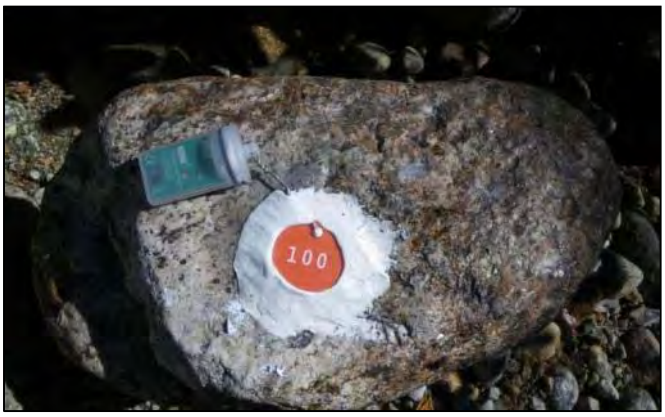



**Photo Plate 2:** HOBO data logger Eco_06 Tag 100 installed in Taite Creek September 14, 2010.

Data loggers in 2010 were securely attached with galvanized steel wire to a numbered tag and subsequently secured with an underwater epoxy to large boulders within the stream channel. The underwater epoxy used was PC 11 white epoxy paste, mixed and applied as per manufacturer's specifications. The epoxy was applied to the back of the plastic identifying tag, as well as to the rock. No epoxy was applied to the logger itself, so as to not inhibit data retrieval. Gloves were worn to avoid contact with the epoxy and a wire brush was used to clean the rock surface before applying the epoxy and securing the tag. Depending on the location, efforts were made to camouflage the site by sticking leaves, sticks and sand to the white epoxy.

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, and the loggers are capable of recording 64 bytes of memory, or up to 28,000 combined temperature and light readings or events (product info sheet).

For data quality control and assurance, data retrieval was attempted at all six locations in spring 2012 prior to freshet. This was to reduce the risk of data loss associated with high stream flows and potential damage or loss of data loggers.

In 2011 it was found that, in some instances, loss of data loggers was due to the epoxy separating from the rock or the wire leading to the logger breaking. Subsequently, 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 stable rooted large woody debris (LWD) was present.


**Photo Plate 3:** Looking towards HOBO data logger installation along the left bank of Taite Creek in a side channel using a combination of rebar and galvanized wire. The previously installed Taite Creek data logger was lost during freshet, with the logger separating from the epoxy.

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.

## 3.7 Fish Sampling

Ecoscape has utilized a Smith Root 12-B POW backpack electrofisher during spring survey periods in 2009, 2010 and 2011. The intent has been to opportunistically sample creeks to provide additional incidental information on tributary fish assemblages. However, in 2012, stream temperatures were below 5°C during March and April assessments and precluded the use of electrofishing as per best management practices, permit conditions and crew safety. Similarly, in May high stream flows prevented fish sampling in some of the tributaries while in others water temperatures were still too cold (<5°C). Thus fish sampling was not carried out at all sites in 2012.

Visual observations of reservoir elevation and stream flow and channel conditions and identification of drawdown zone obstructions have enabled determination of fish passage during sampling periods. Incorporation of velocity measurements at cross-sections and

stream temperature data also helps to assess timing of life history stages in relation to reservoir elevation and fish passage.

## 3.8 Passage Score Matrix

The passage matrix that was developed following the 2010 field data collections and modified in 2011 produces a passage score (P) based on current and forecasted reservoir levels and relative stream discharge classes (i.e., very low, low, moderate, and high). This matrix was again tested during the 2012 monitoring program to assess its reliability and to calibrate it further. The matrix will provide an index to assess fish migration access potential into tributaries by factoring the combined effect of relative stream discharge (% Qmax) and reservoir elevations. This may assist to predict when reservoir elevations and relative discharge are approaching passage thresholds during important fish life history stages such as spawning migrations.

### 3.8.1 Matrix Development and Calibration

The two (2) components of the matrix are relative stream discharge, and reservoir elevation.

1. Relative stream discharge is the rate of 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 flow rate to the highest.

| Relative Discharge Class | Initial Value |
|---|---|
| Very Low | 1 |
| Low | 2 |
| Moderate | 3 |
| High | 4 |

2. Reservoir elevation was divided into 25 categories (classes) based on a 1-m elevational gradient spanning the maximum range between the extreme low water (418 m asl) and full pool (442 m asl) levels. Arbitrary values were assigned to each category in ascending order from the lowest elevation to the highest elevation based on the assumption that higher reservoir levels progressively improve passage conditions for fish as more of the drawdown zone is inundated.

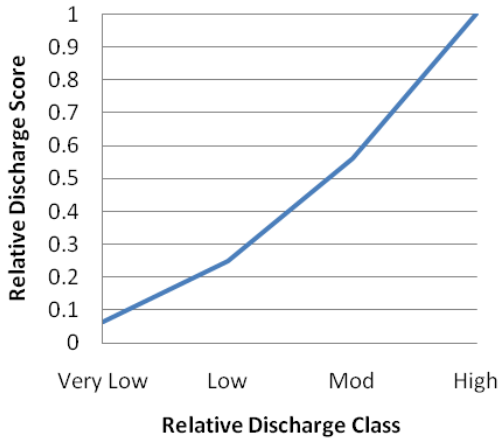
| Reservoir Elevation Class | Initial Value |
|---|---|
| 418m | 1 |
| 419m | 2 |
| 420m | 3 |
| . | . |
| . | . |
| . | . |
| 442m | 25 |

The two components were then weighted equally by proportionately adjusting category values so the maximum initial category value equaled 1. To do this, individual category scores were divided by the maximum score as shown in the revised tables below:

| Relative Discharge Class | Initial Value | Adjusted Value |
|---|---|---|
| Very Low | 1 | .25 |
| Low | 2 | .5 |
| Moderate | 3 | .75 |
| High | 4 | 1 |

| Reservoir Elevation Class | Initial Value | Adjusted Value |
|---|---|---|
| 418m | 1 | .04 |
| 419m | 2 | .08 |
| 420m | 3 | .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 (field observations). As a result, the adjusted scores were transformed 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 passage condition changes and threshold values relative to stream flow and reservoir elevation.



Transformed, the equally weighted matrix components are rewritten:

| Relative Discharge | |
|---|---|
| **Class** | **Matrix Score ($D_s$)** |
| Very Low | .0625 |
| Low | 0.25 |
| Moderate | .5625 |
| High | 1 |

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

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

| | | | Reservoir Elevation (m) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 425 | 426 | 427 | 428 | 429 | 430 | 431 | 432 | 433 | 434 | 435 | 436 | 437 | 438 |
| | | Score | 0.1024 | 0.1296 | 0.1600 | 0.1936 | 0.2304 | 0.2704 | 0.3136 | 0.3600 | 0.4096 | 0.4624 | 0.5184 | 0.5776 | 0.6400 | 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 Figure 4 for colour codes.

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 84 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 the 2009 calendar year. The 2009 hydrometric data represents the reference condition for relative

stream discharge to correspond with the initiation of the CLBMON-32 monitoring program. Flow data for subsequent years (2010,2011, and 2012) were adjusted relative to the 2009 discharge (reference) score by dividing mean daily discharges of the current year by corresponding days of the 2009 reference discharge data (to yield a percentage value). Discharge percentage values of the four reference watercourses were then averaged and multiplied by the 2009 relative discharge values for the same day.

The resulting % Qmax value for each day of the year was tabulated for each watercourse and plotted (Figure 3). This conversion to % Qmax enabled a comparison of the relative discharges of watercourses despite a wide variation in magnitude. Subsequently, the mean % Qmax was calculated for each day by averaging the % Qmax of the four watercourses on respective days. The mean % Qmax was then corrected so the maximum value equalled 1.00. The tabulated results were then plotted over the individual watercourse plots (Figure 3) for comparison; where y = relative discharge (% Qmax) and x = 2009 calendar year. The graphical output was examined and the four (4) relative discharge classes, used in the passage matrix, were identified. The relative discharge class breaks interpreted from the plot (Figure 3) closely resemble the scores assigned to the matrix; where very low = 0.0625, low = 0.25, and moderate = 0.5625. Thus we were able to translate the mean % Qmax values into the 4 discharge classes (very low, low, moderate, and high) of the matrix.

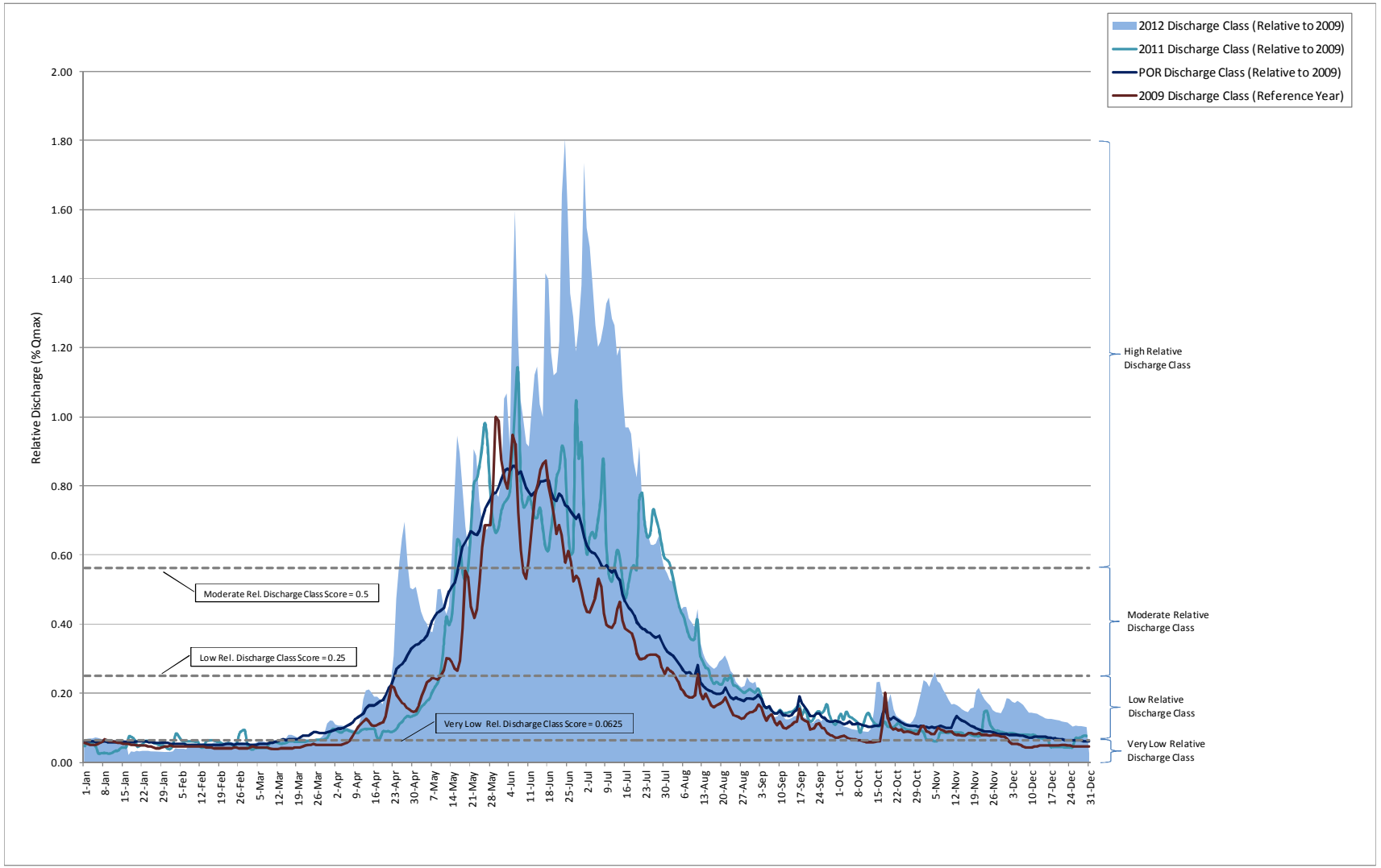



**Figure 3.** Relative discharge curves (% Qmax) developed from the four reference watercourses within the middle and lower Columbia River catchments and interpretation of relative discharge classes assigned to the passage matrix for the Arrow Reservoir. The reference year is 2009 hydrometric data obtained from the Water Survey of Canada. The period of record (POR) is based on 15-84 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 2012 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 Figure 4.

Passage scores were calculated based on the daily mean elevations from 2009, 2010, and those averaged out over the past 26 years (1984-2010) using the mean %Qmax scores for each calendar day. We interpolated a best fit curve for the 26-year daily average elevation passage scores and then projected fish life history timings over the curve to examine the various life history stages in relation to passage scores and to evaluate potential fish passage concerns. This information is presented in Section 4.2.

| Passage Score Spectrum | |
|---|---|
| 0.01 | No Passage |
| 0.02 | |
| 0.03 | |
| 0.04 | Marginal passage conditions |
| 0.05 | |
| 0.06 | Passage conditions improving with occasional concerns on some tributaries |
| 0.07 | |
| 0.08 | |
| 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 |
| 0.1 | |
| 0.11 | |
| 0.12 | |
| 0.13 | |
| 0.14 | |
| 0.15 | |
| 0.16 | |
| 0.17 | |
| 0.18 | |
| 0.19 | |
| 0.2 | |
| 0.3 | |
| 0.4 | |
| 0.5 | |
| 0.6 | |
| 0.7 | |

**Figure 4**. Passage score threshold values based on interpretation of the matrix and field inspections. Field observations in 2012 indicated that streams were not passable to fish when passage scores were below 0.03. When scores were between 0.03 - 0.05 passage concerns had been identified but close to half (n=13) of these tributaries were still deemed passable to fish.

# 4.0 RESULTS

Spring surveys to evaluate low reservoir elevations and Rainbow Trout passage were conducted from March 30-April 5, 2012. Subsequent passage assessments, timed with Rainbow Trout migration and spawning, were completed from May 13-16, and Kokanee access monitoring was carried out from September 8–11, 2012.

Upon the commencement of the late March – early April surveys, the reservoir level was around 427.5 m, just under 2 m higher than the mean elevation of the reservoir between 1984 and 2008 (Figure 5). This level was the lowest recorded level for Arrow Reservoir in 2012. The reservoir elevation climbed slowly to about 428 m by the end of April. At the beginning of May, levels began to increase sharply, paralleling the rate of increase exhibited over the period of record. At the beginning of the month, levels were increasing at a rate of about 5 cm/day and gradually increased to 20 cm/day by the end of May. September reservoir elevations were approximately 1.5 m higher than the 434 m (asl) soft operating constraint.

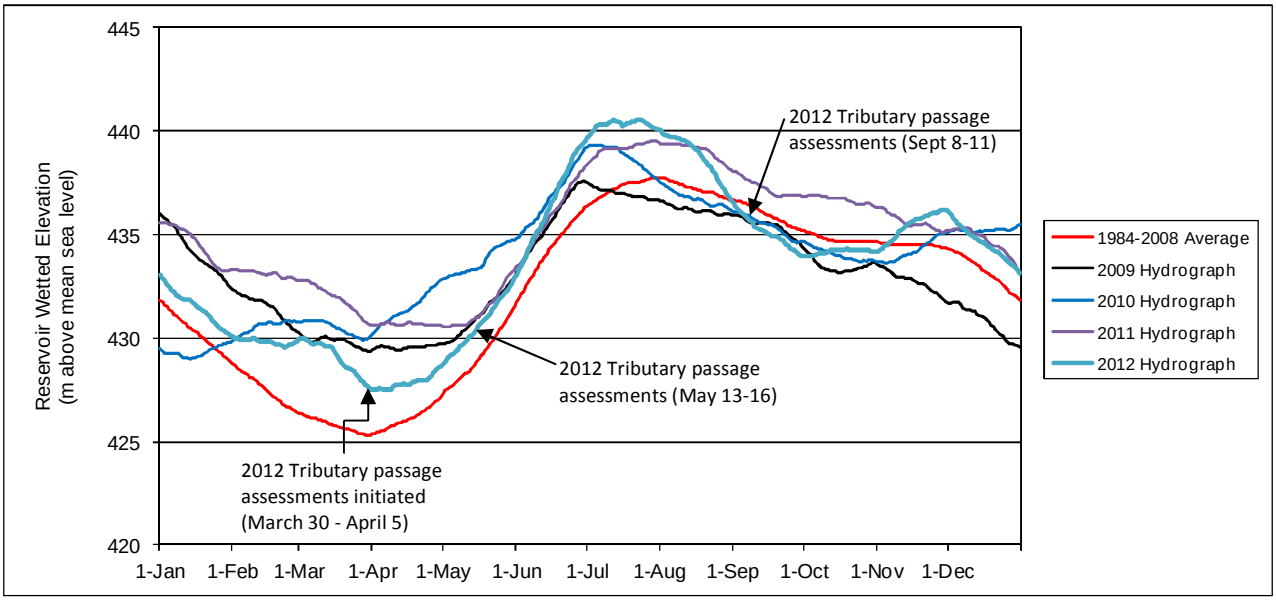



**Figure 5.** Arrow Lakes Reservoir hydrograph for 2009, 2010, 2011, 2012, and mean hydrograph from 1984-2008 (Fauquier).

Ten tributaries were assessed as passable and 8 as inaccessible or having passage concerns during the spring low reservoir-low flow survey period (March 30-April 5) (Table 5). 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 of the 18 tributaries had passage concerns during September Kokanee passage assessments.

Increased fall passage concerns were attributed to a combination of low flows and channel morphology changes that occurred as a result of flood stage discharges and very high summer reservoir levels. On many tributaries, new sand/gravel fans were formed at the upper limit of the drawdown zone. As the reservoir levels and stream flows subsequently receded, new upstream migration barriers were evident on some of the smaller tributaries.

None of the creeks assessed as impassable during the March/April inspections had stream temperatures greater than 5°C, which is recognized as the temperature at which Rainbow Trout migration commences. Due to loss of data loggers and variable launch times, temperature data is not available for the year's duration for each tributary. Drimmie Creek has been the only system where data has consistently been recorded since initial deployment of the data loggers in September 2010. All 18 tributaries had sensors up until the May 2012 inspections and data retrieval period. However, summer flood level discharges and resultant channel avulsions, erosion, and substrate resorting resulted in the loss of 10 sensors. These sensors had either been fastened to steel posts that had been driven into the creek bed or were nailed to rooted stumps.

**Table 5 .** Tributary monitoring dates, discharge, relative discharge class, corresponding reservoir elevations, and passage observations (field observations) with passage index (matrix) scores, for the 2012 fish migration access monitoring program (CLBMON-32A).

| | Survey/Monitoring Period | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | March/April Surveys | | | | | | May Surveys | | | | | | September Surveys | | | | | |
| Tributary | Date | Res. Elev | Disch. ($m^3$/sec) | Rel. Dish. Class | Strm Temp (°C) | Passage (field obs./ index score) | Date | Res. Elev | Disch. ($m^3$/sec) | Rel. Dish. Class | Strm Temp (°C) | Passage (field obs./ index score) | Date | Res. Elev | Disch. ($m^3$/sec) | Rel. Dish. Class | Strm Temp (°C) | Passage (field obs./ index score) |
| Bannock Creek | 03-Apr | 427.54 | 0.81 | Mod | 2.9 | Y/.09 | 15-May | 430.41 | 0.91 | Mod | 13 | Y/.15 | 09-Sep | 435.56 | 0.10 | Low | 9.7 | Y/.14 |
| Blanket Creek | 04-Apr | 427.56 | 0.70 | Low | 2.9 | Y/.05 | 16-May | 430.59 | Too Swift | High | 4.8 | Y/.31 | 08-Sep | 435.66 | 1.30 | Mod | 10.7 | Y/.32 |
| Burton Creek | 02-Apr | 427.53 | 0.93 | Low | 6.2 | Y/.05 | 13-May | 430.15 | Too Swift | High | 5.1 | Y/.27 | 10-Sep | 435.4 | 2.36 | Low | 11.3 | Y/.13 |
| Caribou Creek | 02-Apr | 427.53 | 1.47 | Low | 6.4 | Y/.05 | 14-May | 430.23 | Too Swift | High | 4.8 | Y/.27 | 10-Sep | 435.4 | 2.09 | Low | 11.4 | Y/.13 |
| Cranberry Creek | 05-Apr | 427.55 | 1.73 | Low | 2.5 | N/.05 | 15-May | 430.41 | Too Swift | High | 4.9 | Y/.27 | 09-Sep | 435.56 | 0.76 | Mod | 11.4 | Y/.32 |
| Crawford Creek | 04-Apr | 427.56 | 0.29 | Low | 3.1 | N/.05 | 16-May | 430.59 | 3.01 | High | 5.4 | Y/.31 | 08-Sep | 435.66 | 0.36 | Low | 9.8 | Y/.14 |
| Deer Creek | 30-Mar | 427.65 | 0.17 | Low | 4.3 | N/.05 | 14-May | 430.23 | 2.25 | Mod | 5.7 | Y/.15 | 11-Sep | 435.29 | 0.31 | Low | 11.8 | Y/.13 |
| Dog Creek | 31-Mar | 427.54 | 1.15 | Low | 2.2 | Y/.05 | 14-May | 430.23 | Too Swift | High | 6.1 | Y/.27 | 11-Sep | 435.29 | 0.12 | V. Low | 9.9 | N/.03 |
| Drimmie Creek | 05-Apr | 427.55 | 0.28 | Low | 4.4 | Y/.05 | 15-May | 430.41 | NA | Mod | 5.2 | Y/.15 | 08-Sep | 435.66 | 0.35 | Low | 9.1 | Y/.14 |
| Eagle Creek | 01-Apr | 427.54 | 0.38 | Low | 3.6 | N/.05 | 14-May | 430.23 | Too Swift | High | 6.4 | Y/.27 | 10-Sep | 435.4 | 0.08 | V. Low | 14.8 | N/.03 |
| Johnston Creek | 31-Mar | 427.54 | 1.03 | Mod | 3.9 | Y/.09 | 14-May | 430.23 | Too Swift | High | 4.1 | Y/.27 | 11-Sep | 435.29 | 0.13 | Low | NA | Y/.13 |
| Little Cayuse Creek | 30-Mar | 427.65 | 0.02 | V. Low | 3.2 | N/.01 | 14-May | 430.23 | 0.09 | Mod | 5.2 | Y/.15 | 11-Sep | 435.29 | 0.02 | V.Low | 12.9 | N/.03 |
| Mackenzie Creek | 03-Apr | 427.54 | 0.32 | Mod | 2.5 | Y/.09 | 15-May | 430.41 | 1.67 | High | 6.9 | Y/.27 | 09-Sep | 435.56 | 0.12 | Low | 9.7 | Y/.14 |
| Nacillewaet Creek | 03-Apr | 427.54 | 0.42 | Mod | 3.5 | N/.09 | 15-May | 430.41 | 2.41 | High | 7.3 | Y/.27 | 09-Sep | 435.56 | 0.38 | Low | 9.5 | N/.14* |
| Octopus Creek | 01-Apr | 427.54 | 0.16 | Low | 4.3 | N/.05 | 13-May | 430.15 | 2.13 | High | 6.7 | Y/.27 | 10-Sep | 435.4 | 0.09 | Low | 11.7 | N/.13* |
| Payne Creek | 03-Apr | 427.54 | 0.12 | Low | 4.8 | Y/.05 | 15-May | 430.41 | 0.61 | High | 9.0 | Y/.27 | 09-Sep | 435.56 | 0.09 | Low | 10.5 | Y/.14 |
| Renata Creek | 30-Mar | 427.65 | 0.20 | Low | 2.6 | N/.05 | 14-May | 430.23 | 4.48 | High | 7.2 | Y/.27 | 11-Sep | 435.29 | 0.04 | V. Low | 9.7 | N.03 |
| Taite Creek | 01-Apr | 427.54 | 0.26 | Low | 1.9 | Y/.05 | 14-May | 430.23 | 3.81 | Mod | 4.9 | Y/.15 | 10-Sep | 435.4 | 0.07 | Low | 11.5 | Y/.13 |

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

Based on the reference passage score, tributaries were becoming accessible over the drawdown zone on around April 10, 2012 as the passage threshold (0.03) was surpassed (Figure 6). 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 in 2012. 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 0.1 indicating no passage concerns. Payne Creek and Bannock Creek were the only tributaries with available data that experienced mean daily temperatures in excess of 7.2°C as early as the end of April 2012 when passage scores were between 0.08 and 0.1. Based on stream temperatures, Rainbow Trout spawning within Arrow Lakes Reservoir tributaries in 2012 may not have occurred 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.

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 8-11). During this time passage scores were between 0.08 and 0.05 indicating that there is an increased potential for passage concerns on some tributaries.

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). The temperature dropped below 9°C towards the third week in September and below 5°C by late October to early November (Figure 6). By the final day of Kokanee passage observations (September 11, 2012), temperatures on Upper Arrow tributaries had reached or were close to 9°C, but were not consistently remaining below this temperature. From this we assume that Bull Trout spawning may have been in early stages, if it had been initiated. No adult Bull Trout were observed during 2012 field surveys, nor in the previous ones.

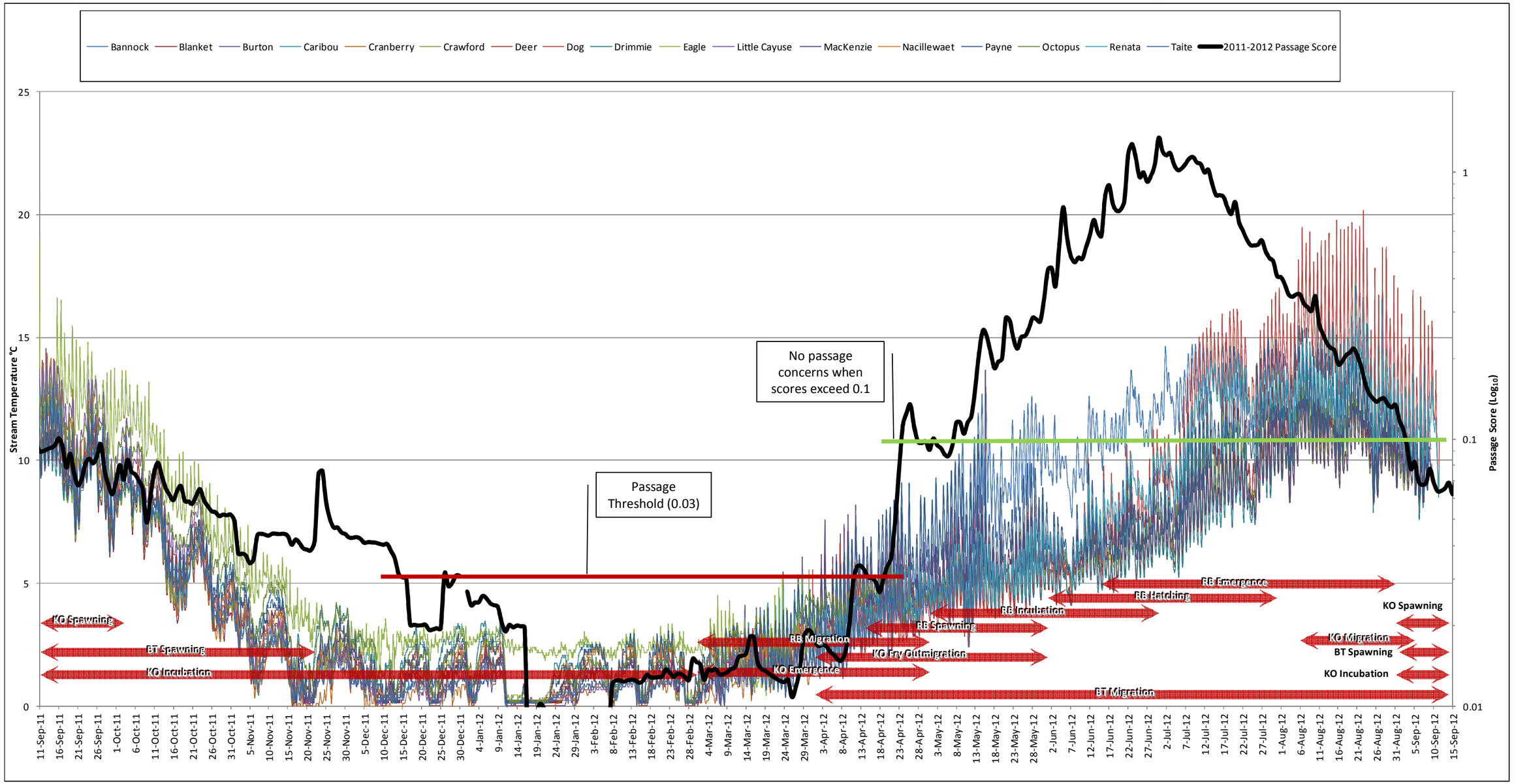



**Figure 6.** Mean daily temperatures recorded from Sept 2011-2012 with HOBO temperature data loggers on Arrow Lakes tributaries, with reference to typical life history timing of Rainbow Trout, Kokanee and Bull Trout (Shaded bands). The Passage Score for the corresponding period of record (reference creeks) is plotted on the secondary axis - illustrating the passage threshold (0.03) being surpassed on April 12 (2012) just when stream temperatures begin to reach the 5°C temperature cue for Rainbow Trout migration and spawning.

## 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. The flood-stage discharges experienced in many of the tributaries during the summer 2012, when Arrow Reservoir levels were at or near full pool, demonstrated this dynamic character (Photo Plates 4-6).

Table 6 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. New obstructions recorded in 2012 included:

- Little Cayuse; where high flows and high reservoir levels resulted in the formation of a new gravel bar at the reservoir high water level, up which fall Kokanee passage was not possible;
- Taite Creek; where, as a result of flood level discharges occurring during the period when Arrow was near full pool, the mainstem channel became plugged with bedload and debris – diverting flows through a secondary left bank channel with passage concerns; and,
- Octopus Creek; where a major debris flow (including rock debris and trees) took out the bridge and created a large, new debris fan. Octopus Creek flows were observed braiding over this new material, down a steep slope to the wetted level of Arrow Reservoir.

**Table 6. Drawdown zone obstruction features and attributes observed during 2009, 2010, 2011, 2012 tributary access monitoring. Highlighted cells indicate features/obstructions recorded in 2012 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. |
| 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. |
| 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. |
| Mackenzie | 09/09/2012 | Log Jam | Fall | 439.8 | Low | 435.6 | New LWD jam from 2012 hwl. 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. |
| 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. |
| Payne | 09/09/2012 | Persistent Debris | Fall | 441.0 | Low | 435.6 | 2012 high reservoir levels resorted 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. |
| 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. |
| | | | Median | 435.5 | | | |
| | | | Max | 441.1 | | | |
| | | | Min | 428.0 | | | |

**Photo Plate 4.** Looking upstream over the former mainstem channel of Taite Creek, now plugged with debris and sediments from flood stage discharges that occurred when Arrow Reservoir was at full pool. The flows now follow the left bank, and passage in the Fall was assessed as marginal (*left photo*). A new gravel fan formed at the upper level of the Little Cayuse Creek drawdown zone was a barrier to Fall Kokanee migration and spawning access was blocked (r*ight photo*).

**Photo Plate 5.** Looking upstream along new mainstem flows of Burton Creek (*left photo*). Large volumes of sand and gravel outwash occurred during flood stage discharges, which filled the former channel when substrates were deposited at full pool reservoir levels (*right photo*). Unlike some other tributaries, high numbers of Kokanee were observed spawning in Burton Creek in the new gravels, which before was a more coarse-textured substrate channel.

**Photo Plate 6.** Looking upstream over the former mainstem channel of Caribou Creek, which is now plugged with debris and sediment from flood stage discharges that occurred when Arrow Reservoir was at full pool. The flows now follow the left bank extents. However, there were no passage concerns (*left photo*). A debris flow occurred in the Octopus Creek drainage in summer 2012 (*right photo*). The flow of material (including rock debris and trees) took out the bridge and created a large new debris fan. Octopus Creek flows were observed braided over this new material, down a steep slope to the wetted level of Arrow Reservoir. Octopus Creek was not accessible to fish in the Fall 2012.

## 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 3 and 4 (Section 3.8.1) 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 2012, 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. Passage scores subsequently increased sharply from 0.05 on April 23 to over 0.1 on April 25– coinciding with increased reservoir levels and stream discharges.

Passage scores were low (indicating potential passage impediments) during the winter months extending into early April, based on 2009 and 2010 reservoir levels (Figure 8). In 2012, passage scores were reaching threshold levels by April 10th and plateaued at or just below the threshold level until April 20th and then began to climb quickly, with a series of successive spikes to over 0.1, above which there are no passage concerns.

Over the period of record (POR) for the reference creeks, used to establish the relative discharge curve, stream flows typically increased from Very Low to Low stage classes by early to mid March. Using the relative discharge curve developed from the POR (1984-2012), 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 2012 relative discharge score at the end of March was about the same as the period of record. With the lower reservoir levels observed in spring 2012, the matrix score indicated that the threshold of greatest passage concern (0.03) would not be surpassed until April 10.

An exception to the passage score predictions was observed in 2012, when flood level stream discharges, occurring when the reservoir was at full pool, created conditions that formed new potential upstream migration barriers. In 2012, increased passage concerns were documented on creeks where new outwash fans were formed - perched at the upper limit of the drawdown zone. These new features were observed to be fall barriers to Kokanee passage as the reservoir levels receded and streamflows dropped. Based on these observations, very high passage scores (>0.750) should be regarded as a combination of factors that may dramatically alter the character of stream mouths over the drawdown zone and create new potential barriers to upstream passage by fish as reservoir levels and flows recede (Figure 7).

| | | | Reservoir Elevation | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 428 | 429 | 430 | 431 | 432 | 433 | 434 | 435 | 436 | 437 | 438 | 439 | 440 | 441 | 442 |
| | | | 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 | 1 |
| Stage | High | 1 | 0.1936 | 0.2304 | 0.2704 | 0.3136 | 0.3600 | 0.4096 | 0.4624 | 0.5184 | 0.5776 | 0.6400 | 0.7056 | 0.7744 | **0.8464** | **0.9216** | **1.0000** |
| | Mod | 0.5625 | 0.1089 | 0.1296 | 0.1521 | 0.1764 | 0.2025 | 0.2304 | 0.2601 | 0.2916 | 0.3249 | 0.3600 | 0.3969 | 0.4356 | 0.4761 | 0.5184 | 0.5625 |
| | Low | 0.25 | 0.0484 | 0.0576 | 0.0676 | 0.0784 | 0.0900 | 0.1024 | 0.1156 | 0.1296 | 0.1444 | 0.1600 | 0.1764 | 0.1936 | 0.2116 | 0.2304 | 0.2500 |
| | V.Low | 0.0625 | **0.0121** | **0.0144** | **0.0169** | **0.0196** | **0.0225** | **0.0256** | 0.0289 | 0.0324 | 0.0361 | 0.0400 | 0.0441 | 0.0484 | 0.0529 | 0.0576 | 0.0625 |

**Figure 7.** Passage score matrix highlighting the very high scores in the upper right corner that may create new tributary passage concerns (circled red).

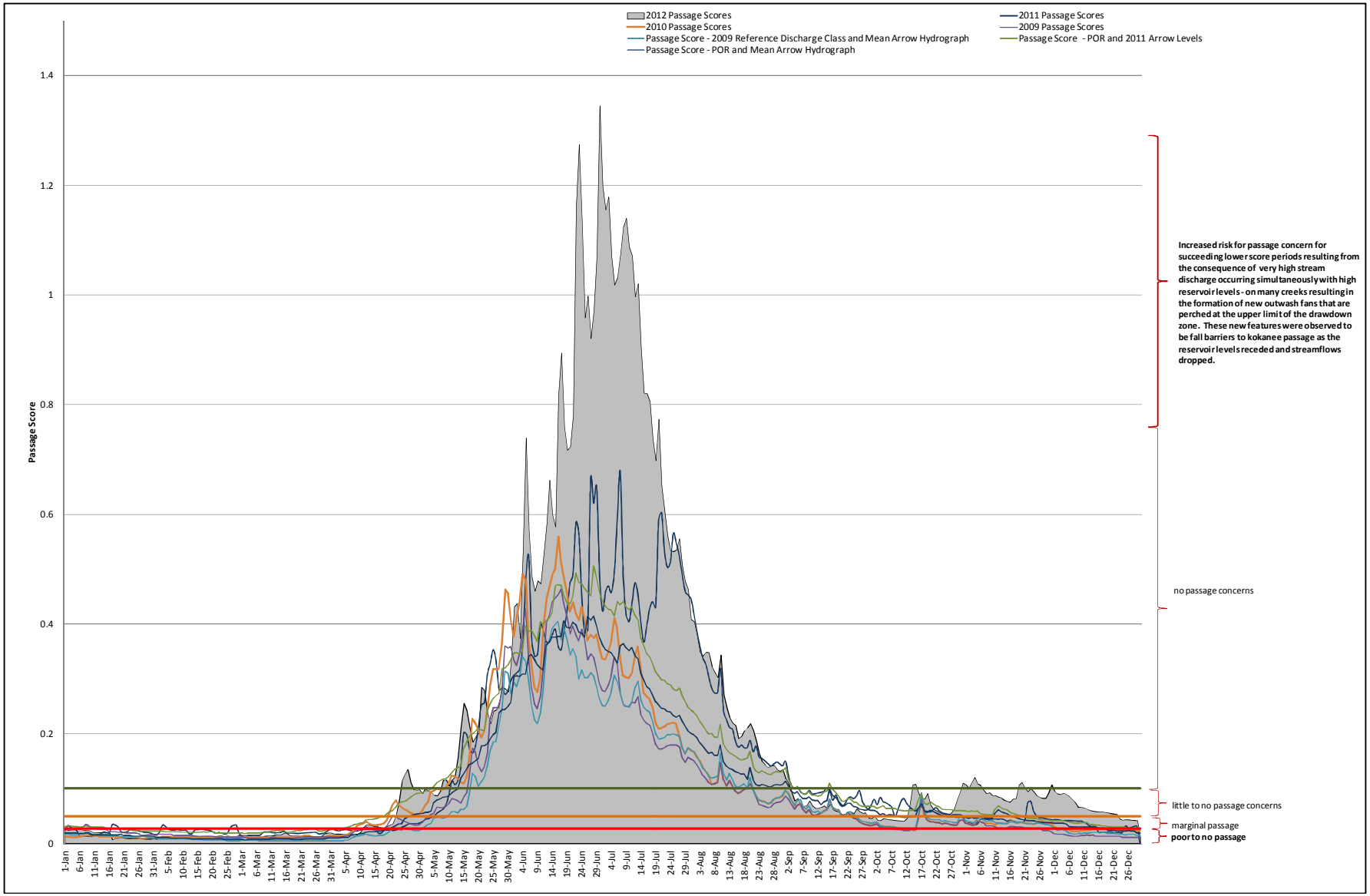



**Figure 8.** Tributary passage score plot based on the reservoir elevation: relative discharge passage matrix. The shaded curve represents 2012 passage scores based on 2012 reservoir levels and 2012 relative stream discharges.

## 4.3 Tributary Access by Focal Fish Species

The typical life history timing of Rainbow Trout, Bull Trout and Kokanee were projected over the 2012 passage score plot (Figure 9) and are discussed separately below.

### 4.3.1 Rainbow Trout Access

Passage scores, derived from the mean Arrow Lakes Reservoir hydrograph (1984-2012) 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 2012, 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 April10 (Figures 7 and 9). At this time, stream temperatures of some tributaries were just beginning to reach daily highs of 5°C. While no observations of spawning Rainbow Trout were made in 2012, passage scores had exceeded the 0.03 passage threshold by April 23 and were near 0.1 two days later when stream temperatures were sustained at 5°C. This suggests that Rainbow Trout migration would not have been impeded by reservoir operations in 2012. Field observations of key tributaries identified no passage concerns when passage scores for individual tributaries (based field measurements of stage and relative discharge measurements) were equal to or greater than 0.09.

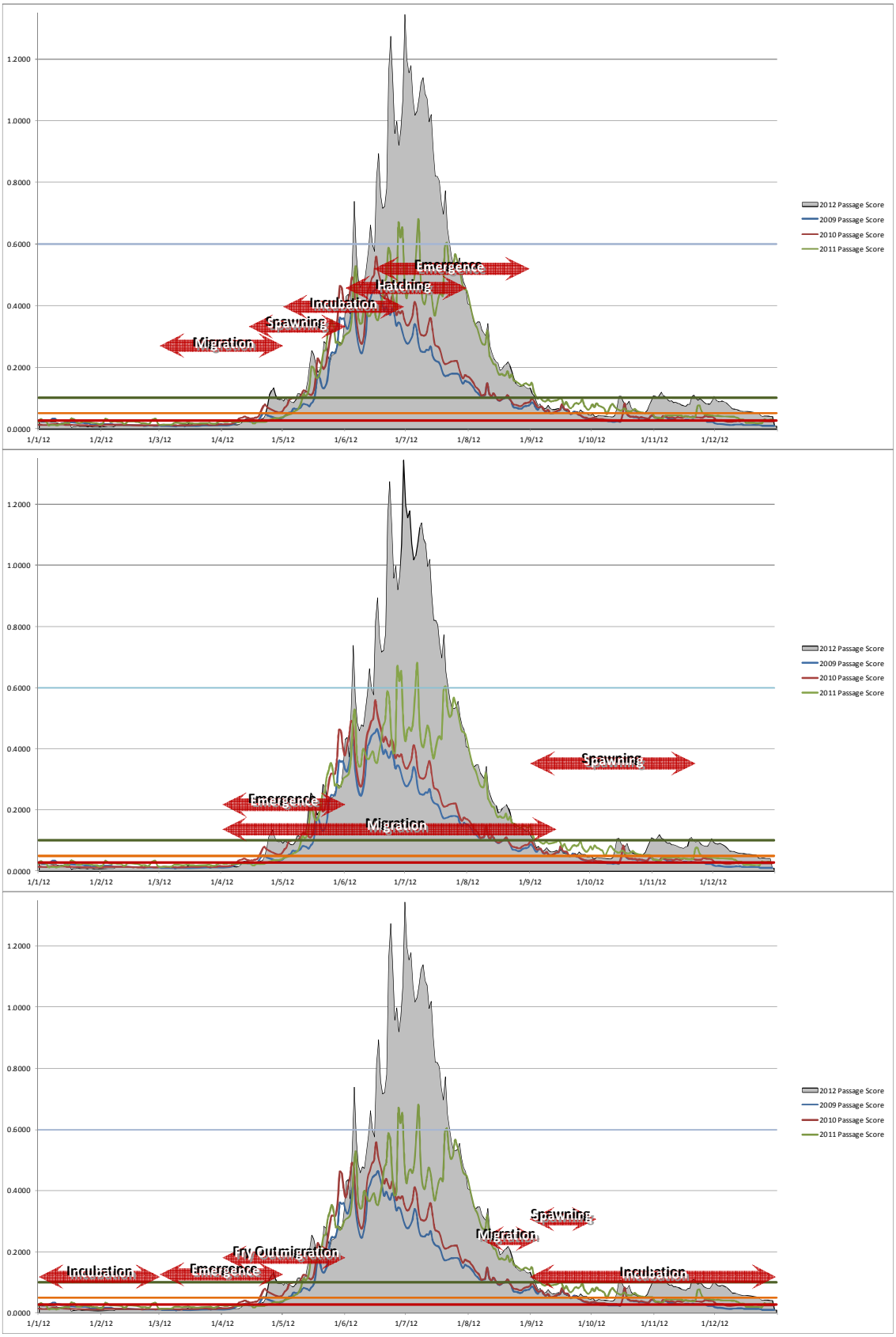



**Figure 9.** Passage score curve (from Figure 7) in relation to Rainbow Trout (top), Bull Trout (middle), and Kokanee (bottom) life histories.

### 4.3.2 Bull Trout Access

Bull Trout migrations 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 9º (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.

While juvenile Bull Trout have been observed in the drawdon zone of tributaries during previous spring passage assessments for Rainbow Trout, no adult Bull Trout have been observed during the four years of the tributary monitoring program. However, based on observed tributary temperatures in 2012, Bull Trout spawning would have likely started by early September. Temperatures of Upper Arrow tributaries were approaching 9°C (Figure 6-Section 4.0) by September 11, 2012. At this time passage scores were between 0.08 and 0.05 and remained above the 0.03 threshold through to the end of December (Figures 7 and 9) – a result of higher than average reservoir levels for this time. This suggests that Bull Trout access to Arrow tributaries was not impeded in 2012. Of the 6 tributaries identified in as being impassable during September 2012 field inspections (to Kokanee), none are known to be frequented by Bull Trout.

### 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 in the previous three years (2009-2011) of September field inspection.

During the 2012 September passage assessments, 6 of the 18 tributaries were assessed as impassable or had notable passage concerns. This was in spite of passage scores being in excess of the 0.03 passage score threshold. However, the identified obstructions on three of the tributaries (Little Cayuse Creek, Octopus Creek, Taite Creek) were new physical barriers (i.e., steep-faced gravel outwash fans) that been formed during the summer when stream flows were at flood stage and the Arrow Reservoir was at or near full pool levels. Thus these obstructions were not a consequence of the September stream flows and reservoir levels reflected in the passage scores using the matrix.

The Renata Creek drawdown zone was dry in 2010, preventing upstream migration and resulting in stranding and observed mortality of Rainbow Trout fry, longnose dace, and sculpin species. In 2012, very low flows in Renata resulted in a non-passable field designation. However, two 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 2012. In 2010, approximately 400-500 Kokanee were observed staging at the reservoir confluence with Nacillewaet Creek, and redds were noted within approximately 1 m wetted depth on. In

2011, Kokanee were documented throughout the drawdown zone of Nacillewaet Creek, primarily spawning in gravel patches along the stream margins. Similarly, no Kokanee were observed in Bannock Creek in 2012 in spite of good passage conditions (P = 0.14), where they had been documented spawning in 2011.

## 4.4 Drawdown Zone Spawning and Associated Habitat

In addition to tributary fan passage conditions, suitable spawning substrates for Rainbow Trout and Kokanee within the drawdown zone were identified and surveyed in 2009. The average elevation of suitable spawning sites within the drawdown zone was 433.6 m (maximum 439.6, minimum 429.3, median 432.5).

### 4.4.1 Rainbow Trout Drawdown Zone Utilization (Spawning)

In 2012, reservoir levels had inundated potential spawning habitats in the drawdown zone up to the mean surveyed elevation by early June (Figure 10) with the entire drawdown zone being inundated by the end of June. Based on the mean hydrograph, sites situated above the mean elevation of identified spawning sites (433.6 m) have the potential for successful incubation and hatching. However, this would be contingent upon ideal incubation conditions – ensuring an early hatch and subsequent emergence from gravels prior to inundation by rising reservoir levels, which could result in siltation of redds, reduced levels of dissolved oxygen and potential egg/alevin mortality. Complete inundation of the drawdown zone in 2012 had occurred by about the mid-point of the Rainbow Trout hatching period. Considering the high stream flows that were observed during this period, high siltation at tributary confluences may have had adverse effects on successful incubation and hatching if spawning had occurred in the drawdown zone prior to inundation.

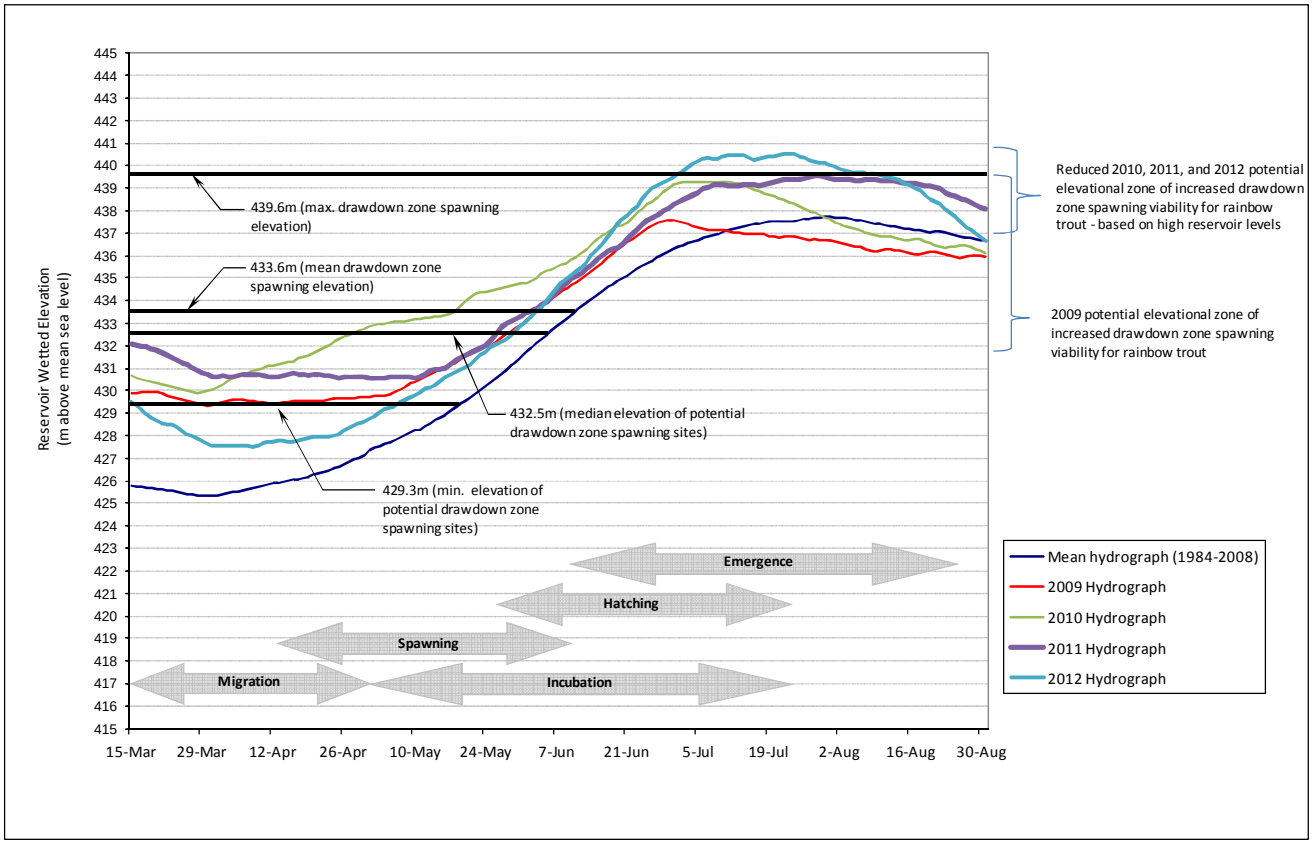



**Figure 10.** Life history timing of Rainbow Trout projected over the Lower Arrow Reservoir (LARL) hydrograph at Fauquier. The figure illustrates the elevation range of documented habitat units during the 2009, 2010, 2011, and 2012 survey periods with spawning suitability in the drawdown zone.

### 4.4.2 Kokanee Drawdown Zone Utilization (Spawning)

While drawdown zone spawning was observed in five (5) tributaries in 2009, Kokanee were observed to be spawning in the drawdown zone of 13 of the 19 tributaries in September 2010 (Table 7). Drawdown zone spawning was not confirmed in Caribou, Burton, Bannock and Mackenzie Creeks, although there were suitable substrates. In 2010, Kokanee spawning was not possible in Renata Creek due to very low to subsurface flows throughout the drawdown zone. In some watercourses, such as Octopus, Blanket, and Nacillewaet Creeks, spawning was noted to occur within or near the reservoir wetted level. Nacillewaet Creek was also observed to have shoal spawning potential in 2010, as several hundred Kokanee were staging at the reservoir confluence, but it was unknown whether all would be able to ascend the step-pools and cascades associated with large woody debris above the reservoir wetted level.

During the 2012 September passage surveys (September 8-11), the mean daily reservoir elevation was about 435.5 m. Drawdown zone spawning was not prevalent during the 2012 inspections, with occurrences near the upper limit of the drawdown zone in 6 of the 18 tributaries.

While one of the prominent observations during the September surveys was the negative effect that summer high flows and reservoir levels had on fall passage, the potential positive effect of gravel recruitment for improved spawning habitat condition was less apparent. This was documented in Burton Creek, where large volumes of gravel (outwash) were deposited at full pool reservoir levels. Unlike some other tributaries, high numbers of Kokanee were observed spawning in Burton Creek in the new gravels, which before was a more coarse-textured substrate channel. In previous years Kokanee spawning in Burton Creek hadn't been observed until about 200m further upstream and in smaller aggregations among large woody debris and residual pools where suitable substrates were present.

The primary concern with drawdown zone and shoal spawning behaviour is that egg stranding and desiccation may occur as reservoir levels recede over the winter months. In some instances, such as in Blanket Creek, Kokanee were spawning within the wetted level of the reservoir in 2011. Unless the eggs are deposited in the thalweg of the creek, they may become stranded as the reservoir levels drop - depending on how the stream channel changes during drawdown. No shoal spawning Kokanee were observed in 2012.

Kokanee eggs typically incubate for a period ranging from 39 to 140 days from September to March and remain in the gravel until alevins have absorbed their yolk sac (Ford et al. 1995). Hatching generally occurs in March with fry emergence occurring between March and May (Ford et al. 1995). In the Arrow Lakes Reservoir, fry outmigration generally occurs between mid-April and mid-June (R L and L Environmental Services, 1997; Schindler et al., 2006; Manson, 2005). Therefore, with reservoir elevations dropping between October and May, and stream flows not typically increasing until freshet between April and June, developing Kokanee within the drawdown zone are particularly vulnerable to stranding. Additionally, the braided nature and subsequent shallow water depths experienced in the majority of the tributary fans may also contribute to potential for mortality from freezing or lack of oxygen if flows are insufficient. There is also the potential for impoundment and stranding, given the dynamic nature of substrates within braided drawdown zones. In spite of these concerns increasing flows by mid April 2012 resulted in passage scores surpassing the impasse threshold (0.03) thereby improving outmigrating conditions for Kokanee.

**Table 7.** Arrow Lakes Reservoir 2012 drawdown zone spawning observations

| Tributary | Drawdown Spawning | Comments |
|---|---|---|
| Dog Creek | No | Very low flows and warms stream temperatures |
| Renata Creek | No | Very low to dry conditions throughout drawdown zone and no opportunities for fish passage in the fall. Unsuitable for RB spawning |
| Johnston Creek | Yes | Kokanee observed spawning in upper limits of drawdown zone in gravel pockets among boulders. |
| Caribou Creek | Yes | High Kokanee spawning use in upper drawdown zone in new gravel substrates recruited during very high summer stream discharges-occurring simultaneously as high reservoir levels. However, the 2013 freshet is expected to scour out much of this gravel downstream (during lower reservoir levels). |
| Burton Creek | Yes | |
| Taite Creek | No | High summer steam discharge 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 a reduced habitat value. |
| Octopus Creek | No | A summer debris flow completely re-shaped the fan, downing trees, blowing out the bridge and resulted in flows sheeting over the new fan and down a steep bank to the reservoir level. As a result, no fall Kokanee passage was possible. |
| Deer Creek | No | Lower Kokanee number observed in 2012. Fish observed in drawdown zone appeared to be moving upstream with no spawning behaviour exhibited. |
| Little Cayuse Creek | No | Steep gravel bar, formed during high flows and reservoir high reservoir levels, prevents fall upstream Kokanee passage. A single Kokanee was observed in a small plunge pool below the new obstruction. No drawdown zone spawning was documented. |
| Bannock Creek | No | No drawdown zone spawning was documented. |
| Cranberry Creek | No | Good fall passage conditions and large volume of new gravel would be suitable for spawning in upper limit of the drawdown zone. However, no Kokanee were observed during the 2012 inspection, which may have had to do with warm stream temperatures (11.4°C). |
| Blanket Creek | No | No Kokanee or redds observed until upstream of the drawdown zone. Similar to other systems, a large sand/gravel bar had formed at the upper limit of the drawdown zone during the 2012 full pool level. In spite of this gravel recruitment no Kokanee utilization observed. |
| Drimmie Creek | Yes | Potential Kokanee spawners observed in upper limit of drawdown zone. |
| Crawford Creek | No | No Kokanee observed through the drawdown zone. |
| Mackenzie Creek | No | No Kokanee observed through the drawdown zone. |
| Payne Creek | Potential | Kokanee holding among dense LWD in upper limit of drawdown zone. No fish were observed below this point. |
| Nacillewaet Creek | No | No Kokanee observed staging or spawning in 2012. |
| Eagle Creek | Yes | No Kokanee observed in drawdown zone, which was assessed as impassable. |

# 5.0 SUMMARY OF 2012 TRIBUTARY ACCESS MONITORING

The previous four (4) 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. The high vertical fluctuations of the reservoir contribute to channel instability, aggrading and braiding, in some tributary fans. 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 around the onset of Kokanee migration and spawning in early September. 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. This reduced access is a result of low to very low stream flows and wider, more poorly defined channels that are prevalent over the drawdown zone in some tributaries.

**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 – 0.05. At a passage score of 0.05, about half of the tributaries will have migration barriers in the drawdown zone and below 0.03, there is a high risk that tributaries will not be accessible to fish. During Kokanee migration and spawning, the current soft operating constraint of 434 m represents a key elevational threshold. The observed very low stream flows that occur late August – early September results in passage scores of about 0.03 when Arrow Reservoir is at 434 m.

Reservoir elevation passage thresholds are dependent on stream flows that occur during the same point in time. The 2010-2012 stream temperature monitoring suggests that spring Rainbow Trout migrations may not occur until mid-April. 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 Migrations were initiated in late March to early April when flows are still low to very low.

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

Spring surveys in 2012 were mostly completed prior to Rainbow Trout migration when stream temperatures were approaching 5°C and stream stages were still low. Passage concerns were noted in March/April in 8 of the 18 creeks at mean reservoir elevations of 427.5 m. Between mid-April and late May, when tributaries were consistently reaching 5°C, the mean daily reservoir elevations climbed from 427.7 to about 432 m. Stream flows were also increasing accordingly with spring runoff. The effect of increased stream flows was demonstrated in the passage matrix in 2012, where a sharp increase in the relative discharge of reference creeks resulted in passage scores jumping from the low passage threshold of 0.03 to over 0.1 in under three days between April 23 – 26. This was also observed on tributaries that experience earlier seasonal runoff and increased flows such as Mackenzie Creek, which had moderate flows occurring by the beginning of April and a passage score of 0.09 – with no passage concerns identified. Therefore, consistent with observations from previous years, high stream flows in tributaries in the spring can mitigate potential impacts of low reservoir elevations.

# 6.0 RECOMMENDATIONS

## 6.1 2013 Passage Monitoring

The following bullets highlight the recommended scope of monitoring for 2013:

- Hydrological assessments should be continued on all key tributaries being monitored to improve tributary specific discharge curves to allow a better understanding of the potential flow thresholds in individual tributaries at which passage may become hindered.

- Drawdown zone biophysical mapping and change monitoring should continue so that annual changes can be measured and quantified as the 5-year monitoring program continues.

- Topographic surveys should be carried out again to illustrate spatial and potential elevation shifts of tributary fans to enable an assessment of the relative stability of stream channels within the drawdown zone. Attention should be focussed on tributaries where new barriers were formed during 2012 high flow events to document how subsequent freshet re-scoured the channels and distributed substrates that had deposited in a fan at the upper limit of the drawdown zone. This exercise will help in the refinement of identifying reservoir elevation thresholds – notably the elevation thresholds above which channel braiding is decreased and or the elevation at which low flow barriers exist.

- Potential areas for drawdown zone spawning should be surveyed during the spring of 2013. Given the challenges associated with adult Rainbow Trout (spawner) detection during high stream flows, underwater inspections to detect fish presence (emulating a snorkel survey) should be facilitated using an AquaVu® HD system fitted to a telescopic boom. Underwater inspections will focus along the river banks and among structure (i.e., in deep pools and among LWD). In September areas of observed Kokanee drawdown zone spawning should be mapped during the September surveys.

- Collection of temperature data has been a cost effective means for collecting and charting daily and seasonal temperature changes, which are important cues for fish life history timing. Continuous temperature monitoring will refine the temperature profiles and assist in the identification of migration onset temperature cues. For data quality control and assurance, data retrieval should continue to occur during each monitoring period. This reduces the risk of data loss associated with high stream flows and potential damage or loss of data loggers.

## 6.2 Tributary Fan Enhancements through the Drawdown Zone

In 2009, close to 60% of the potential spawning sites recorded were associated with anchored (root wads) and embedded large woody debris and associated scour pools. Adjacency to cover in the drawdown zone may provide increased shelter from predation, as well as substrate retention and stability.

Physical alteration of stream channels within the drawdown zone fans may be the most viable approach to maintaining or improving tributary access during periods of potential passage impairment. As indicated by Hawes and Wagner (2010), this may be accomplished through installation of channel controlling structures, and restoration and maintenance of a more defined channel in areas where passage is currently impeded by braiding and subsequently potential low flow barriers. Simultaneously, these works may provide more structural cover for fish migrating through the drawdown zone, thereby helping to alleviate potential increased predation pressure, which may be exacerbated by shallow braided flows and migration bottlenecks with little cover. This is supported by other studies including that by Cunningham et.al. (2002) who concluded that levels of predation may be elevated near natural obstructions to fish migration, where there is little cover for adult fish and where streams become shallower.

Tributaries containing rooted stumps and other anchored structures through the drawdown zone fan (e.g., Cranberry, Payne, and Mackenzie Creeks) tended to have improved channel scour as a result of these features, thereby maintaining a more defined and passable channel, and at the same time contributing to fish habitat values. Consistent with the recommendations by Gebhart (1999), debris providing fish habitat values should not be removed unless they become unstable. The design and placement/anchoring of structures

through the unstable drawdown zone may function to reduce channel braiding and help to maintain a more defined thalweg. Emulating the function of rooted tree stumps and rootwads may be a viable option with the use of untreated timber piles placed/driven strategically to influence fluvial morphology.

While not a component of the CLBMON-32 monitoring program, it is recommended that the viability of creating and maintaining stable habitat structures within the drawdown zone be explored. These features (boulders, pilings, engineered LWD jams, etc.) would serve multiple functions:

1. Help to physically confine the channel through installation of rock, berm or bioengineering strategies, with the goal of reducing extensive channel braiding that increases the risk of low flow passage barriers over fans.

2. Provide local channel scour and cover/habitat for fish as they migrate both up and down the fans. In addition to providing resting habitat, this cover may allow some protection from predation, particularly that experienced by spawning Kokanee. Predation by species such as bald eagle (*Haliaeetus leucocephalus*), osprey (*Pandion haliaetus*), gull species, common mergansers (*Mergus merganser*) and grizzly bear (*Ursus arctos*) have been observed throughout the monitoring program.

3. Create potential retention of higher water depths and residual pools which could reduce stranding of eggs, alevin and fry life stages as reservoir levels fluctuate.

During the 2011 tributary passage surveys, drawdown zone cover and braiding extents were reviewed for each watercourse. Time was taken to determine which tributaries could potentially be utilized as trial sites for establishing increased drawdown zone cover, with the goal of improving tributary passage and habitat condition. On more coarsely textured and aggraded alluvial fans (e.g., Eagle Creek), physical alterations (periodic channel excavation to mitigate aggrading through drawdown zone) may be a more feasible and practical approach to restore/maintain tributary access for fish.

Tributaries which would be good candidate sites for structural habitat enhancement within the drawdown zone include Drimmie Creek in the Upper Arrow Reservoir and Eagle Creek in the Lower Arrow Reservoir.

In the Upper Arrow Reservoir, Drimmie Creek could benefit from instream modifications above the culvert crossing, where cover is largely limited to overhanging grasses, small undercut banks and boulder cover associated with riprap armouring along the left bank channel extents. These cover types occur largely along the right and left bank extents and cover is further limited to absent over much of the braided fan. Drimmie Creek would be easily accessible for implementation of instream works and would also be visible to the public for interpretive education opportunities. Drimmie Creek provides habitat to Kokanee, Rainbow Trout and Bull Trout. Accessible habitat has been reported as being approximately 1 km before a natural access barrier (BC Hydro 1992; Andrusak and Slaney 2004), while 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). While prescriptions were not developed as part of the 2011 work program, options may include

confining intensely braided sections through the use of a berm in combination with riprap placement and/or tree revetments. Pile driving of untreated fir piles or anchoring of LWD and root wads across the drawdown zone would provide additional habitat complexity and encourage scour pools.

Similar treatments could be applied to Eagle Creek in the Lower Arrow Reservoir, where the expansive braided fan throughout the drawdown zone has repeatedly been identified as a passage concern during spring and fall of each monitoring year during low to very low stream flows. If drawdown zone navigation is feasible, Kokanee would have access to approximately 4.3 km of Eagle Creek before a 2 m barrier to fish passage (Seaton 1978), while Bull Trout could navigate this barrier and potentially access 9.2 km (Seaton 1978; Lindsay and Seaton 1978) of stream length. The habitat potential, combined with accessibility for implementation of instream works and public visibility makes Eagle Creek a good candidate for a trial restoration site. Instream cover within the Eagle Creek drawdown zone is essentially absent, with deeper water and boulder cover along the left bank associated with the riprap dyke providing the most significant cover below the high water level.

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# TRIBUTARY MAPS AND DATA

# Bannock Creek

## Year 5 (2012) 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: | April, 2013 |
| Survey Date: | April 3, May 15, and September 9, 2012 |

## Legend

- Fish Habitat
- Obstruction
- Reservoir Elevation Level
- Hydrometric Location (2010) / Cross Section Location
- Temperature Logger
- Stream Limits (April, 2012)
- 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 Sarsey, 2004). The stream has been classified as a low value stream (del Bleaan and Ost, 2003), 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 identified barriers, spawning habitats within the stream may be limited by the depth of pools and siltation due to upstream forestry practices (del Bleaan and Ost, 2003; RL & L Environmental Services, 2002). 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 downstream zone was not an issue during 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.

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.

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Meters
1 : 5 0 0

BC hydro

ECOSCAPE Environmental Consultants Ltd.

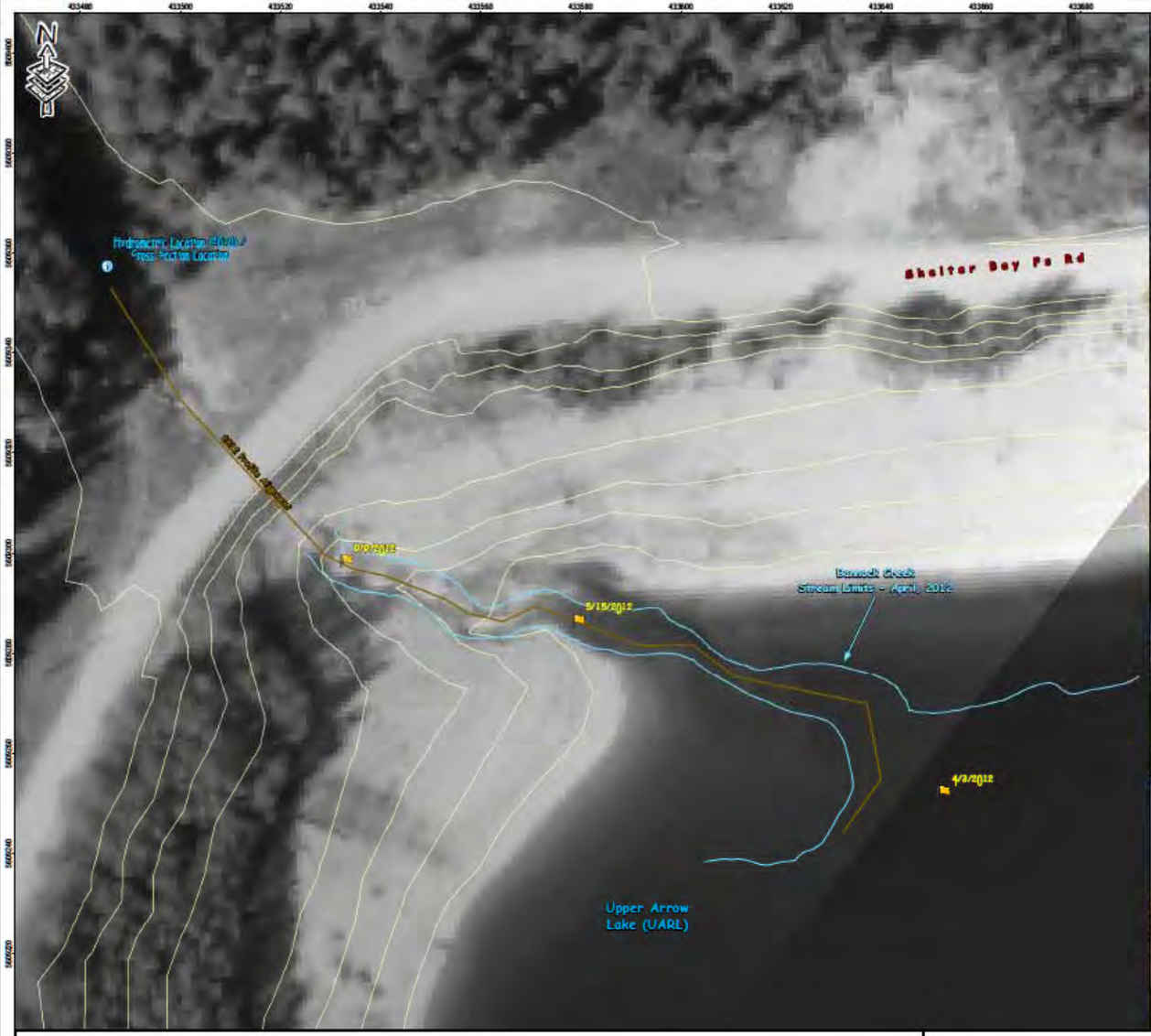




Photo: P1060102 - Taken from culvert looking downstream over Bannock Creek drawdown zone (April 3, 2012).


Photo: P1060106 - Looking upstream along Bannock Creek drawdown zone (April 3, 2012).


Photo: P1060066 - Looking upstream towards cross section location (April 3, 2012).


Photo: P1070313 - Looking downstream along Bannock Creek drawdown zone (May 15, 2012).

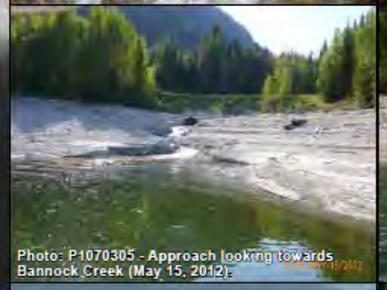


Photo: P1070305 - Approach looking towards Bannock Creek (May 15, 2012).

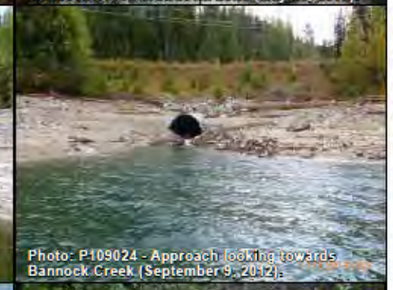
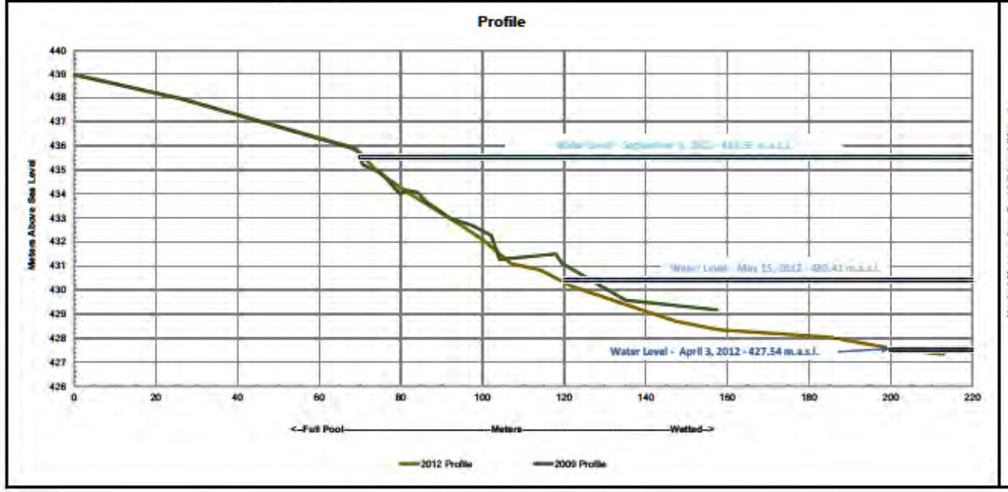
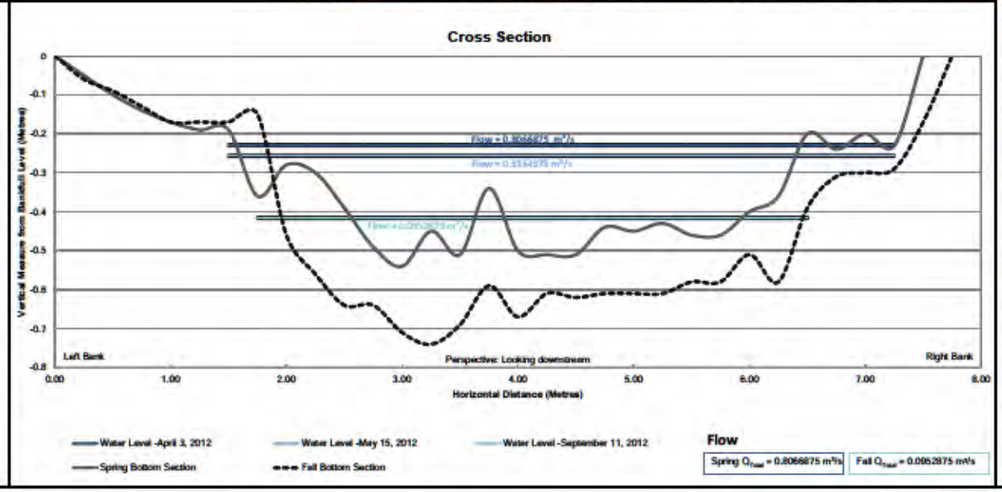


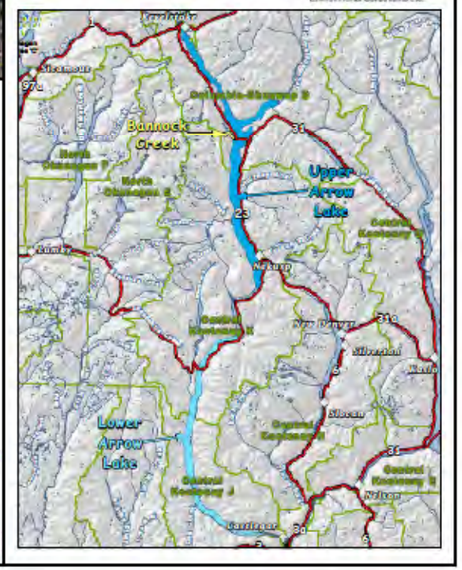
Photo: P109024 - Approach looking towards Bannock Creek (September 9, 2012).


Photo: P1090028 - Looking downstream along Bannock Creek drawdown zone (September 9, 2012).


Photo: P1090036 - Looking upstream towards cross-section location (September 9, 2012).



# Blanket Creek

## Year 5 (2012) 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: | April, 2013 |
| Survey Date: | April 4, May 16, and September 8, 2012 |

## Legend

- Fish Habitat
- Obstruction
- Reservoir Elevation Level
- Hydrometric Location (2010) / Cross Section Location
- Temperature Logger
- Stream Limits (April, 2012)
- 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.

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.



Photo: Panorama taken from Blanket Creek left bank (April 4, 2012).


Photo: P1070348 - Looking upstream over the drawdown zone (May 16, 2012).


Photo: P1070343 - Looking downstream over the drawdown zone (May 16, 2012).


Photo: P1070363 - Looking upstream towards cross section location (May 16, 2012).


Photo: P1080904 - Approach looking towards Blanket Creek (September 8, 2012).


Photo: P1080908 - Looking upstream from Blanket Creek left bank (September 8, 2012).


Photo: P1080927 - Looking upstream towards cross section location (September 8, 2012).

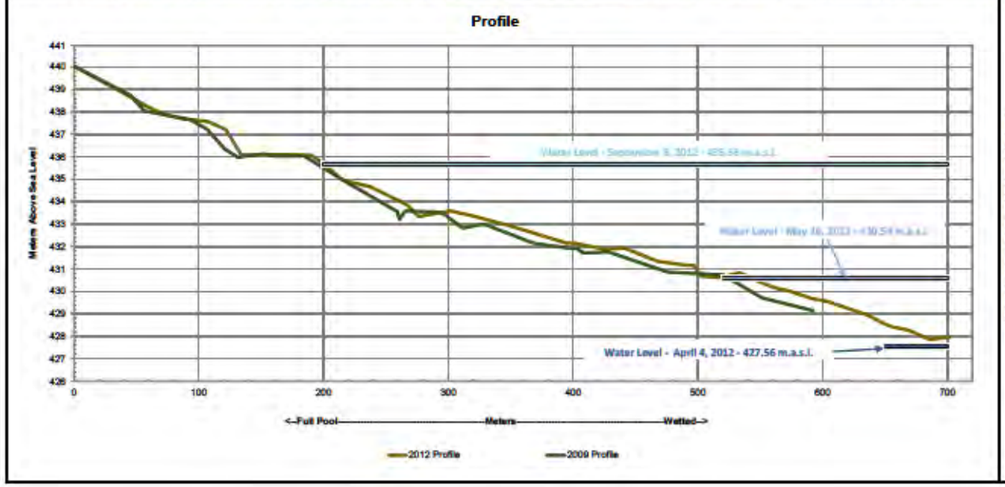
30 15 0 30 60 90 120 150

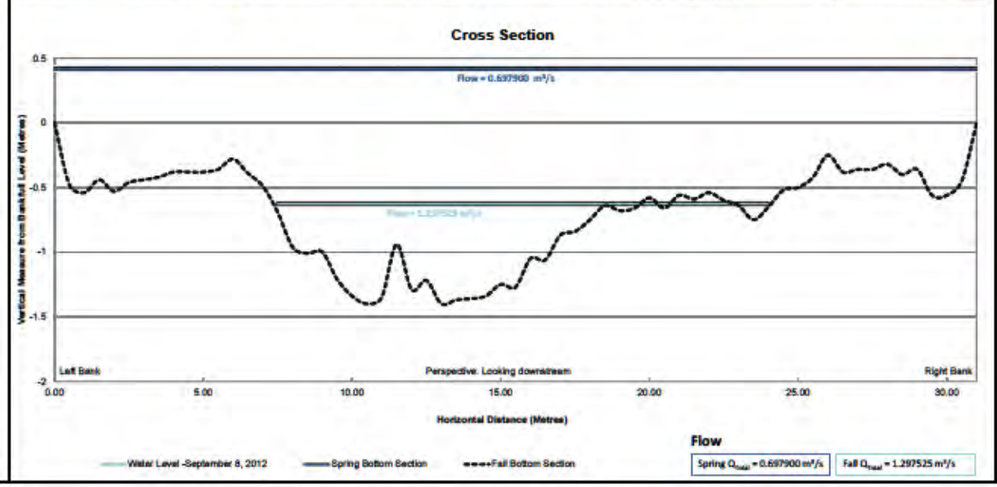
Meters

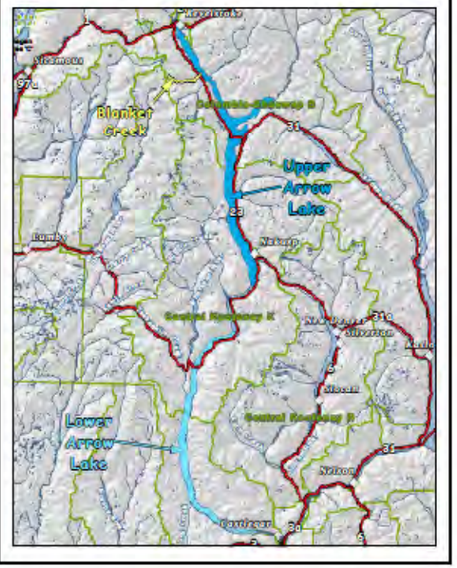
1 : 1,600

BC hydro

ECOSCAPE Environmental Consultants Ltd.



# Burton Creek and Caribou Creek Confluence

## Year 5 (2012) 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: | April, 2013 |
| Survey Date: | April 2, May 13-14, and September 10, 2012 |

## Legend

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



Photo: Panorama taken from left bank looking over Caribou and Burton drawdown zones (April 2, 2012).


Photo: Panorama looking downstream over Caribou and Burton drawdown zone from highway bridge (April 2, 2012).


Photo: Panorama looking downstream from highway bridge over inundated drawdown zone (May 15, 2012).


Photo: Panorama looking downstream from highway bridge over inundated drawdown zone; no passage concerns (September 10, 2012).

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 (R. and I. Environmental Services Ltd, 1987).

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 downtown 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. On September 10, 2009 greater 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.

2012 Observations:

April 3, 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 shooting 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 10, 2012 - The reservoir level extended upstream beneath an Highway 6 bridge beyond the confluence of Burton and Caribou Creeks. There were no passage concerns noted.

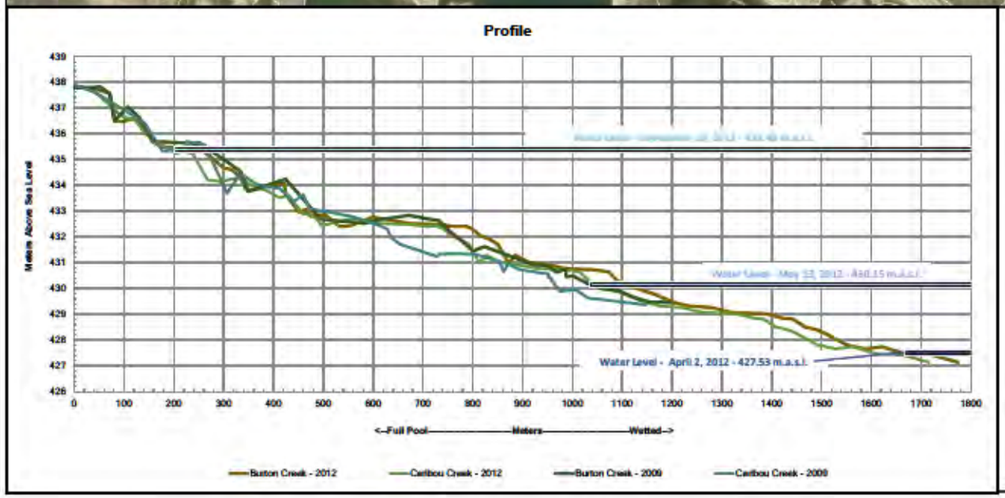
40 20 0 40 80 120 160 200

Meters

1 : 2 , 2 5 0

BC hydro

ECOSCAPE Environmental Consultants Ltd.




Hydrometric cross-section was not completed.



Photo: Panorama taken from highway bridge looking upstream over Burton Creek (April 12, 2012).


Photo: P1070180 - Taken from highway bridge looking upstream over Burton Creek (May 15, 2012).

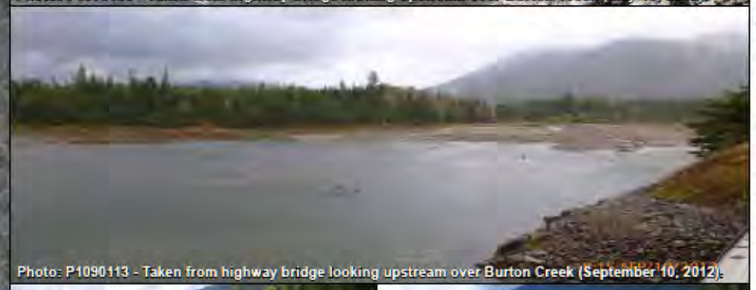


Photo: P1090113 - Taken from highway bridge looking upstream over Burton Creek (September 10, 2012).

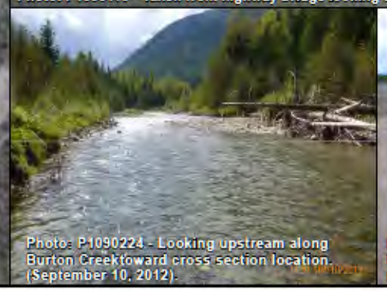


Photo: P1090224 - Looking upstream along Burton Creektoward cross section location. (September 10, 2012).


Photo: P1090190 - Looking downstream over Burton Creek toward highway bridge (September 10, 2012).

# Burton Creek

**Year 5 (2012) 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: | April, 2013 |
| Survey Date: | April 2, May 14, and September 10, 2012 |

## Legend

- Fish Habitat
- Obstruction
- Reservoir Elevation Level
- Hydrometric Location (2010) / Cross Section Location
- Temperature Logger
- Stream Limits (April and September, 2012)
- 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 (R. and I. Environmental Services Ltd, 1987).

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. On September 10, 2009, greater than 10,000 staging kokanee were observed in this pool, along with at least four (4) adult bull trout (observations made during snorkel surveys).

2012 Observations:

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

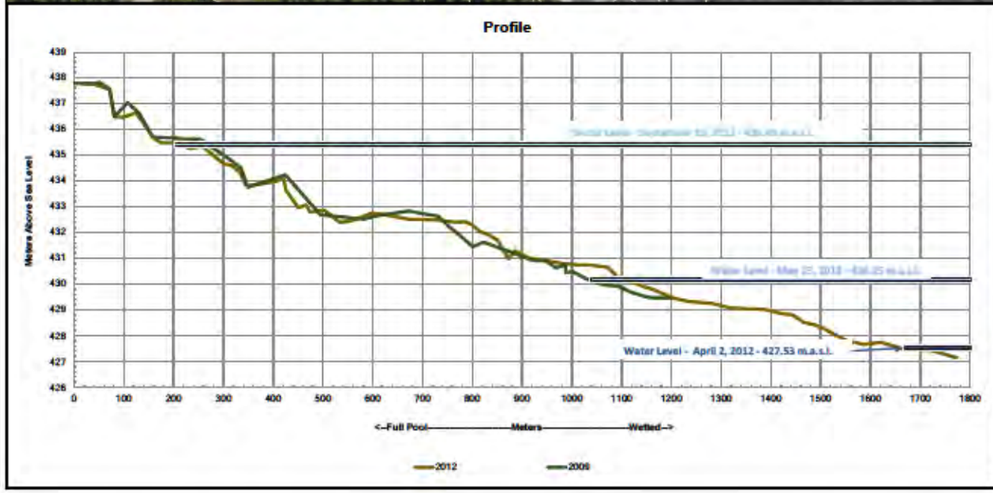
May 12, 2012 - Passage concerns were not observed at the moderate to high flows.

September 10, 2012 - Large sediment deposition and beach formations were observed as a result of very high stream flows occurring simultaneously at 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 scouring 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.

50 25 0 50 100 150 200
Meters
1 : 2,000

BC hydro

ECOSCAPE
Environmental Consultants Ltd.



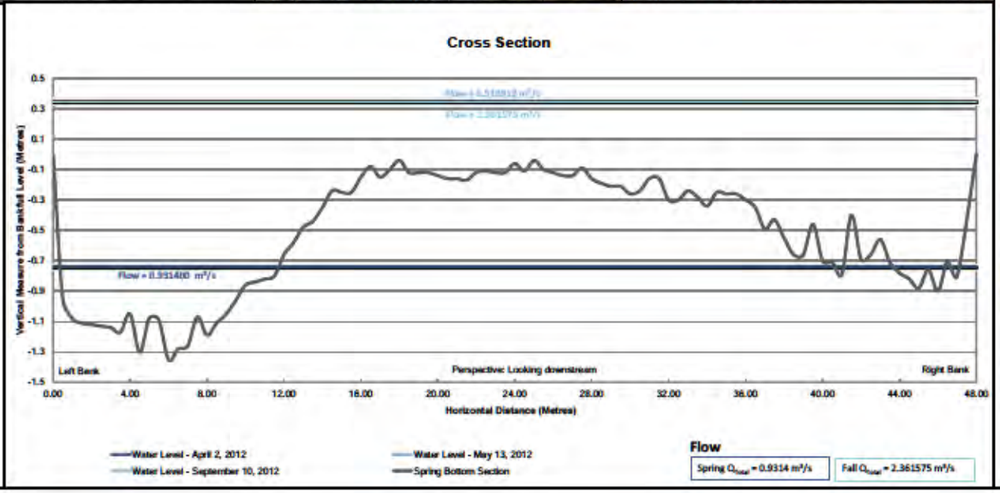





Photo: Panorama looking upstream from highway bridge over Caribou Creek (April 2, 2012).

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

Photo: P1090127 - Looking downstream toward highway bridge from left bank (September 10, 2012).

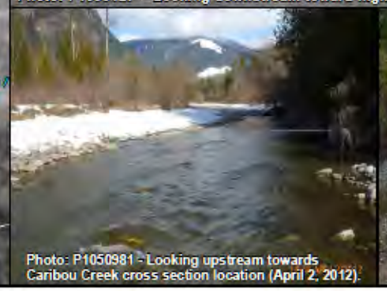


Photo: P1050981 - Looking upstream towards Caribou Creek cross section location (April 2, 2012).

Photo: P1090133 - Looking downstream towards Caribou Creek cross section location (September 10, 2012).

# Caribou Creek

**Year 5 (2012) 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: | April, 2013 |
| Survey Date: | April 2, May 14, and September 10, 2012 |

## Legend

- Fish Habitat
- Obstruction
- Reservoir Elevation Level
- Hydrometric Location (2010) / Cross Section Location
- Temperature Logger
- Erosion
- 2012 Profile Alignment
- Stream Limits (April and September, 2012)
- 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 2008 survey period. While the bar 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/fish was of concern, the deep pool beneath the Highway 6 bridge provides significant cover for staging fish. On September 10, 2008 greater than 10,000 staging kokanee were observed in this pool along with at least four (4) adult bull trout (observations made during snorkel surveys).

2012 Observations:

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

May 3, 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).

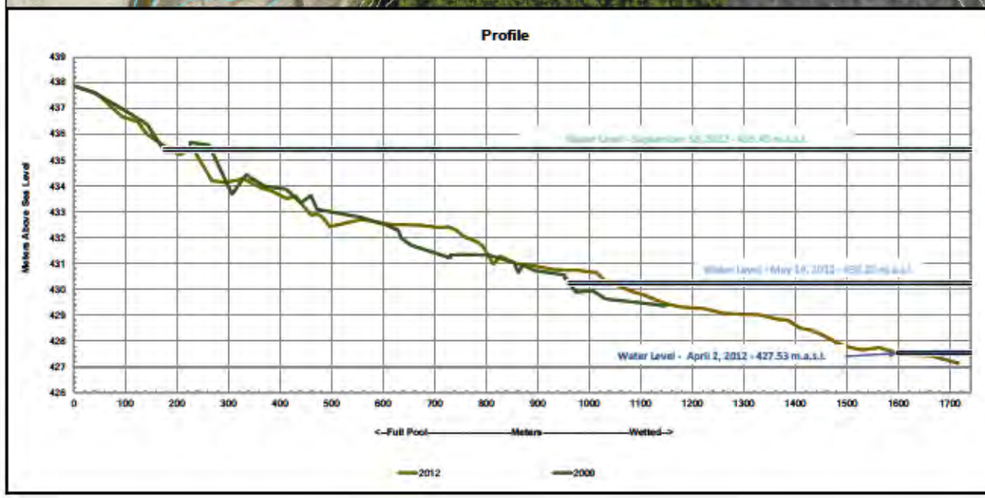
30 15 0 30 60 90 120 150

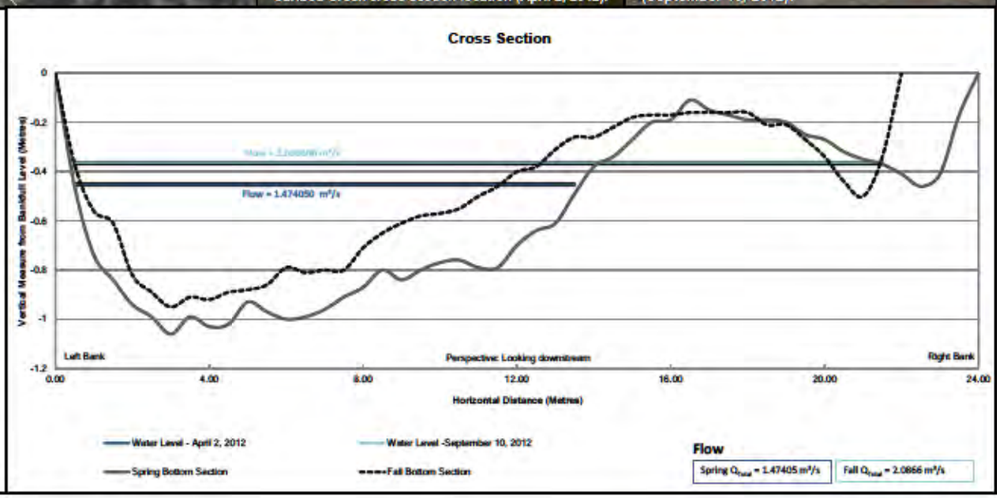
Meters

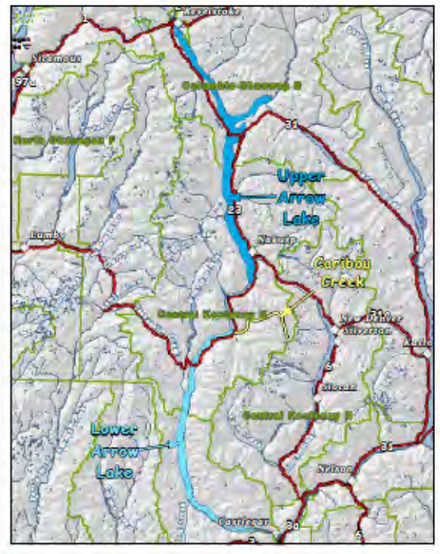
1 : 1,250

BC hydro

ECOSCAPE Environmental Consultants Ltd.



# Cranberry Creek

## Year 5 (2012) 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: | April, 2013 |
| Survey Date: | April 5, May 15, and September 9, 2012 |

## Legend

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

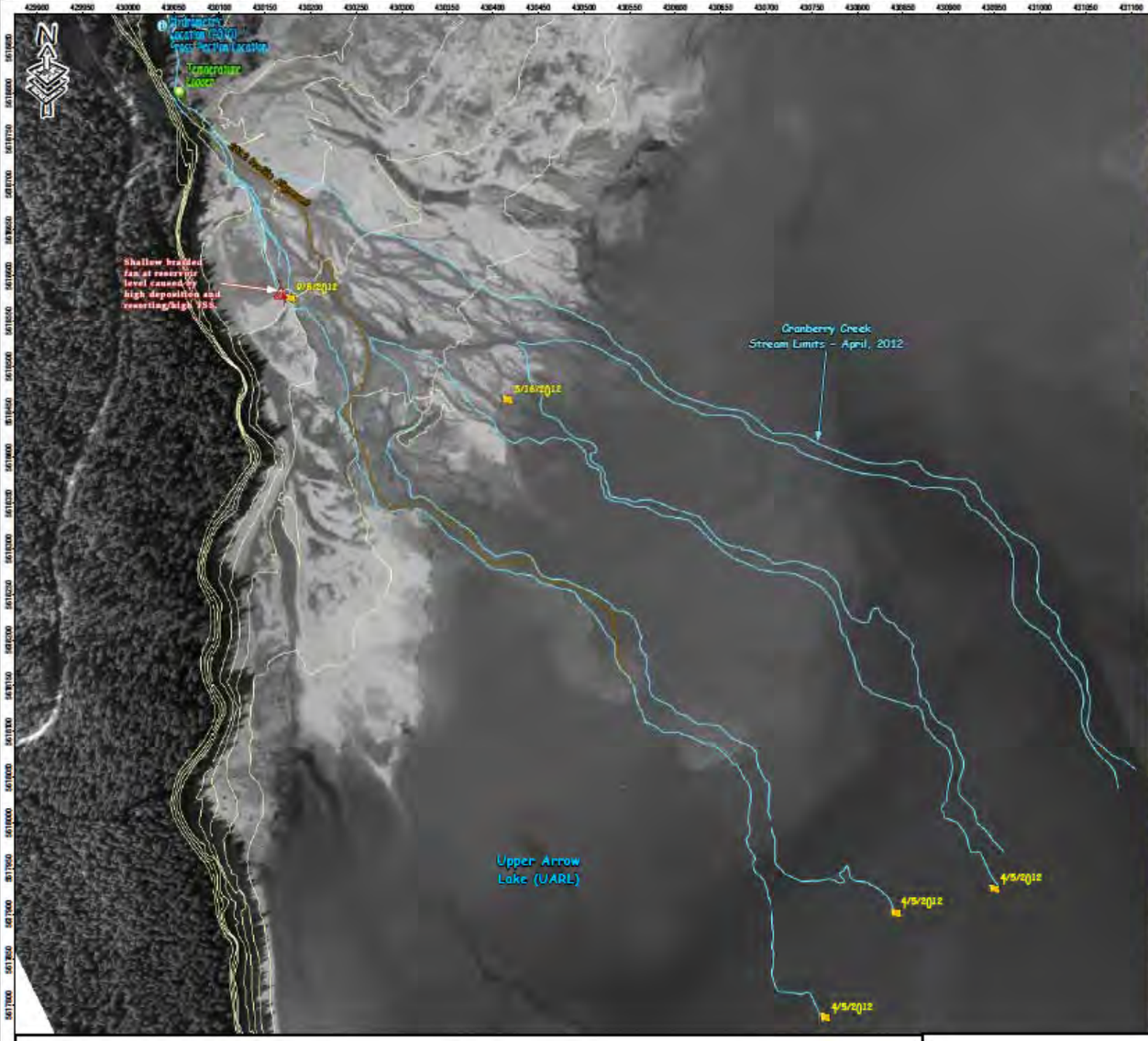




Photo: P1060261 - Looking upstream at Cranberry Creek cross section location (April 5, 2012).


Photo: P1060263 - Looking downstream along Cranberry Creek towards UARL (April 5, 2012).


Photo: P1060272 - Looking doenstream towards large woody debris and stumps providing cover and stability within the drawdown zone (April 5, 2012).


Photo: P1070398 - Looking downstream towards confluence of UARL wetted level and Cranberry Creek (May 16, 2012).


Photo: P1070414 - Looking upstream at Cranberry Creek cross section location (May 16, 2012).


Photo: P1090041 - Approaching Cranberry Creek (September 9, 2012).


Photo: Panorama - Looking from right bank at confluence of Cranberry Creek and UARL (September 9, 2012).

In the spring of 2009, flows were too high to sample for 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, 2008, 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.

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 15, 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/reworking and high TSS. Erosion and channel migration was observed along the left bank.

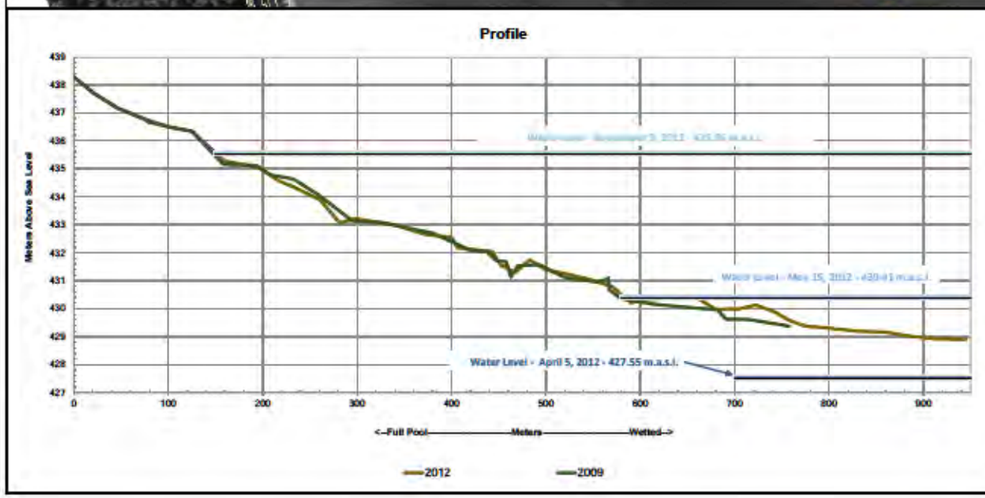
60 25 0 60 100 150 200 250 300

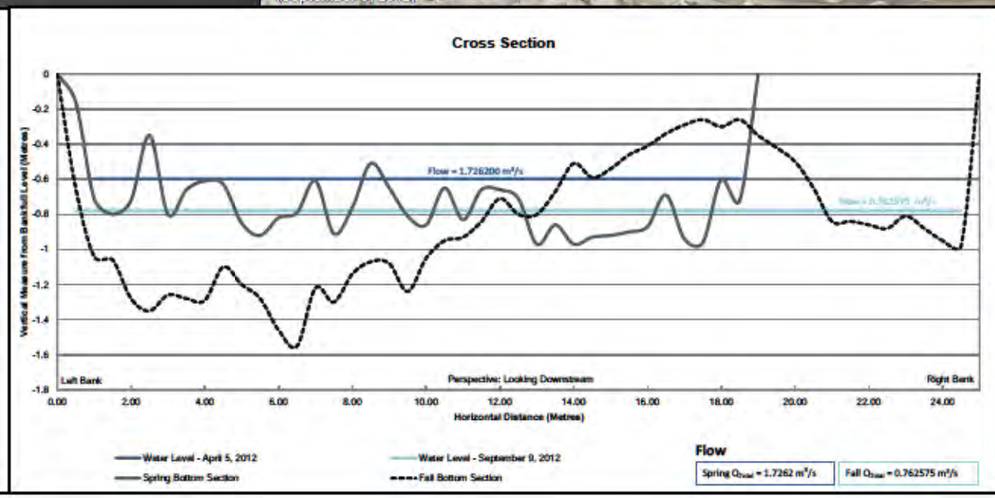
Meters

1 : 2,750

BC hydro

ECOSCAPE Environmental Consultants Ltd.




# Crawford Creek

## Year 5 (2012) 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: | April, 2013 |
| Survey Date: | April 4, May 16, and September 8, 2012 |

## Legend

- Fish Habitat
- Obstruction
- Reservoir Elevation Level
- Hydrometric Location (2010) / Cross Section Location
- Temperature Logger
- 2012 Profile Alignment
- Stream Limits (April, 2012)
- 2 Metre Contours
- New Gravel Bar

Crawford Creek was not documented as having any access problems due to reservoir elevation. However, stream depth and braiding in the downstream zone may impede fish access at low reservoir levels (Anonymous 2003). During the spring 2008 survey 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 downstream zone consist predominantly of fines, with coarser material being highly embedded. Thus the downstream zone is not suitable for spawning.

In 2008, upstream access by kokanee was confirmed by visual observations. It was noted that the channel form 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 reacts and develops when the reservoir levels drop.

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.

40 20 0 40 80 120 160 200

Meters

1 : 2,000

BC hydro

ECOSCAPE Environmental Consultants Ltd.

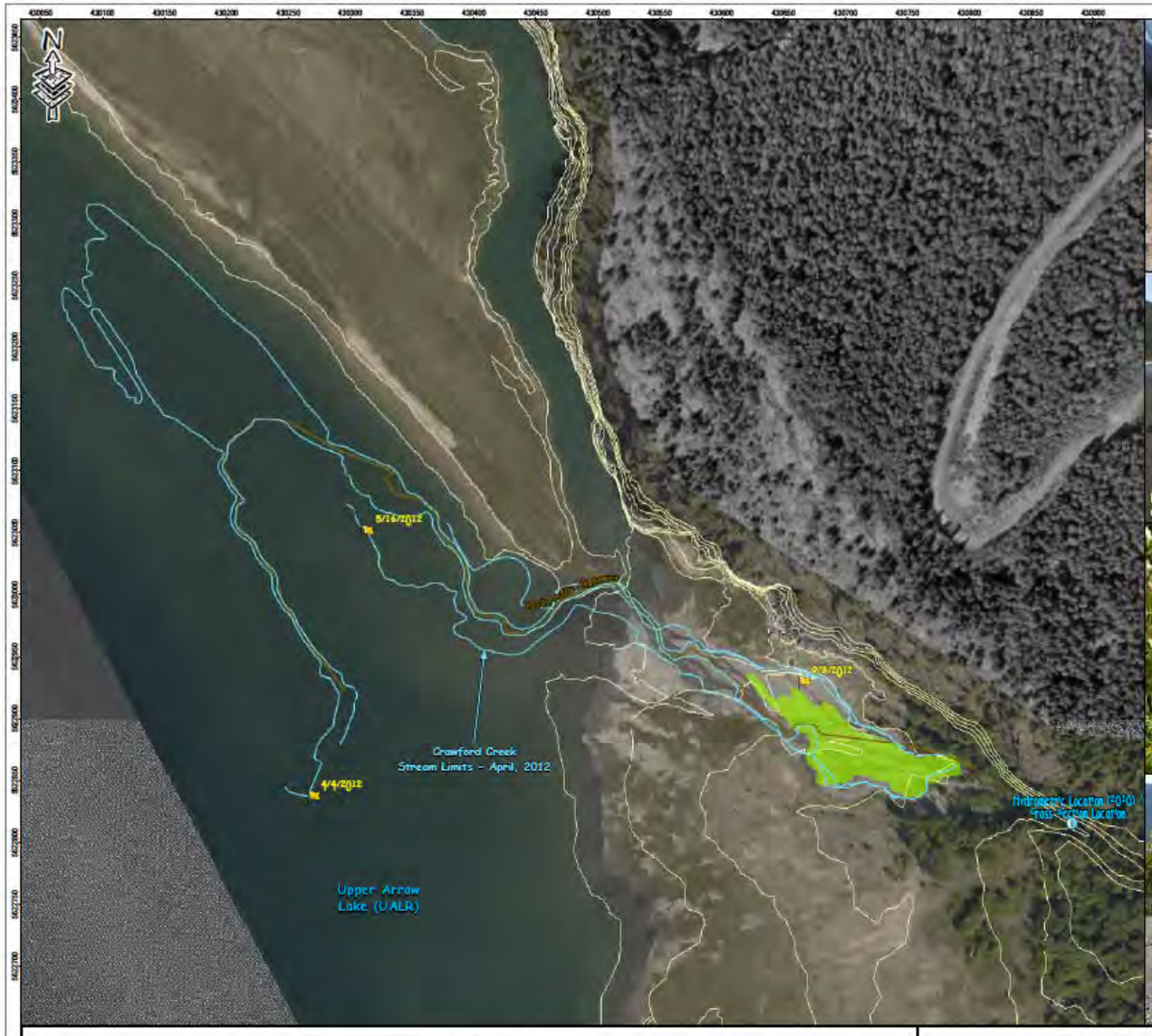




Photo: Panorama taken from right bank looking over drawdown zone towards UARL (April 13, 2011).


Photo: P1000490 -Looking downstream over drawdown zone towards UARL (April 13, 2011).

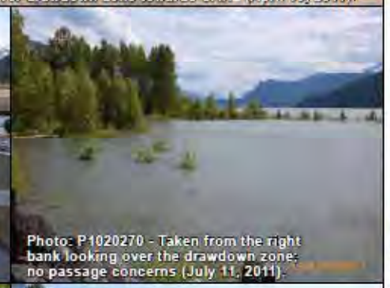


Photo: P1020270 - Taken from the right bank looking over the drawdown zone: no passage concerns (July 11, 2011).

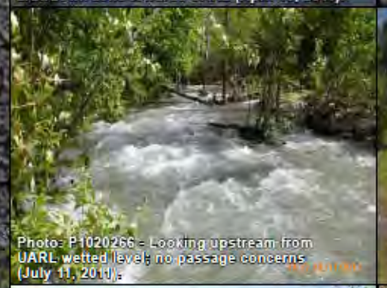


Photo: P1020266 - Looking upstream from UARL wetted level; no passage concerns (July 11, 2011).


Photo: P1030601 - Taken from right bank looking towards confluence of UARL and Crawford Creek (September 9, 2011).


Photo: P1030608 - Looking downstream over the drawdown zone (September 9, 2011).

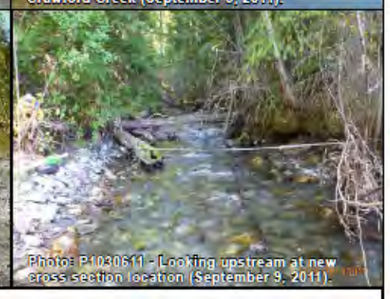
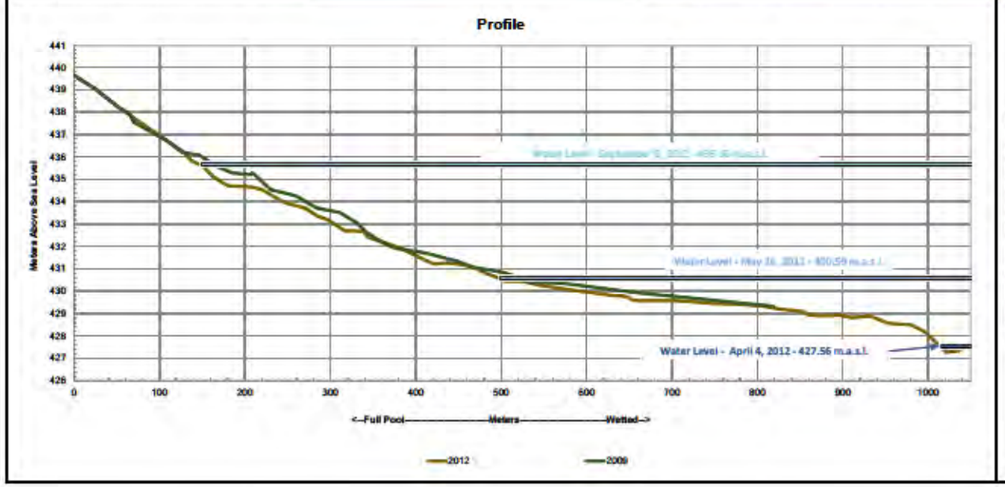
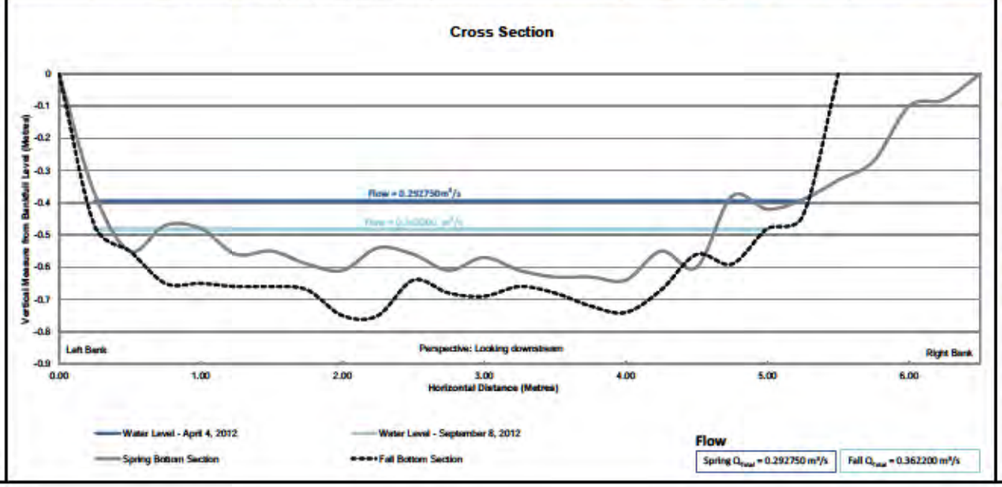


Photo: P1030611 - Looking upstream at new cross section location (September 9, 2011).




# Deer Creek

**Year 5 (2012) 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: | April, 2013 |
| Survey Date: | March 30, May 14, and September 11, 2012 |

## Legend

- Fish Habitat
- Obstruction
- Erosion
- Reservoir Elevation Level
- Hydrometric Location (2010) / Cross Section Location
- Temperature Logger
- Stream Limits (March, 2012)
- 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 (Sayles 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.

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 streated 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.

30 15 0 30 60 90

Meters

1 : 1,000

BC hydro

ECOSCAPE Environmental Consultants Ltd.



Photo: Panorama taken from left bank looking over confluence with LARL and Deer Creek drawdown zone (March 17, 2011).


Photo: IMGP3422 - Looking downstream towards cross section location (March 17, 2011).


Photo: P1020163 - Looking downstream towards cross section location (July 7, 2011).

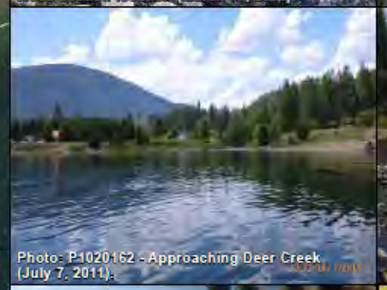


Photo: P1020162 - Approaching Deer Creek (July 7, 2011).

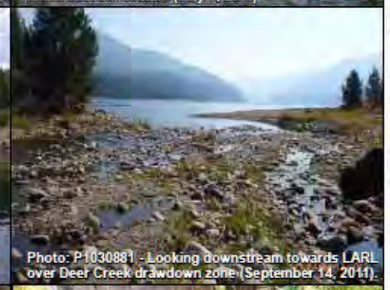


Photo: P1030881 - Looking downstream towards LARL over Deer Creek drawdown zone (September 14, 2011).

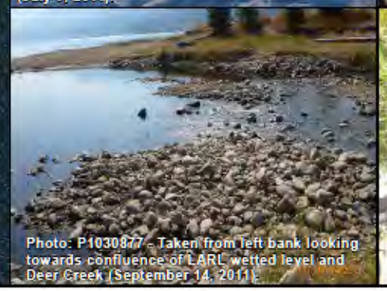
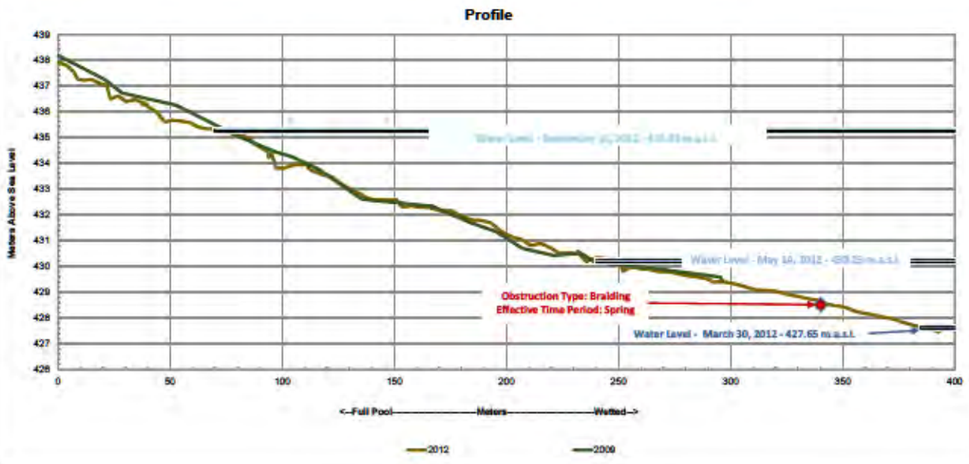


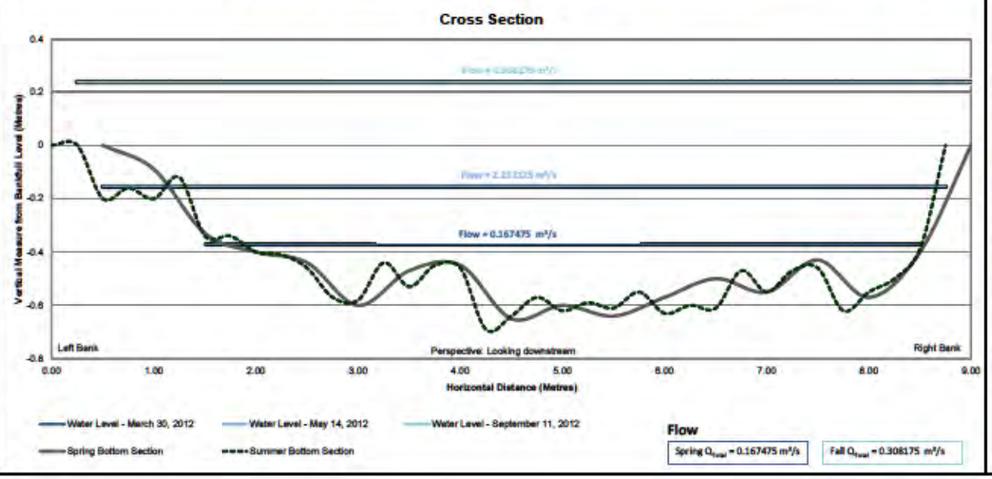
Photo: P1030877 - Taken from left bank looking towards confluence of LARL wetted level and Deer Creek (September 14, 2011).


Photo: P1030886 - Installation of HOBO temperature data logger along right bank at cross section location (September 14, 2011).

## Profile




## Cross Section




**Flow**

Spring $Q_{true}$ = 0.167475 m³/s

Fall $Q_{true}$ = 0.308175 m³/s

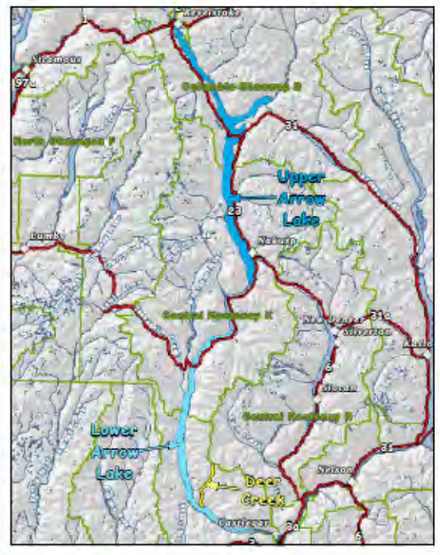




Photo: P1050747 - Looking downstream towards cross section location (March 31, 2012).


Photo: P1050740 - Looking upstream over the Dog Creek drawdown zone from LARL wetted level (March 31, 2012).


Photo: P1070052 - Approaching Dog Creek (May 14, 2012).


Photo: P1070056 - Looking upstream over Dog Creek drawdown zone (May 14, 2012).


Photo: P1070064 - Looking downstream towards cross section location (May 14, 2012).


Photo: P1090434 - Approaching Dog Creek (September 11, 2012).


Photo: P1090438 - Looking upstream over Dog Creek drawdown zone (September 11, 2012).


Photo: P1090441 - Looking downstream towards cross section location (September 11, 2012).

# Dog Creek (Lower Arrow)

**Year 5 (2012) 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: | April, 2013 |
| Survey Date: | March 31, May 14, and September 11, 2012 |

## Legend

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

Dog Creek has been stocked with Gerrard rainbow trout. 7,500 Gerrard rainbow trout from the Kootenay Hatchery were released within both Dog and Deer creek in 1986 (Lindsay, 1988). The drawdown zone is described as primarily riffle with limited pools and runs (Canadian Columbia River Inter-Tribal Fisheries Commission, 2008). Low flows and channel braiding within the drawdown zone may also reduce fish access to Dog Creek (Anonymous 2002) and ongoing stream monitoring and rock and transport techniques have been suggested to improve access.

During the spring 2006 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, 2006 and although flows were low, upstream access was permitted.

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.

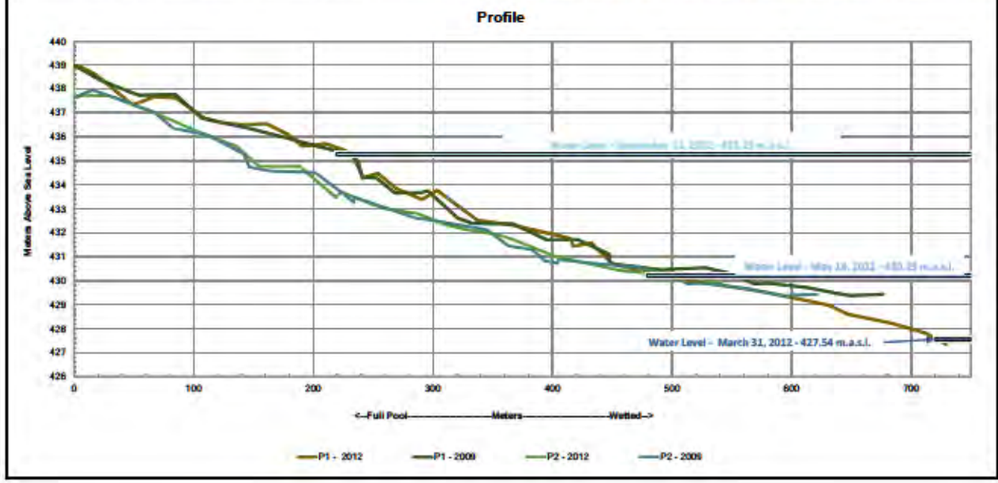
May 14, 2012 - There were no passage concerns through the drawdown zone of Dog Creek at the observed LARL wetted levels and high stream flows.

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.

40 20 0 40 80 120 160 200
Meters
1 : 2,000

BC hydro

ECOSCAPE
Environmental Consultants Ltd.



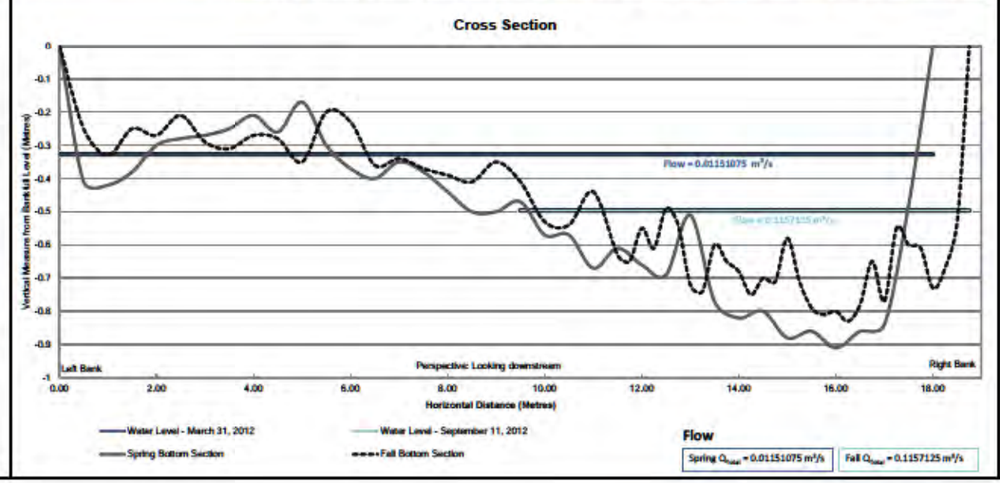






Photo: P1060304 - Looking downstream towards cross section location (April 5, 2012).


Photo: P1060307 - Looking downstream over drawdown zone from culvert crossing (April 5, 2012).


Photo: P1060354 - Looking downstream towards UARL from left bank (April 5, 2012).


Photo: P1060310 - Looking upstream from culvert crossing (April 5, 2012).

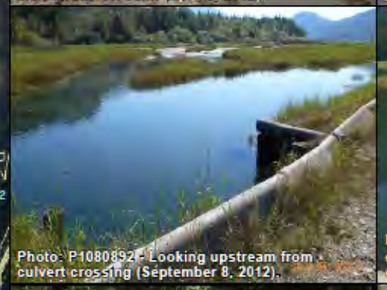


Photo: P1080892 - Looking upstream from culvert crossing (September 8, 2012).

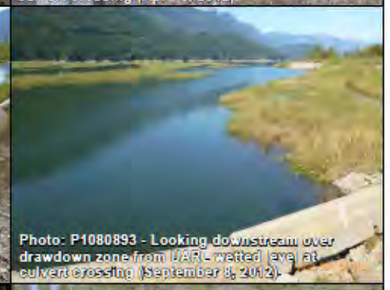


Photo: P1080893 - Looking downstream over drawdown zone from UARL wetted level at culvert crossing (September 8, 2012).


Photo: P7170024 - Looking upstream towards cross section location (July 17, 2012).


Photo: P1080885 - Mainstem flows following along right side of fan through old twin culverts (September 8, 2012).

# Drimmie Creek

## Year 5 (2012) 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: | April, 2013 |
| Survey Date: | April 5, May 15, and September 8, 2012 |

## Legend

- Fish Habitat
- Obstruction
- Reservoir Elevation Level
- Hydrometric Location (2010) / Cross Section Location
- Temperature Logger
- Stream Limits (April, 2012)
- 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 identified as being 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 boulded channel occurring at the downstream end (430.4 m.a.s.l.) 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 29, 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.

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 boulded 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.

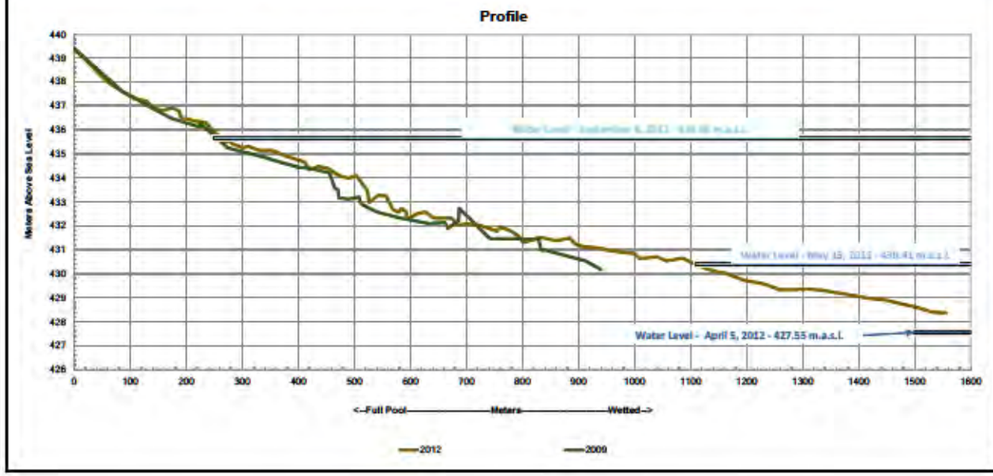
60 25 0 50 100 150 200 250

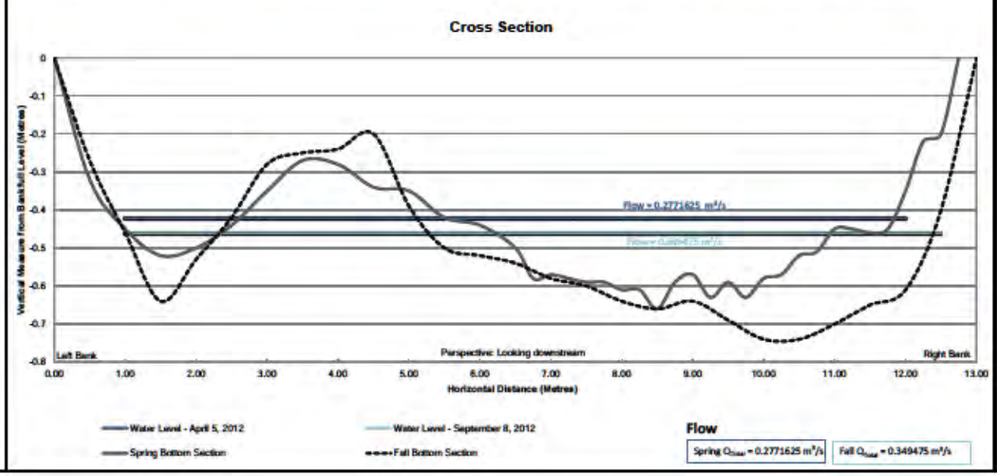
Meters

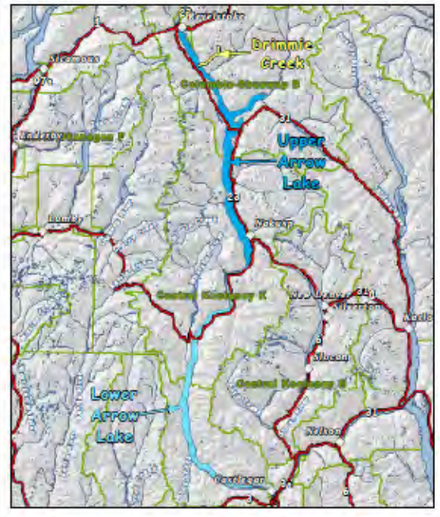
1 : 2,500

BC hydro

ECOSCAPE Environmental Consultants Ltd.



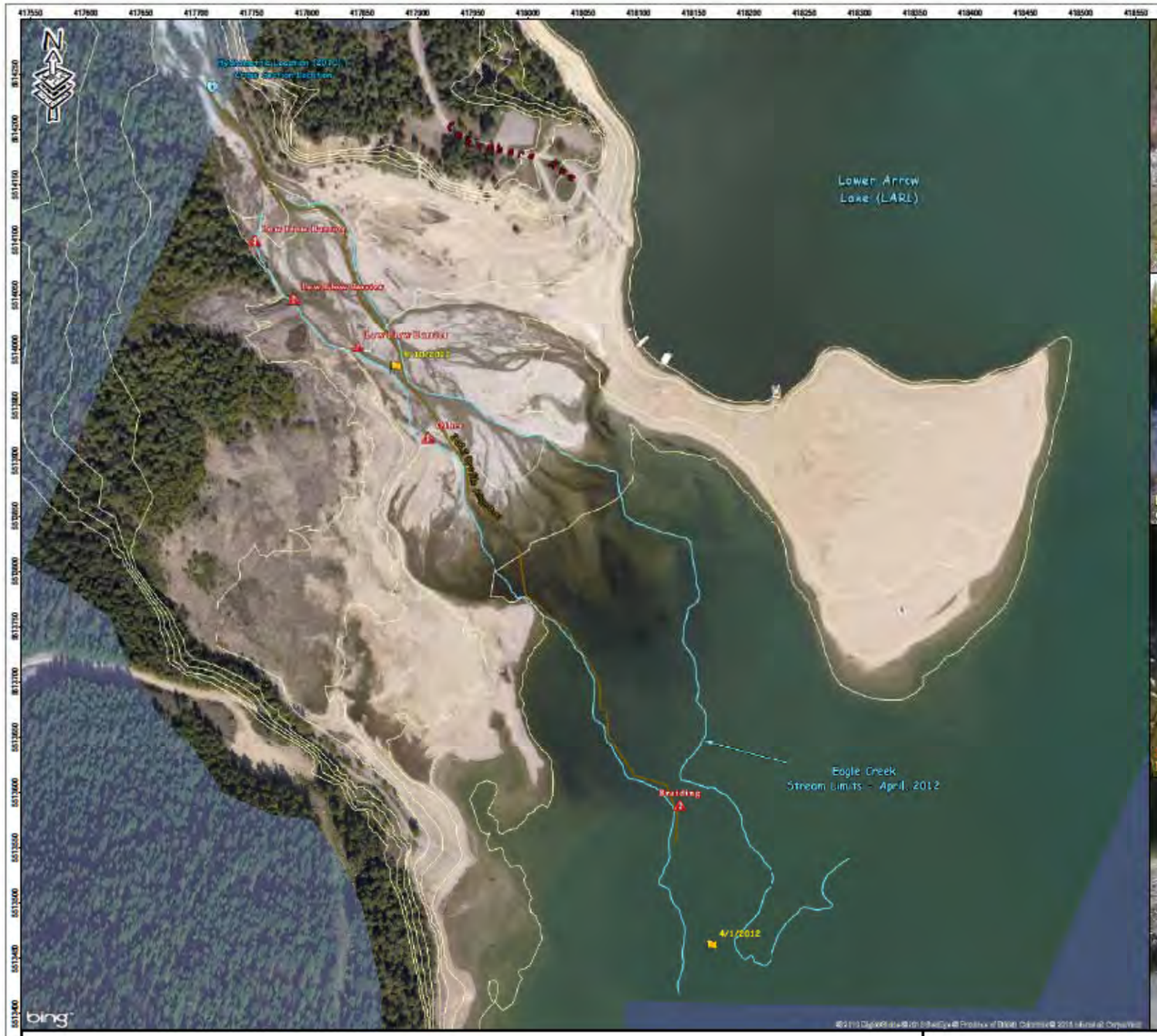




Photo: P1050857 - Looking from left bank at cross section location (April 1, 2012).


Photo: P1050858 - Looking upstream from confluence of Eagle Creek and LARL (April 1, 2012).


Photo: P1070147 - Looking upstream towards cross section location (May 14, 2012).


Photo: P1070136 - Looking upstream from confluence of Eagle Creek and LARL (May 14, 2012).

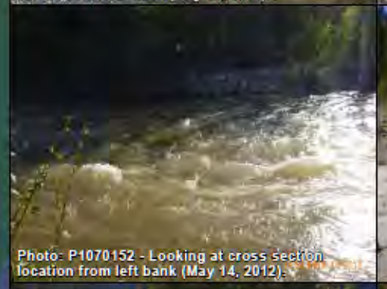


Photo: P1070152 - Looking at cross section location from left bank (May 14, 2012).


Photo: P1090267 - Looking upstream over Eagle Creek drawdown zone (September 10, 2012).


Photo: P1090269 - Looking upstream at Eagle Creek mainstem flows moving towards left bank of drawdown zone (September 10, 2012).

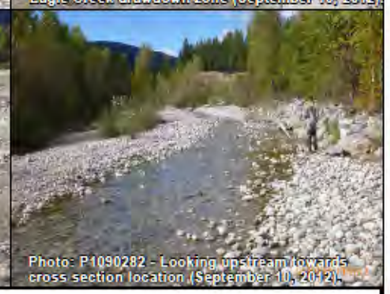


Photo: P1090282 - Looking upstream towards cross section location (September 10, 2012).

# Eagle Creek

## Year 5 (2012) 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: | April, 2013 |
| Survey Date: | April 1, May 14, and September 10, 2012 |

### Legend

- Fish Habitat
- Obstruction
- Temperature Logger
- Hydrometric Location (2010) / Cross Section Location
- Reservoir Elevation Level
- Stream Limits (April, 2012)
- 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, 1967). Kokanee, bull trout and adfluvial rainbow trout have all been documented to utilize Eagle Creek (Swanson, 1970; Sebastian et al, 2000; Toth and Tsumura, 1996). 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 (Andrusiak and Slaney, 2004) and was observed to go subsurface approximately 500 m upstream of the reservoir confluence in 2003 (Canadian Columbia River Inter-Tribal Fisheries Commission, 2006) and dry at 583 m in 1988 (Miller, 1989). Several reports cited low flows and shallow water levels in the fall, as well as channel braiding (BC Hydro, 1982; Bayes and Olmstead, 1967; Miller, 1989; Andrusiak and Slaney, 2004 and Canadian Columbia River Inter-Tribal Fisheries Commission, 2006). During kokanee spawning surveys in 1988, temperature levels were 22.0°C at the mouth, approaching lethal levels for kokanee; spawning occurred in remnant pools with heavy bird predation (Miller, 1989). Heavy bird predation was also documented in 1995 (Bayes and Olmstead, 1967).

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.

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.

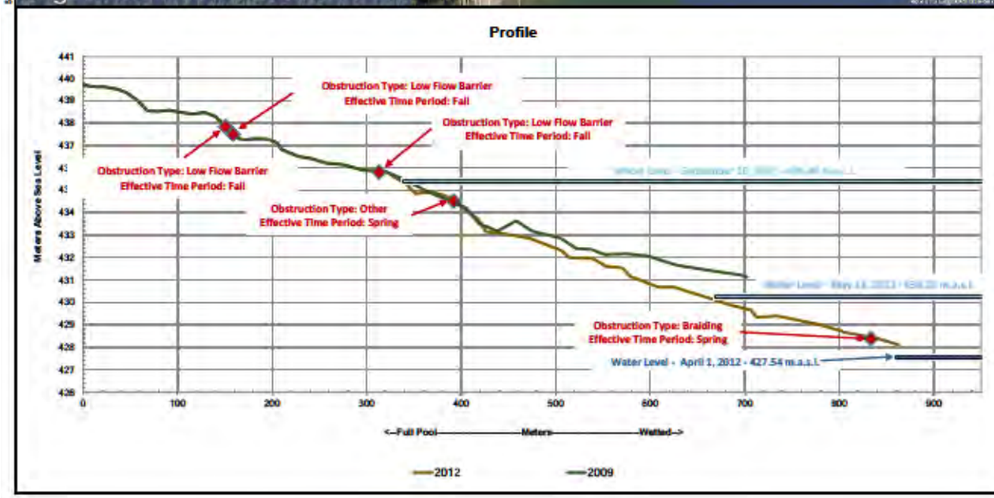
May 14, 2012 - High stream discharge prevented hydrologic measurements. As a result of the flows and deep wetted depths, there were no passage concerns identified in May.

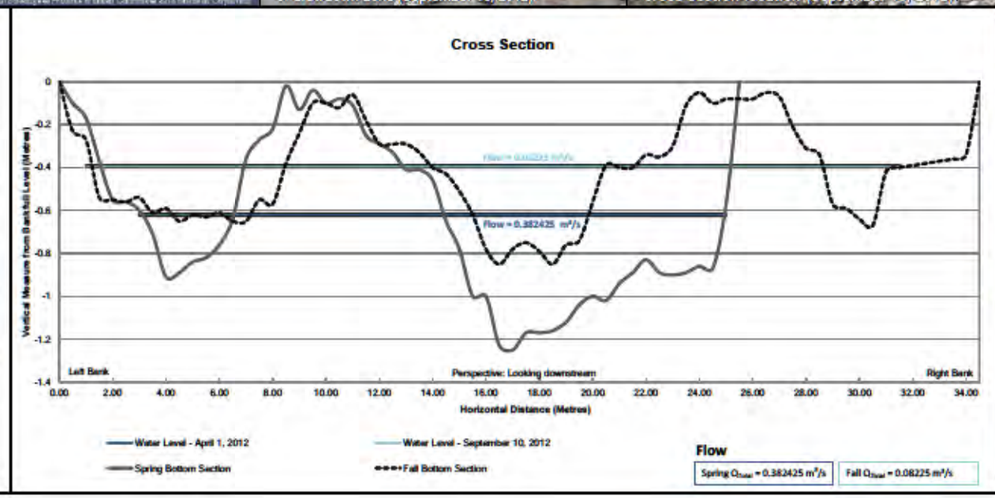
September 10, 2012 - Passage concerns were identified at the confluence of Eagle Creek with the wetted reservoir level as a result of low stream flows. The creek was not braided at the outlet so the impediment was not a function of the reservoir in this instance and was rather a function of low stream flows. Although passage conditions were marginal, kokanee were observed migrating upstream beyond the full pool level of the reservoir.

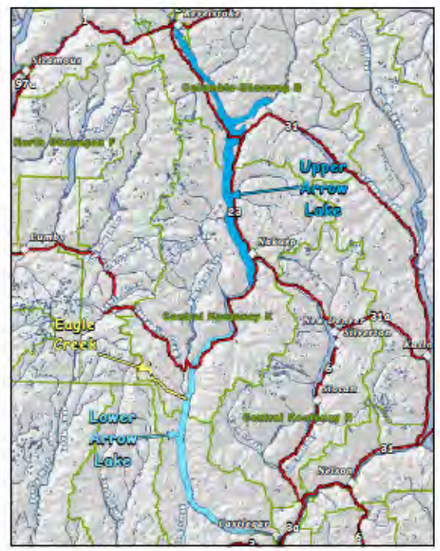
50 25 0 50 100 150 200 250
Meters
1 : 2,250

BC hydro

ECOSCAPE Environmental Consultants Ltd.



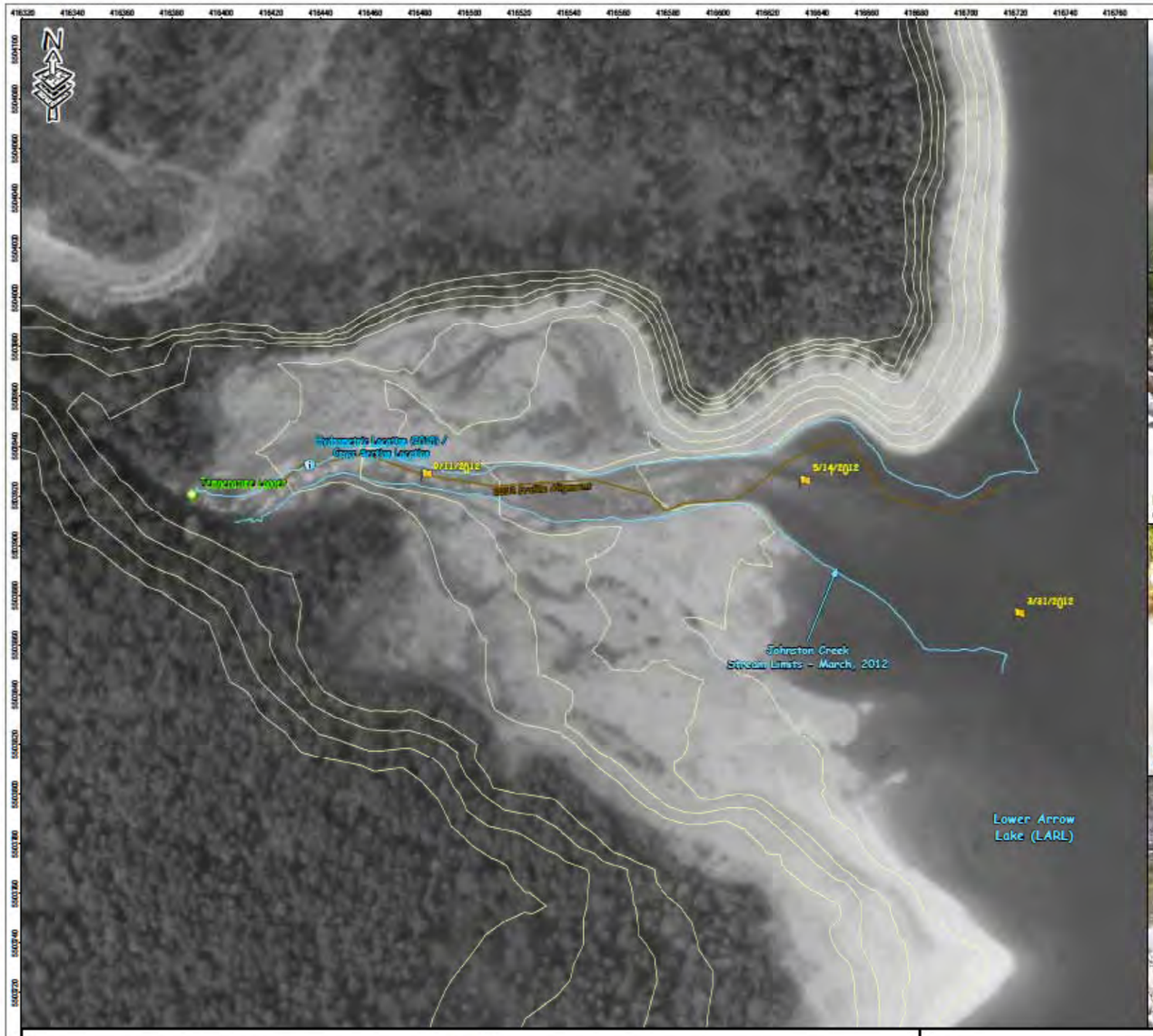




Photo: P1050755 - Approaching Johnston Creek (March 31, 2012).


Photo: P1050772 - Looking upstream from LARL wetted level (March 31, 2012).


Photo: P1050777 - Looking upstream at cross section location (March 31, 2012).


Photo: P1060981 - Looking upstream over drawdown zone (May 14, 2012).


Photo: P1060996 - Looking from left bank at swift flowing cross section location (May 14, 2012).

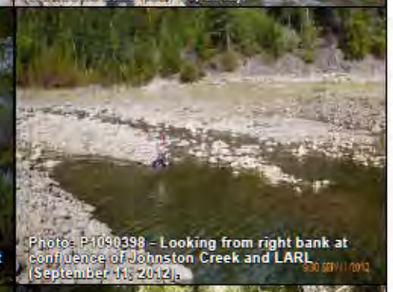


Photo: P1090398 - Looking from right bank at confluence of Johnston Creek and LARL (September 11, 2012).


Photo: P1090405 - Kokanee observed in Johnston Creek (September 11, 2012).


Photo: P1090410 - Looking upstream at cross section location (September 11, 2012).

# Johnston Creek

## Year 5 (2012) 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: | April, 2013 |
| Survey Date: | March 31, May 14, and September 11, 2012 |

## Legend

- Fish Habitat
- Obstruction
- Reservoir Elevation Level
- Hydrometric Location (2010) / Cross Section Location
- Temperature Logger
- Stream Limits (March, 2012)
- 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 390 m upstream of the reservoir where there is a 2.5 m waterfall (Beyes 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 (Beyes 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.

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).

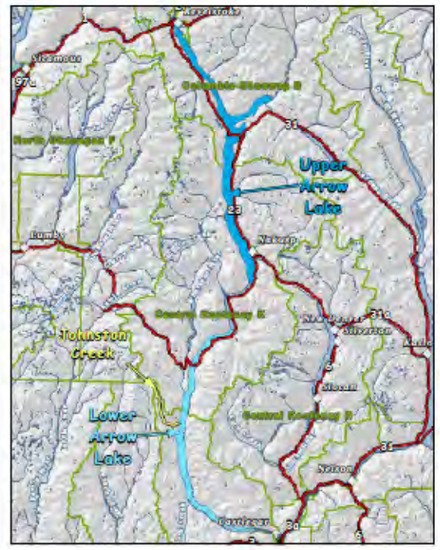
May 14, 2012 - There were no passage concerns identified during high stream discharges.

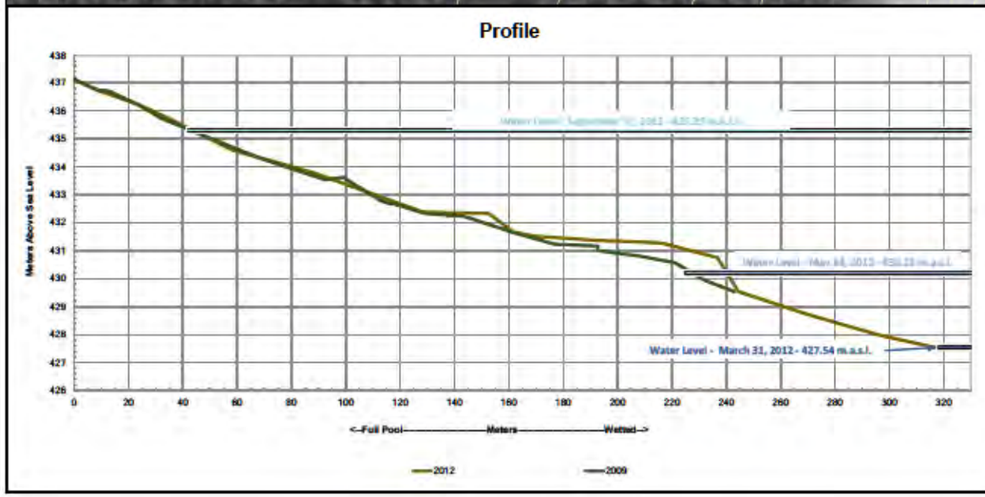
September 11, 2012 - There were no passage concerns observed. Very high spring - early summer discharges resulted in movement of large channel substrates (i.e., boulders). Kokanee were observed spawning in upper limbs of drawdown zone in gravel pockets among boulders.

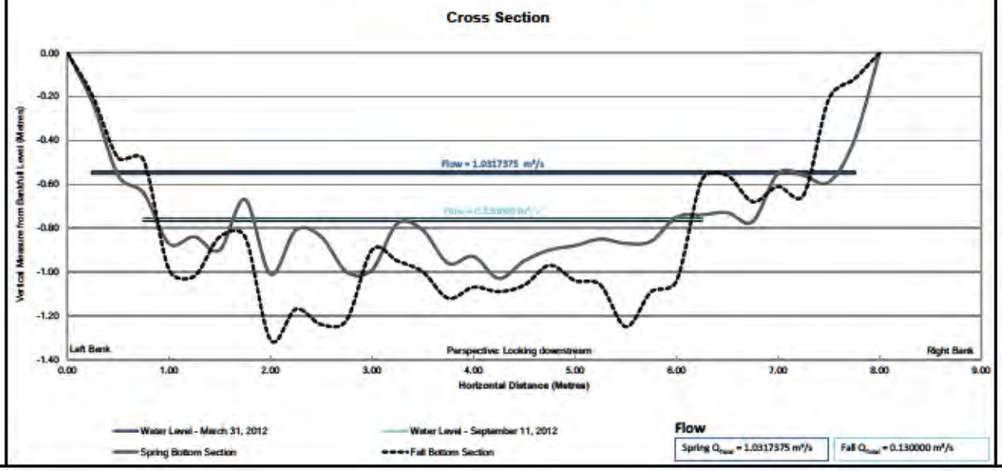
40 20 0 40 80
Meters
1 : 1,000

BC hydro

ECOSCAPE
Environmental Consultants Ltd.



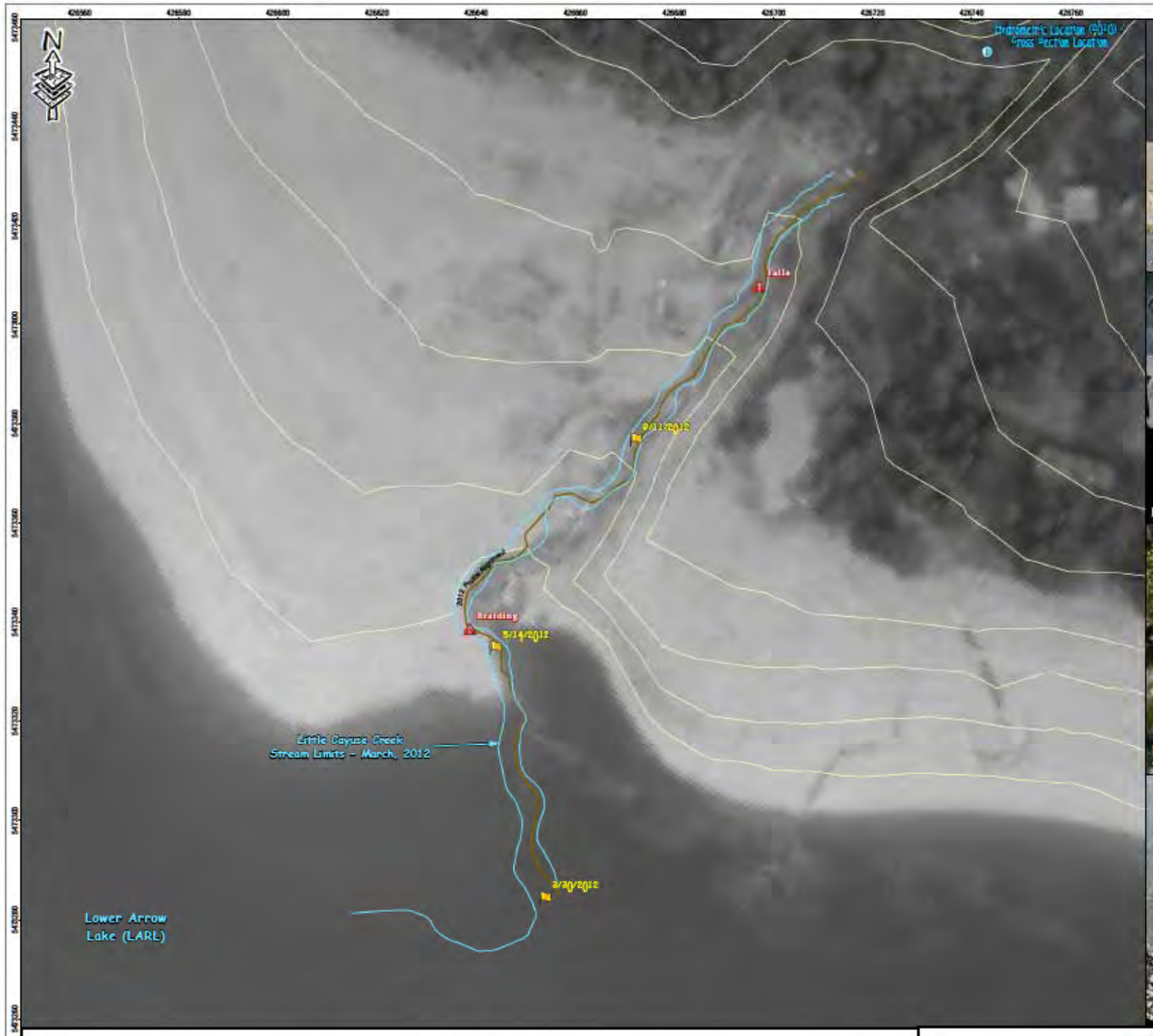




Photo: P1050606 - Approaching Little Cayuse Creek (March 30, 2012).


Photo: P1050613 -Looking from left bank at drawdown zone (March 30, 2012).


Photo: Panorama taken from left bank looking over Little Cayuse Creek drawdown zone (May 14, 2012).


Photo: P1070025 - Looking upstream at cross section location (May 14, 2012).

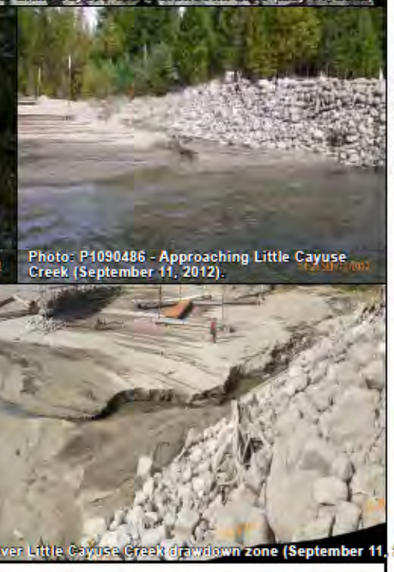


Photo: P1090486 - Approaching Little Cayuse Creek (September 11, 2012).


Photo: Panorama taken from left bank looking over Little Cayuse Creek drawdown zone (September 11, 2012).

# Little Cayuse Creek

**Year 5 (2012) 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: | April, 2013 |
| Survey Date: | March 30, May 14, and September 11, 2012 |

## Legend

- Fish Habitat
- Obstruction
- Reservoir Elevation Level
- Hydrometric Location (2010) / Cross Section Location
- Temperature Logger
- Stream Limits (March, 2012)
- 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 1000 kokanee documented up to 400 m upstream of the reservoir and over 1000 in 1995 (Sayes and Olmstead, 1997). Rainbow trout and long nose dace were also documented (Sayes & 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 (Sayes & 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 that reservoir elevations.

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.

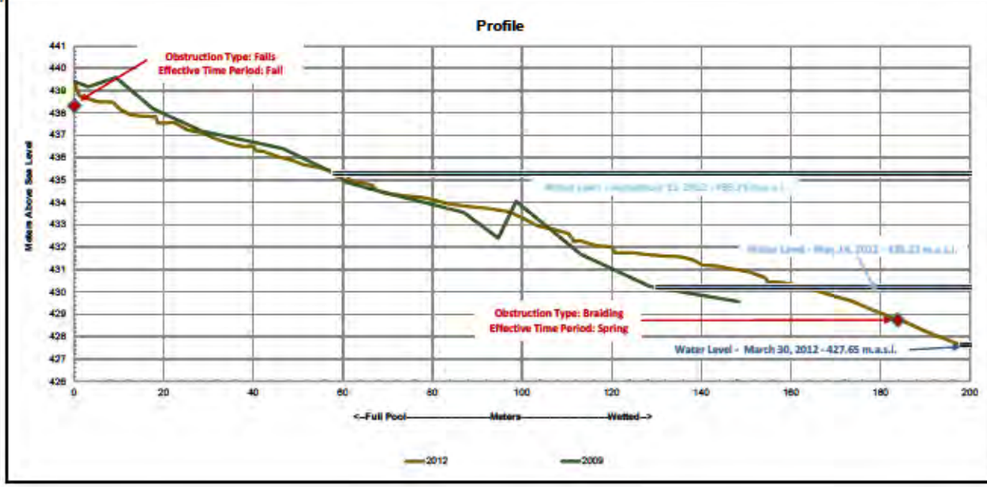
May 14, 2012 - There were no passage concerns observed during the May inspection; with high relative discharges providing adequately deep water to support fish migration and to provide instream cover.

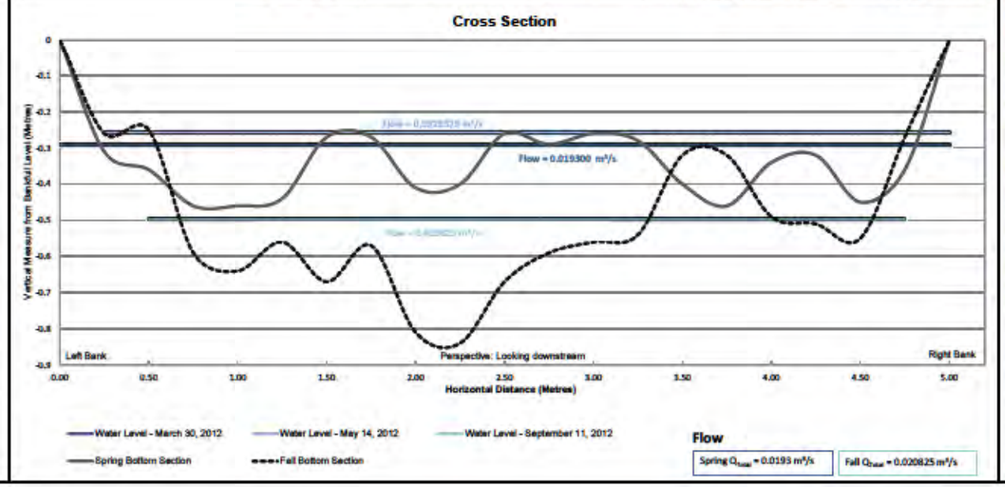
September 11, 2012 - Little Cayuse Creek was impassable to kokanee over a new steep-faced gravel fan that had formed at the upper level of the drawdown zone. One kokanee was observed downstream of the obstruction in the drawdown zone.

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

BC hydro

ECOSCAPE
Environmental Consultants Ltd.



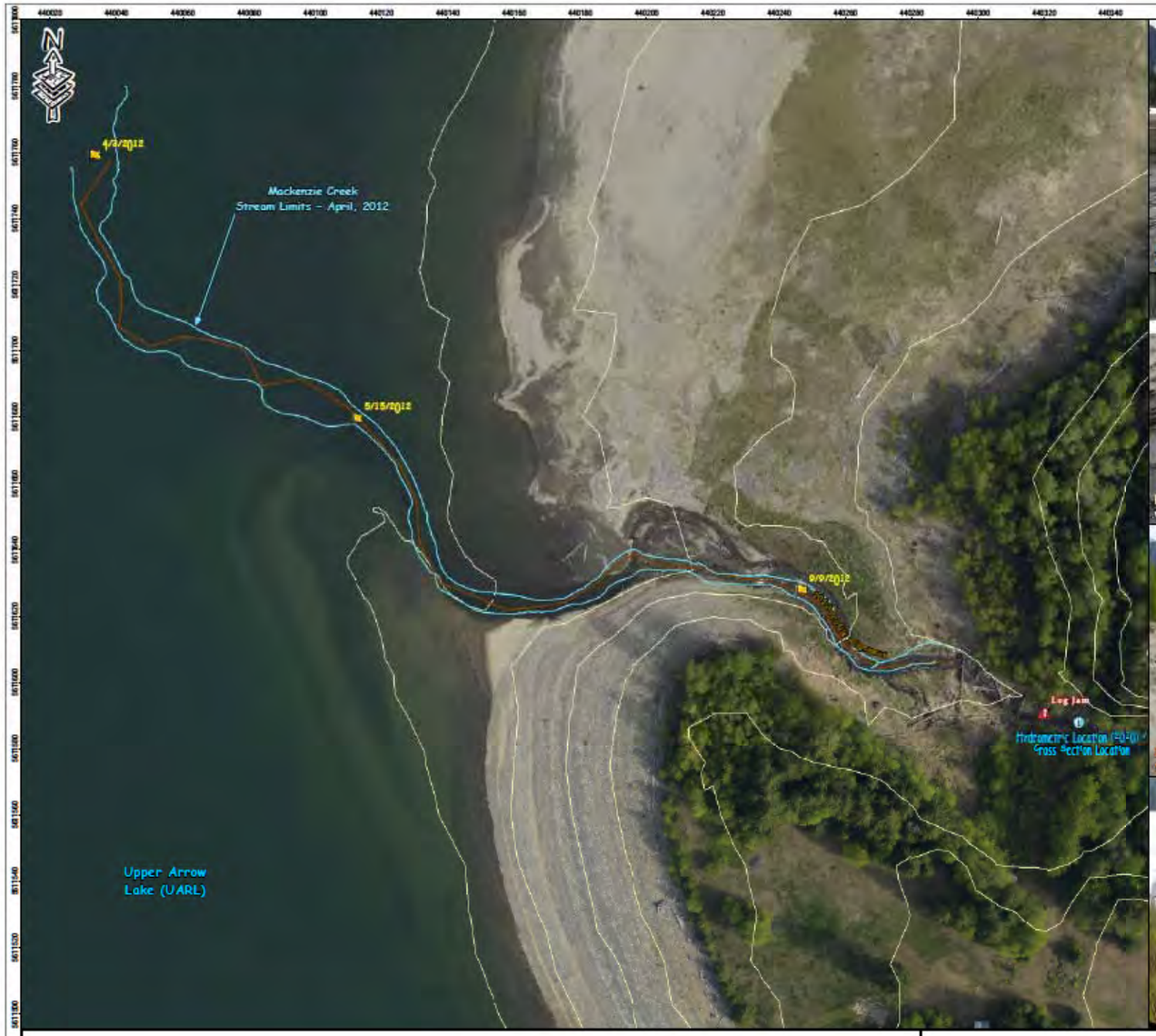





Photo: P1060013 - Approaching MacKenzie Creek (April 3, 2012).


Photo: P1060019 - Looking upstream at cross section location (April 3, 2012).


Photo: P1060033 - Looking upstream from UARL wetted level (April 3, 2012).


Photo: P1070212 - Approaching MacKenzie Creek (May 15, 2012).

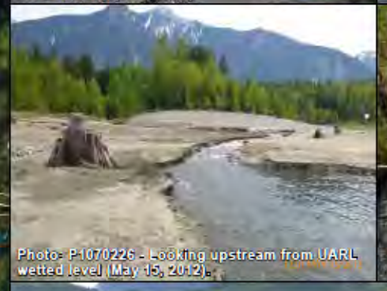


Photo: P1070226 - Looking upstream from UARL wetted level (May 15, 2012).


Photo: P1070244 - Looking downstream at cross section location (May 15, 2012).


Photo: Panorama looking from left bank at confluence of Mackenzie Creek and UARL (September 10, 2012).

# Mackenzie Creek

**Year 5 (2012) 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: | April, 2013 |
| Survey Date: | April 3, May 15, and September 9, 2012 |

## Legend

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

Mackenzie Creek is known to support rainbow trout, kokanee, and bull trout spawning (Decker et al, 2005; Lindsay, 1978). Earlier reports indicate that passage through the downtown 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, 1978; Sebastian et al, 2002).

During the 2008 surveys (spring and fall) there were no impediments to upstream migration through the downtown zone identified. Bull trout fry, kokanee, and rainbow were all sampled / observed within the downtown zone in 2008. 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.

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.

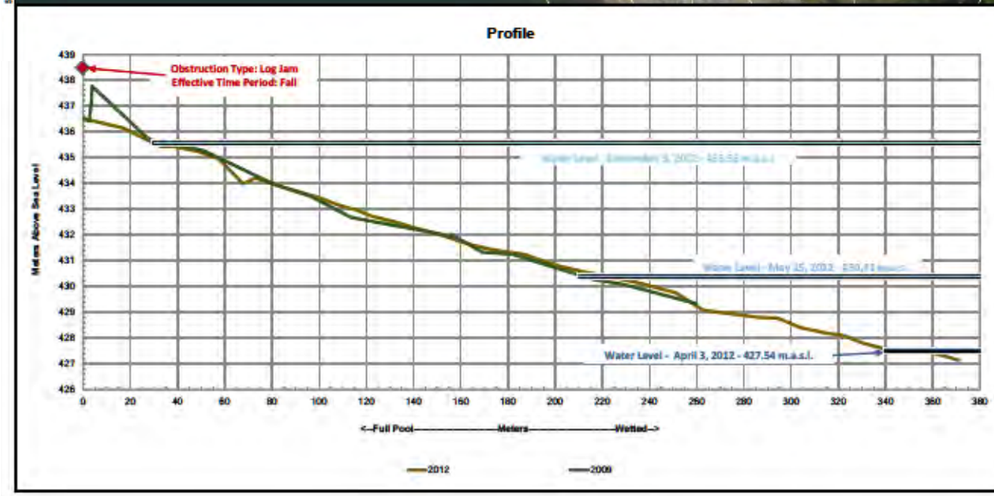
May 15, 2012 - There were no passage concerns observed at the observed streamflows and reservoir levels.

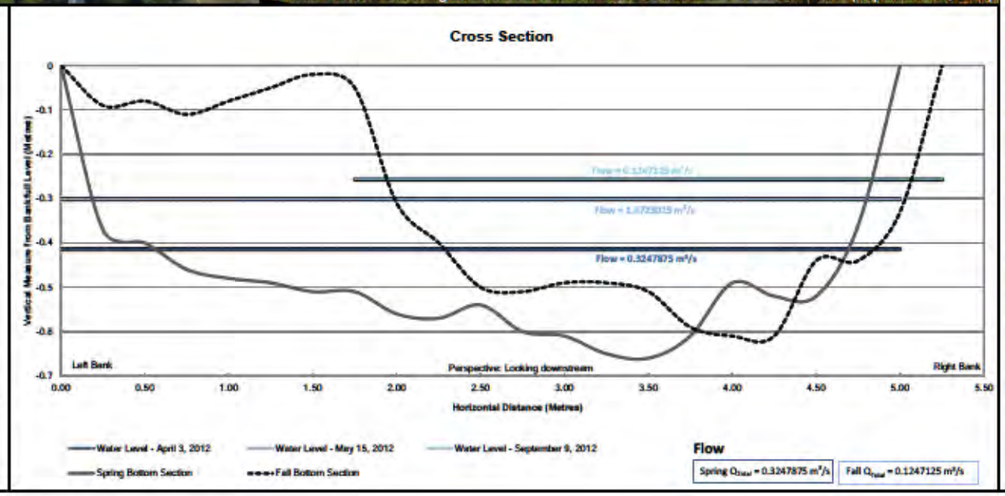
September 9, 2012 - There were no fall passage concerns identified. The summer high reservoir levels reached upstream beyond the cross-section location and rolled a new large woody debris jam at the full pool elevation. In addition, the high reservoir levels resulted in the deposition of sediments at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

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

BC hydro

ECOSCAPE
Environmental Consultants Ltd.



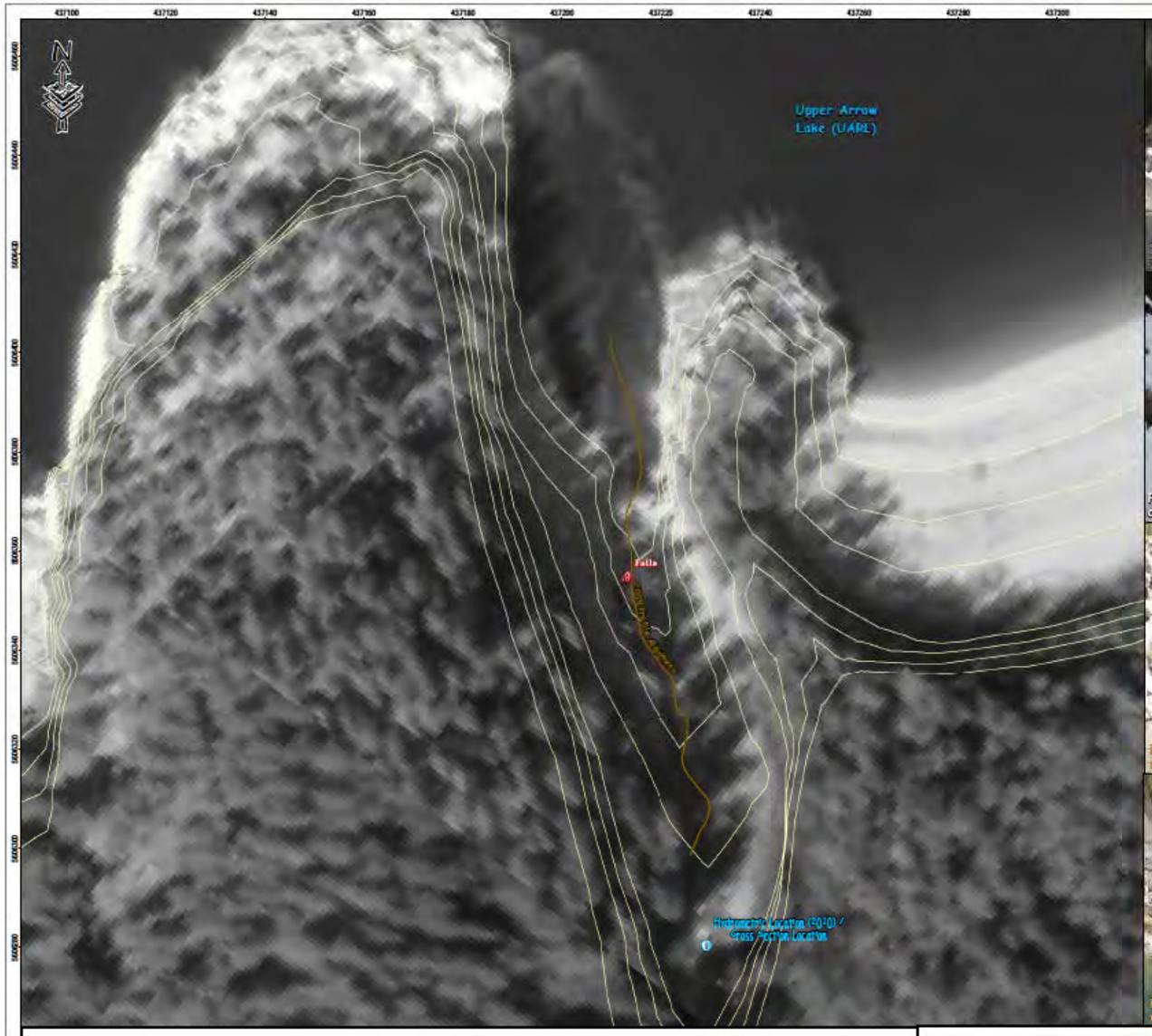





Photo: P1060069 - Approaching Nacillewaet Creek (April 3, 2012).


Photo: P1060074 - Looking upstream at Nacillewaet Creek flows taken near UARL wetted level (April 3, 2012).


Photo: P1060084 - Taken from right bank looking downstream towards UARL (April 3, 2012).


Photo: P1060086 - Looking upstream towards cross section location (April 3, 2012).


Photo: P1070287 - Approaching Nacillewaet Creek (May 15, 2012).


Photo: P1070301 - Looking at cross section location from left bank (May 15, 2012).

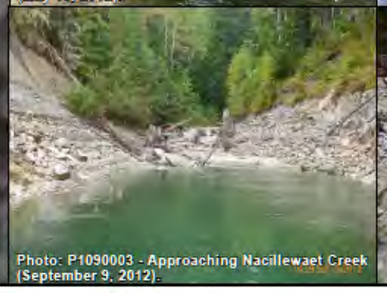


Photo: P1090003 - Approaching Nacillewaet Creek (September 9, 2012).

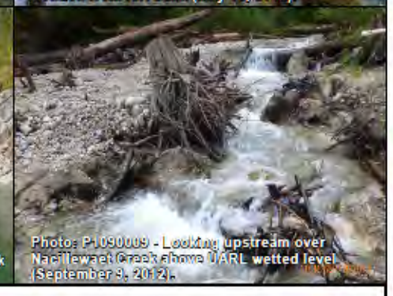


Photo: P1090009 - Looking upstream over Nacillewaet Creek above UARL wetted level (September 9, 2012).

# Nacillewaet Creek

## Year 5 (2012) 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: | April, 2013 |
| Survey Date: | April 3, May 15, and September 9, 2012 |

## Legend

- Fish Habitat
- Obstruction
- Reservoir Elevation Level
- Hydrometric Location (2010) / Cross Section Location
- Temperature Logger
- 2 Metre Contours
- 2009 Profile Alignment

Nacillewaet Creek has been described as having good bull trout habitat characteristics (den Biesen and Ord, 2000). 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, 2000; Gebhart, 1998c; R. & L Environmental Services, 1987). A large set of 3 m falls are located approximately 140 m upstream of the reservoir that is a 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 (R. & L Environmental Services, 1987).

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, this 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.

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.

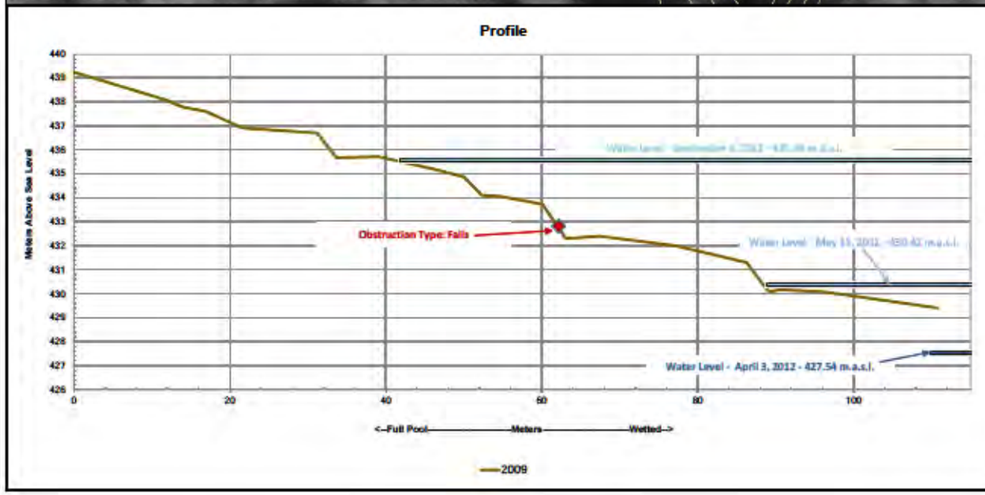
May 15, 2012 - High stream flows improved passage conditions up the drawdown zone from the April inspections.

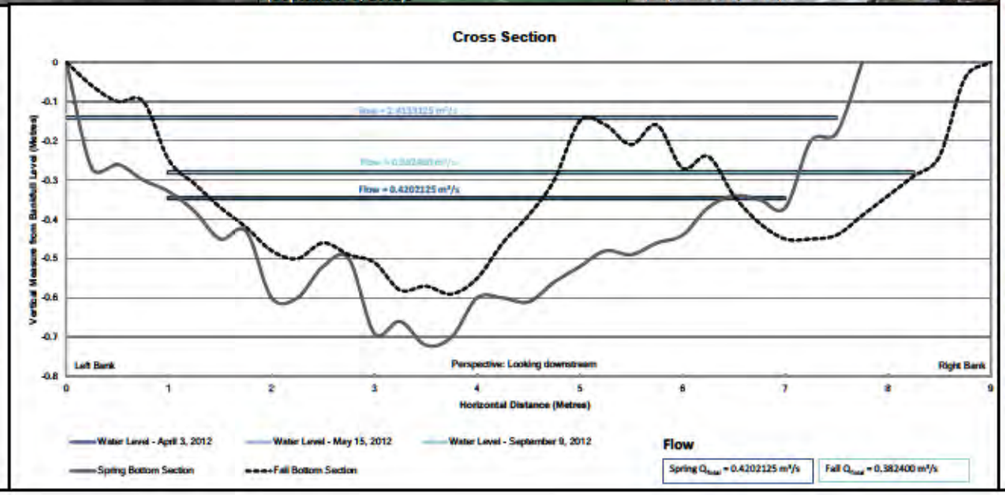
September 9, 2012 - Reworked LWD and boulders reduced fall passage conditions from those observed in previous years. Plunge heights over the LWD and boulders were increased with reduced pool depths observed at the bases of these features - impairing the potential for kokanee to migrate into the drawdown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

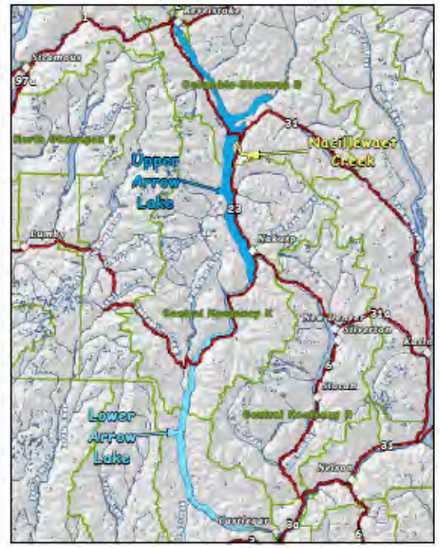
10 5 0 10 20 30 40 60
Meters
1 : 5 0 0

BC hydro

ECOSCAPE Environmental Consultants Ltd.



# Octopus Creek

## Year 5 (2012) 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: | April, 2013 |
| Survey Date: | April 1, May 13, and September 10, 2012 |

## Legend

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

Rainbow trout and kokanee utilize Octopus Creek from the reservoir upstream about 0.5 km to a waterfall (Andrusiak and Sibley, 1994; Sebastian et al, 2000). Previous assessments identified no obstructions in the drawdown zone (Gebhart, 1999; Canadian Columbia River Inter-Tribal Fisheries Commission, 2000; BC Hydro, 1982).

During the 2009 spring surveys, braiding over the lower fan (~432.2 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 20m upstream of the bridge during the spring survey period. There were no impediments to kokanee access in 2006. The reservoir levels were above the lower fan braiding and stream flows were sufficient for migration and spawning.

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.

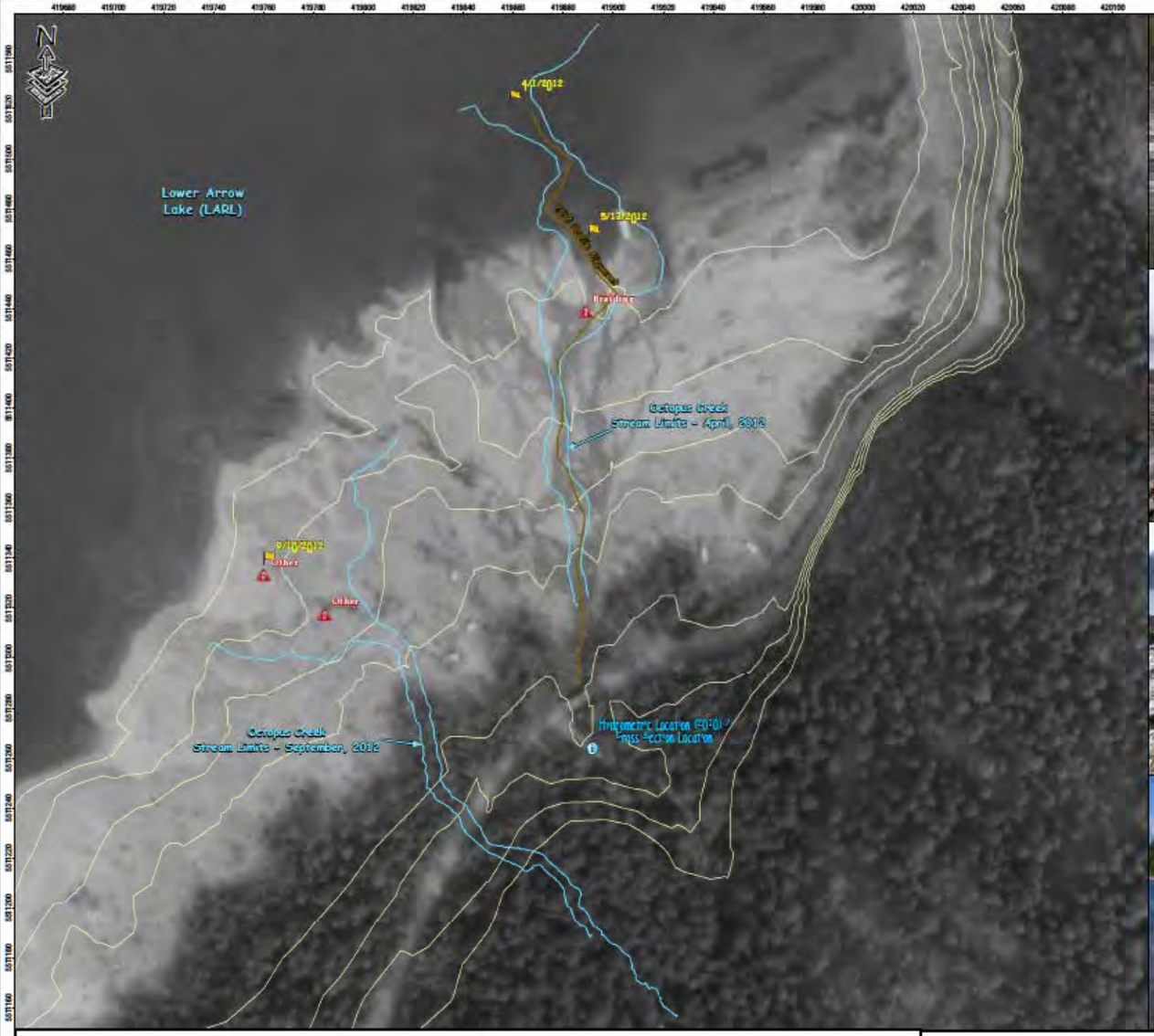
May 13, 2012 - There were no passage concerns at the observed streamflows and reservoir levels.

September 10, 2012 - A large debris flow occurred during summer 2012 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 (a 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.

30 15 0 30 60 90

Meters

1 : 1,000



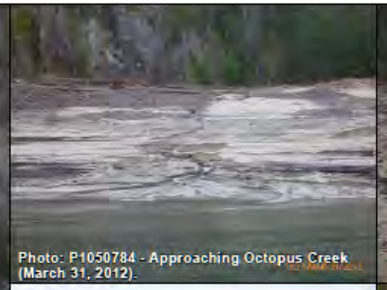



Photo: P1050784 - Approaching Octopus Creek (March 31, 2012).


Photo: P1050789 - Taken near LARL wetted level looking upstream over drawdown zone (April 1, 2012).


Photo: P1050804 - Looking downstream over drawdown zone towards LARL from right bank (April 1, 2011).


Photo: P1060974 - Approaching Octopus Creek (May 13, 2012).


Photo: P1060980 - Looking downstream from right bank towards LARL wetted level and confluence with Octopus Creek (May 15, 2012).


Photo: P1060982 - Looking upstream towards cross section location (May 13, 2012).

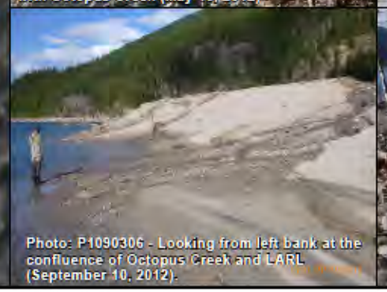
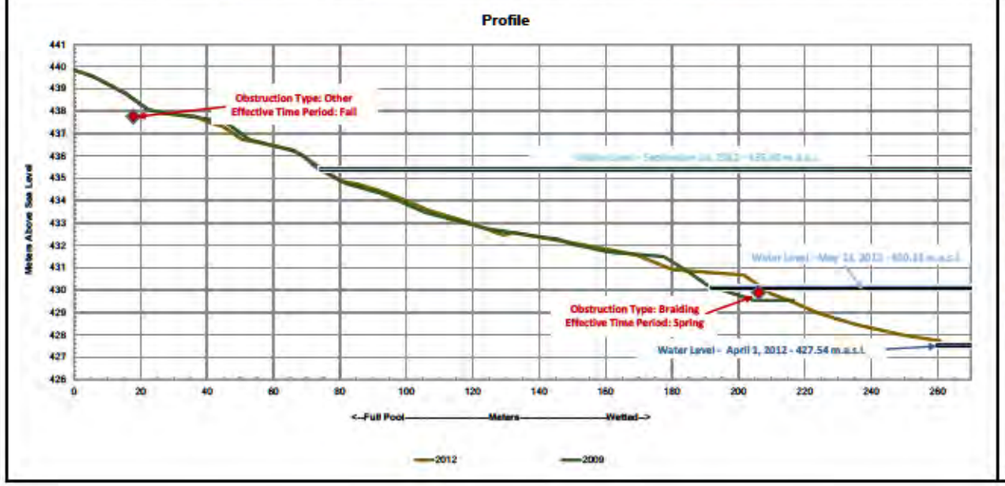
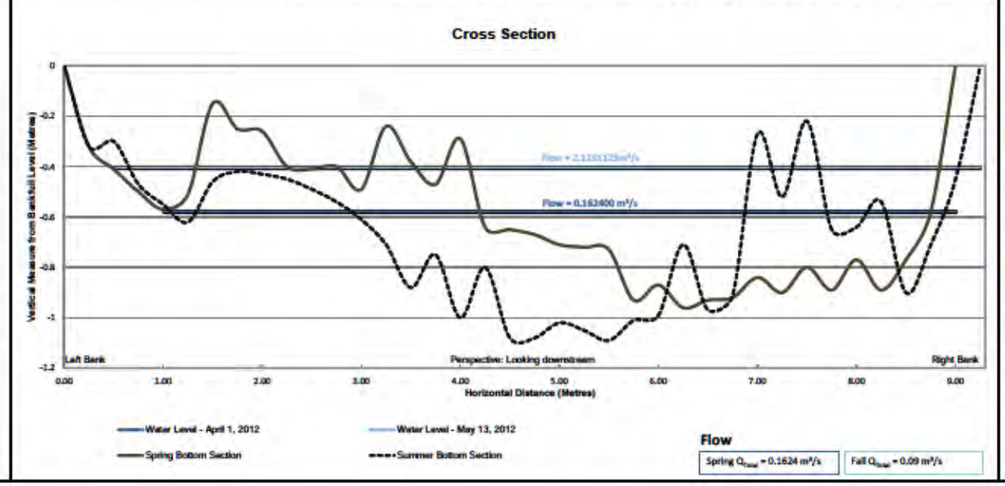


Photo: P1090306 - Looking from left bank at the confluence of Octopus Creek and LARL (September 10, 2012).


Photo: P1090317 - Looking downstream from left bank towards LARL wetted level and confluence with Octopus Creek (September 10, 2012).




# Payne Creek

## Year 5 (2012) 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: | April, 2013 |
| Survey Date: | April 3, May 15, and September 9, 2012 |

## Legend

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

Payne Creek is known to contain spawning habitat for kokanee and bull trout (R. & I. Environmental Services, 1997). However, only about 80 m of Payne Creek is 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; Gebbart, 1999) although some assessors have suggested that access is not a problem (BC Hydro, 1982). 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; R. & I. 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.

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-wetted the LWD jam situated at about 439 m elevation. Field observations noted potential passage impairments as a result of the revested 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.

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

BC hydro

ECOSCAPE Environmental Consultants Ltd.



Photo: Panorama taken from left bank looking over Payne Creek drawdown zone (April 3, 2012).


Photo: Panorama taken from left bank looking over Payne Creek drawdown zone (May 15, 2012).

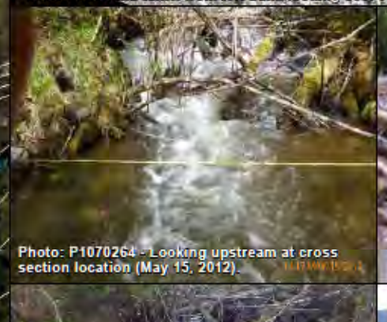
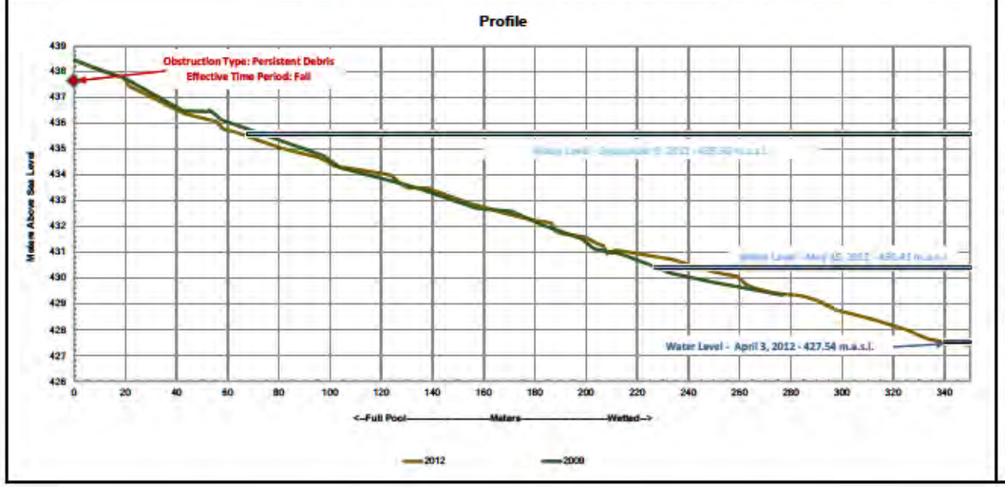


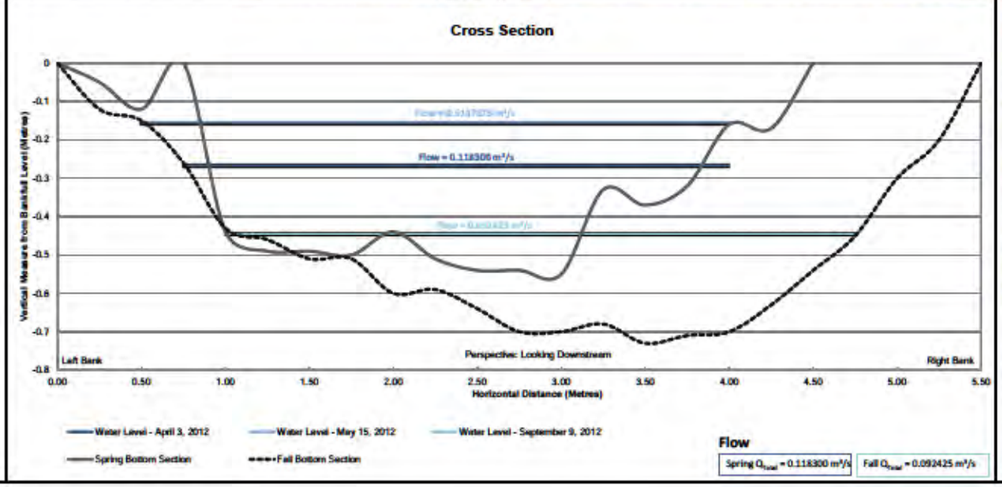
Photo: P1070264 - Looking upstream at cross section location (May 15, 2012).

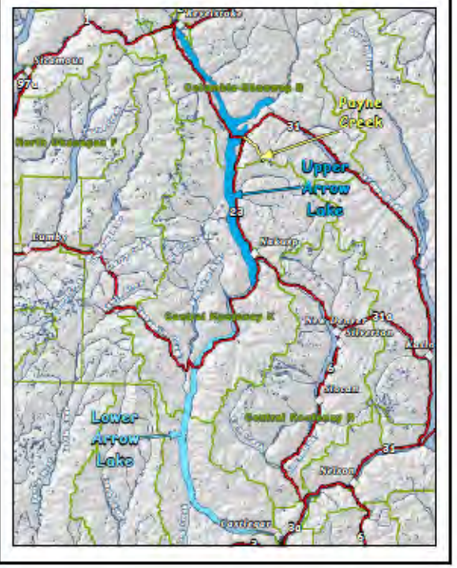

Photo: P1080970 – Looking upstream large woody debris within channel (September 9, 2012).


Photo: P1080967 - Looking upstream at cross section location (September 9, 2012).


Photo: P1080974 - Looking downstream towards UARL wetted level (September 9, 2012).



# Renata Creek

## Year 5 (2012) 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: | April, 2013 |
| Survey Date: | March 30, May 14, and September 11, 2012 |

## Legend

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

Bayer 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 (Graham 1999) found no obstructions in the drawdown zone. The flows of Renata Creek appear to be highly variable (R.L. & L. Environmental Services Ltd 1997), while other studies indicate no flow/no access at the time of assessment (BC Hydro 1982).

Spring rainbow trout access was not impeded by the observed flows during the 2008 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, 2008 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 2008.

2012 Observations:

March 30, 2012 - The lower reaches of the drawdown zone (427.5 m - 429.2 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 instream flows with intermittent sections of dry channel bed occurring in the drawdown zone.

20 10 0 20 40 60 80 100

Meters

1 : 1,000



Photo: P1050687 - Approaching Renata Creek (March 30, 2012).

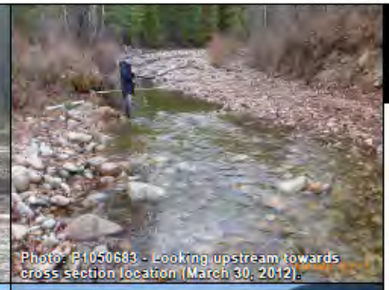


Photo: P1050683 - Looking upstream towards cross section location (March 30, 2012).


Photo: P1070079 - Approaching Renata Creek (May 14, 2012).

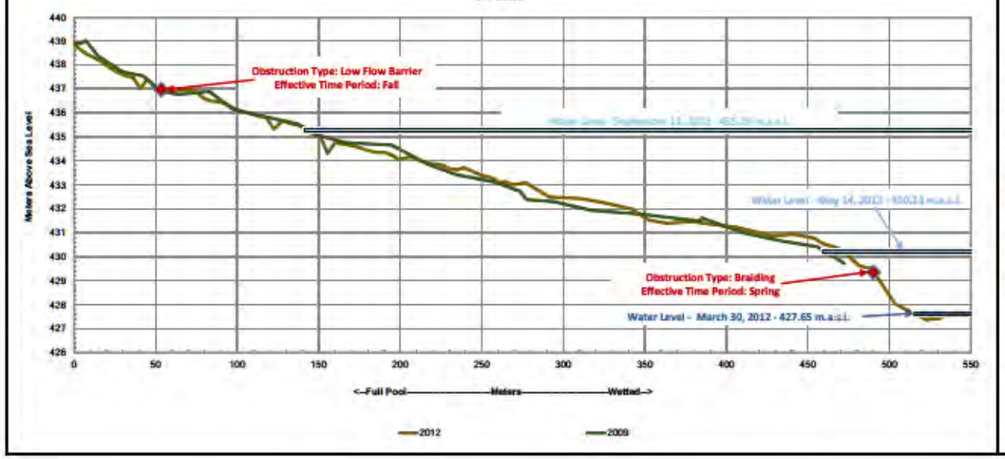

Photo: P1070085 - Looking upstream over drawdown zone from LARL wetted level (May 14, 2012).

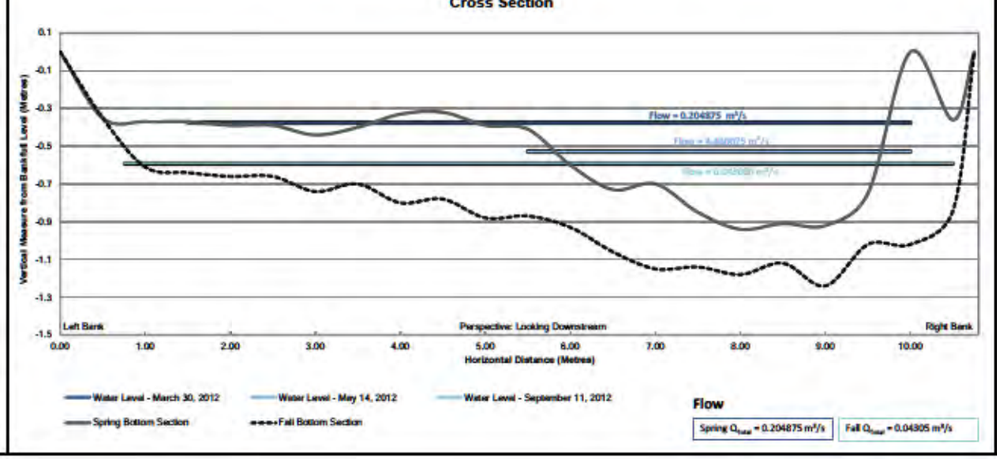

Photo: P1070091 - Looking downstream towards cross section location (May 14, 2012).

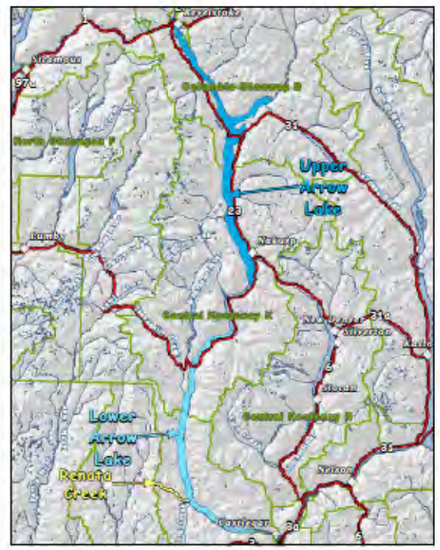

Photo: P1050415 - Looking upstream over drawdown zone and LARL wetted level (September 11, 2012).


Photo: P1090419 - Looking upstream from over drawdown zone (September 11, 2012).


Photo: P1090423 - Looking downstream at eroding right bank (September 11, 2012).



# Taite Creek

## Year 5 (2012) 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: | April, 2013 |
| Survey Date: | April 1, May 14, and September 10, 2012 |

## Legend

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

The drawdown zone of Taite Creek was assessed as passable in the spring 2008 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 30m of the drawdown zone. Good channel definition and stream flows supported kokanee migration and access in September 2008. 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.

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 assec discharge, resulting in marked channel mounting and widening, during fall 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).

20 10 0 20 40 60 80 100 120

Meters

1 : 1,000

BC hydro

ECOSCAPE Environmental Consultants Ltd.



Photo: P1050810 - Approaching Taite Creek (April 1, 2012).


Photo: P1050815 - Looking downstream toward cross section location (April 1, 2012).


Photo: P1050816 - Looking upstream over drawdown zone (April 1, 2012).


Photo: P1070101 - Looking downstream towards LARL wetted level (May 14, 2012).

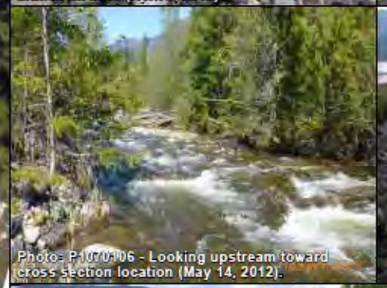
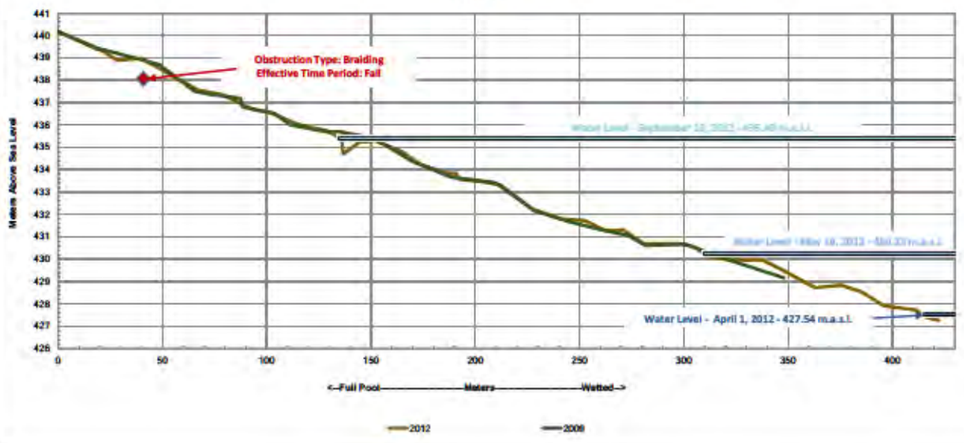


Photo: P1070106 - Looking upstream toward cross section location (May 14, 2012).

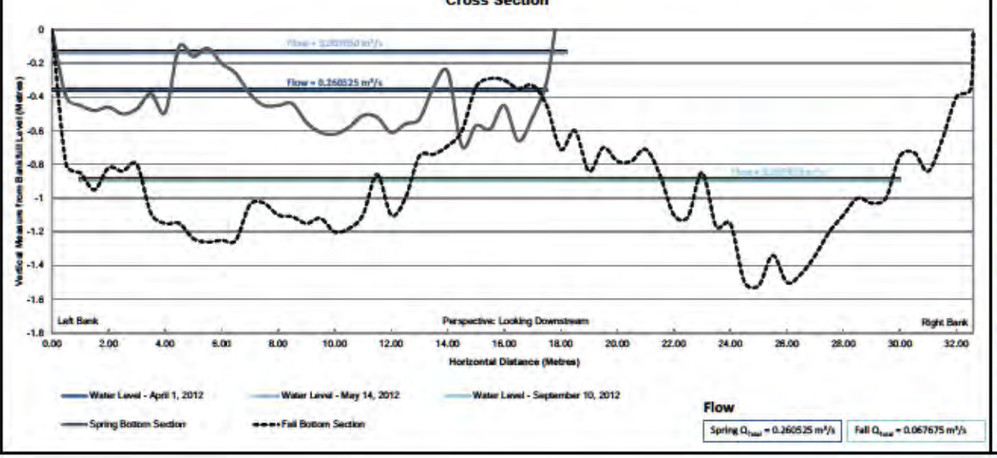

Photo: P1090370 - Looking downstream at confluence of Taite Creek and LARL (September 10, 2012).


Photo: Panorama taken from left bank looking over Taite Creek (September 10, 2012).

### Profile

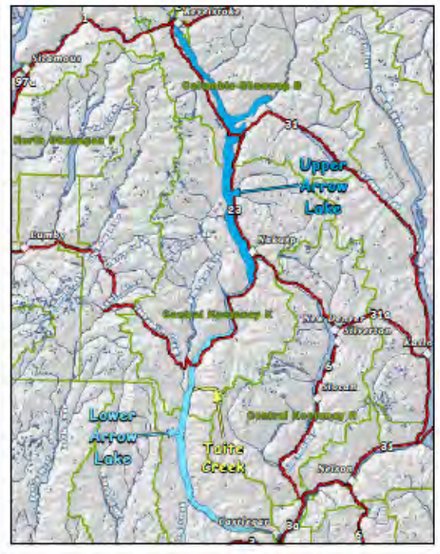



### Cross Section




**Flow**

Spring $Q_{total}$ = 0.260525 m³/s | Fall $Q_{total}$ = 0.067675 m³/s



# 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.

## 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 d/s 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.

## 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 x-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 x-section location. A black cottonwood has fallen along the right bank within the DDZ d/s of the deep pool. The stream was too swift to complete x-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 d/s of x-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.

## 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 x-section has had further beaver damage; could alter channel when falls. Instream cover includes LWD and associated scour, as well as deep water cover d/s 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 x-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.

## 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 eh Highway 6 bridge beyond the confluence of Burton and Caribou Creeks. There were no passage concerns noted.

## 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 x-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 d/s 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 x-section location. Stream flows are too swift to complete x-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 x-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 d/s of the installation point and data was retrieved; the logger was reinstalled at the left bank x-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).

## 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 x-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 brading), 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.

## 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 rootwads 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 rootwads 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 d/s of x-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 x-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 relaunched and moved d/s along right bank. X-section location relocated 2 m d/s 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.

## 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.asl). 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 x-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.

## 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 x-section. RB fry also noted near x-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.

## 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 d/s 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.

## 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 x-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.

## 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 x-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 x-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 dishcarges.

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.

## 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 x-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 x-section. Bird predation noted u/s of x-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.

## 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, 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.

**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 x-section point; therefore, x-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.

## 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 d/s of x-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).

## 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.asl) 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 x-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.

## 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 d/s of x-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.

## 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 x-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 x-section location. Quad use through the creek channel appears frequent, with essentially a road crossing the channel d/s of the x-section. A rock line has also been built up across the channel d/s of x-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 aluvial 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.

## 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 Ck is too high to electrofish, retrieve data logger or complete x-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 x-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 x-section and d/s 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).