# Walter Hardman Project Water Use Plan

## Lower Cranberry Creek: Kokanee Spawning and Incubation habitat Monitoring

**Implementation Year 1**

**Reference: WHNMON-1**

**Study Period: 2012**

**Triton Environmental Consultants Ltd.**

**October 2012**

*Project number: 4383*
*Version: 1*
*October 2012*

# WALTER HARDMAN PROJECT WATER USE PLAN

# LOWER CRANBERRY CREEK: KOKANEE SPAWNING AND INCUBATION HABITAT MONITORING

**Reference: WHNMON#1**

***Walter Hardman Water Use Plan Monitoring Program: Kokanee Spawning and Incubation Habitat Monitoring***

**Study Period: 2011**

*Prepared for:*

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October 2012

# Executive Summary

Triton Environmental Consultants Ltd. (Triton) was retained by BC Hydro to complete a one year habitat monitoring program to determine how Kokanee (*Oncorhynchus nerka*) spawning habitat suitability in lower Cranberry Creek is affected by changes in discharge associated with the Walter Hardman power generating facility. The objective was to gather information to answer the management question of whether a minimum flow through the diversion dam upstream would result in an increase to the quality and quantity of spawning habitat for Kokanee over historical operating practice.

The study focused on a section of lower Cranberry Creek between the confluence of the creek with the Upper Arrow Lakes and an obstruction located approximately 1.7 km upstream. Hydrometric and habitat data were collected at 15 transects established in three habitat types (pools, riffles, and glides). Transects locations were selected to incorporate known Kokanee spawning locations. Field work was initiated in August 2010 but high river flows resulted in the majority of data collection taking place between August and October 2011. Data were collected over a range of flows in order to compare and contrast habitat values at different discharges. The Habitat Suitability Index (HSI) curves for Kokanee spawning habitat were calculated using empirical data collected at each observed redd location. The HSI was based on three parameters (depth, velocity, and substrate) and was used in conjunction with the hydrometric and habitat data to determine the weighted usable width (WUW) for each transect in the study area.

Both depth and velocity were found to increase with discharge. Given their small size Kokanee have a very narrow range of suitable water velocities where spawning can occur, depth however did not appear to be critical in choice of spawning site. An increase in discharge can result in an unsuitable increase in velocity despite depth remaining suitable. Low velocities are also required to allow accumulation of small gravels suitable for nest building by Kokanee. These small substrates are easily mobilized and their distribution may depend on stream discharge. Useable spawning habitat was limited at all transects. The major limiting factor in the study area was the presence of suitably sized substrate.

Sampling occurred over three levels of flow: base flow, moderate flow, and high flow. Sampling at base flows (representative of pre-diversion flow; approximately 0.13 $m^3 \cdot s^{-1}$) identified suitable spawning locations for Kokanee. An increment of 0.1 $m^3 \cdot s^{-1}$ over base flows showed an increase in depth with no effect on habitat preference as well as velocity which demonstrated a reduction in spawner habitat suitability. At moderate background flows (approximately 0.56 $m^3 \cdot s^{-1}$) the amount of suitable spawning habitat diminished and Kokanee were observed to seek out refuge habitat which included the limited pool habitat available. At these flows an increment of 0.1 $m^3s^{-1}$ further exacerbated the reduction of spawning habitat value in Cranberry Creek.

The diversion structure at the Walter Hardman facility is incapable of delivering design flows at 0.1 $m^3s^{-1}$ on a continuous basis, however based on data collected during several natural flow scenarios, a diversion flow of 0.1 $m^3 \cdot s^{-1}$ would not negatively affect Kokanee spawning habitat at low background flows. At higher background flows (above 0.5 $m^3s^{-1}$) any influence from the diversion flows is overwhelmed.

During the study period flows in Cranberry Creek were highly variable. Increases in mean depth and more importantly in channel velocity had a negative effect on the spawning habitat available. WUW decreased with increasing discharge. Elevated discharge resulted in the majority of Kokanee moving into refuge habitats and selecting spawning locations in pools while abandoning potential spawning areas in riffles and glides. Elevated flows provided some spawning habitat along stream margins, however these areas were at risk to dewatering with cessation of spills. The highly variable flows in Cranberry Creek result in a very challenging environment for spawning Kokanee salmon.

### WHNMON-1 Status of Objectives, Management Questions and Hypotheses

| Objectives | Management Questions | Management Hypotheses | Status |
|---|---|---|---|
| To determine the effectiveness of the 0.1 $m^3s^{-1}$ flow release for improving the quality and quantity of Kokanee spawning habitat in Lower Cranberry Creek and provide information on potential fisheries benefits obtained by alternative minimum flow releases. | Does the implementation of the 0.1 $m^3s^{-1}$ minimum flow release improve the quality and quantity of spawning habitat for Kokanee over that predicted for historical operating practice (no minimum flow)? | Overarching hypothesis to be tested by monitoring program:<br><br>$H_0$: Operation of the diversion dam to provide a minimum flow release of 0.1 m3s-1 does not improve the quality and quantity of spawning habitat for Kokanee in Lower Cranberry Creek over conditions of no minimum flow.<br><br>$H_A$: Operation of the diversion dam to provide a minimum flow release of 0.1 m3s-1 does improve the quality and quantity of spawning habitat for Kokanee in Lower Cranberry Creek over conditions of no minimum flow. | The release of a 0.1 $m^3s^{-1}$ minimum flow resulted in a positive effect in pool habitat but a negative trend in riffle and glide habitats. The change however is minimal and the main constraint to production appears to be the high variability of flows during Kokanee spawning period. |
| | Would the implementation of a 0.5 $m^3s^{-1}$ minimum flow release provide increased protection and/or enhancement of Kokanee spawning habitat over that delivered by the 0.1 $m^3s^{-1}$ minimum flow release? | Overarching hypothesis cannot be tested directly because of the variation in the seasonal pattern and magnitude of inflows to Cranberry Creek therefore three sub-hypotheses were tested:<br><br>$H_1$: The release of a 0.1 $m^3s^{-1}$ minimum flow will result in a significant increase in the depth of flow key Kokanee spawning locations.<br><br>$H_2$: The release of a 0.1 $m^3s^{-1}$ minimum flow will not result in an unsuitable increase in the flow velocity in key Kokanee spawning locations.<br><br>$H_3$: The release of a 0.1 $m^3s^{-1}$ minimum flow will result in a significant increase in the suitable (depth and velocity integrated) habitat area in key Kokanee spawning locations. | The release of 0.5 $m^3s^{-1}$ minimum flow will not result in a significant increase in the suitable (depth and velocity integrated) habitat area in key Kokanee spawning locations. |

## Disclaimer

This report is rendered solely for the use of BC Hydro in connection with the Walter Hardman Project Water Use Plan Monitoring Program (WHNMON #1: Kokanee Spawning and Incubation Habitat Monitoring Program), and no person may rely on it for any other purpose without BC Hydro's prior written approval. Should a third party use this report without approval, they may not rely upon it. BC Hydro and Triton accept no responsibility for loss or damages suffered by any third party as a result of decisions made or actions taken based on this report.

This report is based on facts and opinions contained within the referenced documents provided by BC Hydro. We have attempted to identify and consider relevant facts and documents pertaining to the scope of work, as of the time period during which we conducted this analysis. However, our opinions may change if new information is available or if information we have relied on is altered.

We applied accepted professional practices and standards in developing and interpreting data obtained by our field measurement, sampling, and observations. While we used accepted professional practices in interpreting data provided by BC Hydro or third party sources we did not verify the accuracy of data provided by BC Hydro or third party sources.

This report should be considered as a whole and selecting only portions of the report for reliance may create a misleading view of our opinions.

## TABLE OF CONTENTS



## LIST OF FIGURES

## LIST OF TABLES



## LIST OF APPENDICES

# 1.0 Introduction

Triton Environmental Consultants Ltd. (Triton) was retained by BC Hydro in 2010 to complete a one year habitat monitoring program to determine how Kokanee (*Oncorhynchus nerka*) spawning habitat suitability in lower Cranberry Creek is affected by changes in discharge. The objective was to gather information to answer the management question of whether a 0.1 $m^3s^{-1}$ minimum flow through the diversion dam upstream would result in an increase in quality and quantity of spawning habitat for Kokanee over historical operating practice (no diversion flow).

This program is one of several described by the Walter Hardman Water Use Plan (BC Hydro, 2004) which are designed to monitor the outcomes of operational changes and changes to physical works, and provide information on which to base future operating decisions. The overall goal of the programs is to determine the effect of changes in minimal flow on the resident Kokanee and Rainbow Trout populations in Cranberry Creek.

## *1.1 Project Background*

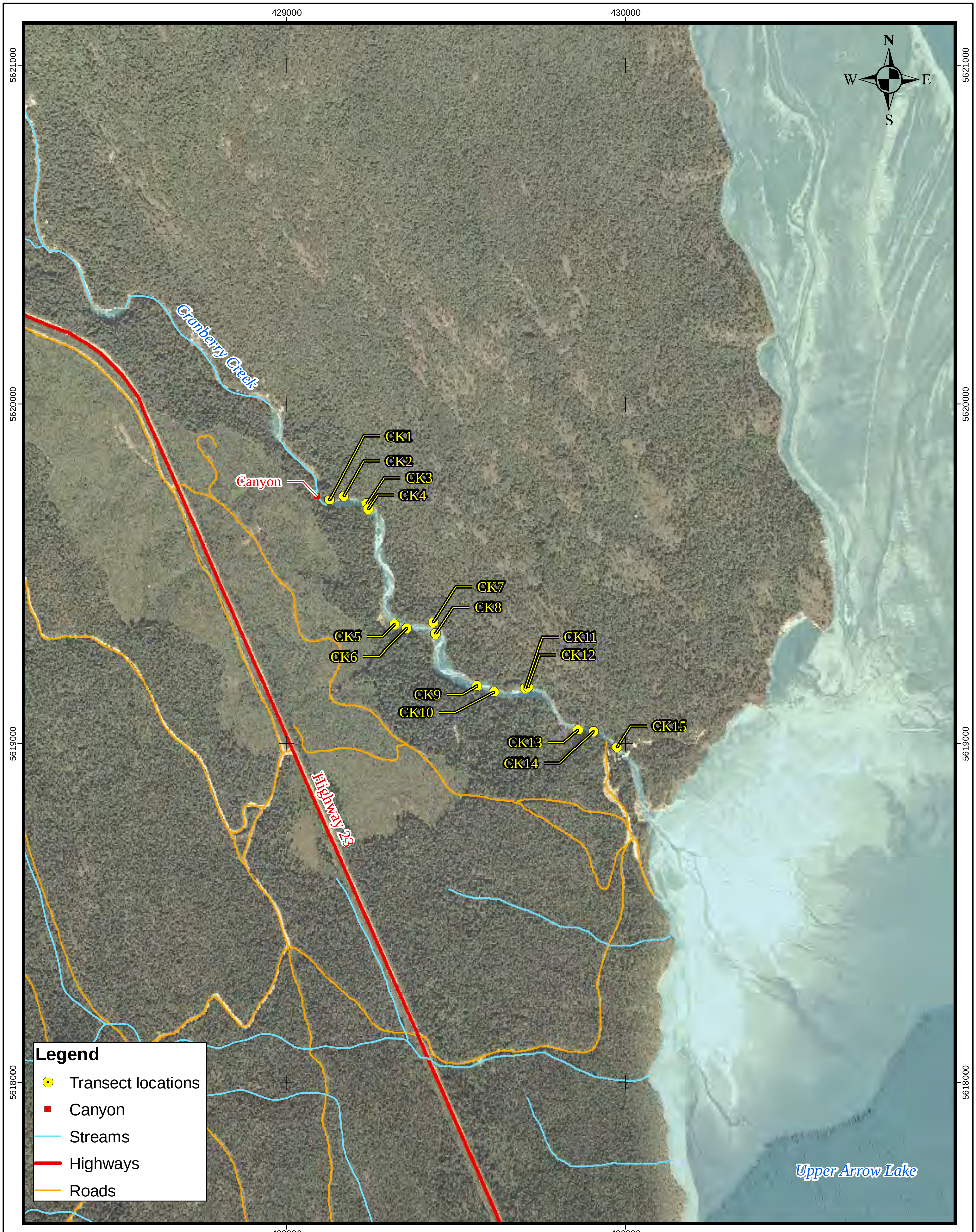
The Walter Hardman Hydroelectric project is located on Cranberry Creek, within the Columbia-Shuswap Regional District. The generating station is approximately 25 km south of Revelstoke, BC and uses water diverted from Cranberry Creek to generate power. When creek flows are greater than plant capacity (approximately 4.3 $m^3s^{-1}$), excess water is diverted to Lower Cranberry Creek; however when flows are less than plant capacity insufficient water is released from the diversion dam to keep the creek downstream wetted.

The cessation of flows at the diversion dam results in the dewatering of Cranberry Creek for 2 to 3 km downstream. The Water Use Planning Committee recognized the impacts associated with the dewatering during low flow periods and hypothesized that the construction of a diversion structure to deliver continuous flows during the year would have a positive effect on Kokanee production. To that end a water diversion structure was installed at the diversion dam with an objective of delivering a minimum flow of 0.1 $m^3s^{-1}$. The objective of the diversion flow is to aid Rainbow Trout production in the stream section downstream from the diversion while not having a negative effect on Kokanee spawning potential (BC Hydro 2010).

Fish usage in Cranberry Creek is limited by an impassible barrier (falls) located approximately 2.3 km upstream from the mouth (Figure 1-1). Kokanee are restricted to the lower stream section, while Rainbow Trout (O*nchorhynchus mykiss*) are the sole sport fish species inhabiting the stream sections above the barrier (sculpins are also present upstream). Downstream from the falls at approximately 1.7 km upstream of the confluence there is a canyon which would be a barrier to Kokanee migration at high flows. This canyon formed the upstream boundary for this study which extends to the confluence.

Kokanee utilize the lower 2.3 km of Cranberry Creek for spawning, which occurs in September, and subsequent incubation. The current low flows in the lower stream section provide spawning habitat for Kokanee, which due to their small size is restricted to low velocity areas with small gravel substrates. The increase of flows associated with the diversion has the potential to increase depths and velocity in lower Cranberry Creek and thereby affect habitat suitability for Kokanee spawning. In addition, elevated flows have the potential to affect the distribution of spawning gravels.

The objective of this report is to address the following scope requirements: To determine how changes in discharge affect the spawning habitat suitability for Kokanee in Cranberry Creek. This report provides a description of Kokanee spawning habitat in Cranberry Creek and assesses the impacts of diversion flows (0.1 $m^3s^{-1}$) on Kokanee spawning habitat values. A second study focussed on flow related impacts on Rainbow Trout in Cranberry Creek upstream of the falls (WHNMON-2).




Cranberry Creek

**Figure 1.1.**
**Site Location Map**

| | | | |
|---|---|---|---|
| **Basemap Source:** British Columbia Imagery WMS | 0 50 100 200 300 400 500 Meters<br>**Scale:** 1:15,000 | | **Map Datum:** UTM NAD 83 Zone 11 |
| **Project No:** 4383 | **File No:** Map#: N:\ACTIVE\4383_Cranberry_Creek \MXD\CranberryCreekFigure1.mxd | **Date:** December 7, 2012 | TRITON ENVIRONMENTAL CONSULTANTS LTD. |

## 2.0 Methods

The methodology for the Lower Cranberry Creek Kokanee Spawning and Incubation Habitat Monitoring program follows the BC Hydro Terms of Reference (BC Hydro, 2010) and adheres to the Resources Information Standards Committee (RIC) Fish and Fish Habitat Inventory (RISC, 2000), and to the Fish Collection Methods and Standards (RISC, 1997).

To address the primary management question regarding the effectiveness of implementing a minimum flow release in improving Kokanee spawning habitat, an overarching hypothesis was developed: Operation of the diversion dam to provide minimum flow releases of 0.1 $m^3s^{-1}$ does improve the quality and quantity of spawning habitat for Kokanee in Lower Cranberry Creek over conditions of no minimum flow. This hypothesis cannot be tested directly because of the variation in the seasonal pattern and magnitude of inflows to Cranberry Creek therefore three sub-hypotheses were tested:

$H_1$: The release of a 0.1 $m^3s^{-1}$ minimum flow will result in a significant increase in the depth of flow in key Kokanee spawning locations.

$H_2$: The release of a 0.1 $m^3s^{-1}$ minimum flow will not result in an unsuitable increase in the flow velocity in key Kokanee spawning locations.

$H_3$: The release of a 0.1 $m^3s^{-1}$ minimum flow will result in a significant increase in the suitable (depth and velocity integrated) habitat area in key Kokanee spawning locations.

### *2.1 Study Design*

The hypotheses were tested by analyzing habitat suitability at various flow rates and determining the effectiveness of a minimum flow of 0.1 $m^3s^{-1}$. Triton targeted collection of habitat measurements at three levels of discharge in Lower Cranberry Creek:

- Low – approximately equivalent to minimum base flow of 0.13 $m^3s^{-1}$
- Moderate – approximately equivalent to discharge of 0.56 $m^3s^{-1}$
- High – during a spill event at the diversion structure .

Low flow ranged from 0.06 $m^3s^{-1}$ to 0.26 $m^3s^{-1}$ when no spills were taking place and is representative of pre-diversion flow. Suitable spawning locations for Kokanee were therefore identified at this flow level. Moderate flow ranged from 0.53 $m^3s^{-1}$ to 0.87 $m^3s^{-1}$ and was aimed to be representative of 0.1 $m^3s^{-1}$ above base flow. High flow ranged from 1.13 $m^3s^{-1}$ to 2.00 $m^3s^{-1}$ and was necessary to determine the effect on habitat availability when background flow is high (e.g., storm run-off). However, not all transects were sampled during high flow. High water created unsafe conditions and two transects (CK5 and CK9) could not be accessed during that time. Sampling at three levels allowed us to directly observe changes in the habitat suitability and availability in Cranberry Creek. Additionally, data taken over a range of flows was used to create relationships and therefore predict the changes in habitat suitability and availability with varying increases of minimum flow.

## 2.2 Field Study

The study area was located along the lower section of Cranberry Creek between the mouth of the creek and a canyon located approximately 1.7 km upstream from Upper Arrow Lake. The canyon created an obstruction to fish passage at high flows but upstream access is possible at low flows. However, an impassable falls 2.7 km upstream from the reservoir defines the upper limit of Kokanee access.

The inability of the structure at the overflow weir to function as designed predicated the need to target natural flow events that would approximate study objective flows. However, the lack of monitoring data at the diversion structure made prediction of discharge conditions difficult and therefore associated field surveys did not always capture ideal flow conditions. In the absence of a discharge monitoring system, data on timing of spills and on release discharges were not available. Therefore the field crew relied on communication with BC Hydro personnel (Karen Bray) in Revelstoke to obtain information on flows in Cranberry Creek. Additionally, local weather reports were accessed to attempt site visits during dry periods and webcam images at the diversion dam provided feedback on spill conditions. This information was used to time field trips. The program involved multiple field visits to collect data; Table 3-1 outlines the schedule of field visits where data was collected.

An initial reconnaissance trip was completed in early September 2010 to identify general habitat conditions and assess Kokanee presence. A subsequent trip was undertaken on September 12, 2010 to install a staff gauge and a continuous recording stage monitoring device to provide information on stream flow variability. Stream flows were elevated during this time and Kokanee were found in refuge habitats, which precluded collection of habitat suitability data. High flow conditions continued through September 2010 and it was decided, based on dialogue with Karen Bray (BC Hydro), that the Kokanee habitat suitability study would be deferred until September 2011.

Flows in Cranberry Creek are unpredictable and there was a risk that flow regimes similar to 2010 could occur during the 2011 Kokanee spawning period. To mitigate this risk it was proposed to collect data at low flows during August before Kokanee had moved into the system to spawn. The risk associated with this revised approach was that transects could only be established at assumed spawning locations as opposed to active redds. However after discussion with the contract authority it was decided that this was the best approach to take. Transects were therefore established in August 2011.

### 2.2.1 Transect Site Selection

The selection of transect sites was based on hydraulic and habitat information obtained from the field reconnaissance conducted in 2010. The rationale for placement of transects was primarily based on the inclusion of suitable Kokanee spawning habitat. This included areas where suitable flow velocities and more importantly deposits of suitably sized gravels (less than 2 cm) were present. In order to determine how the usable spawning habitat in the system changes over a range of flows, transects were established within three representative habitat units: pools, riffles, and glides (Table 2-1). In pools this habitat was found at the tailouts while in glides and riffles it was associated with deposition pockets of small gravels. Additionally, access and safety were considered in the selection process. Specifically transects were located in areas where crews could safely work under a range of flows.

**Table 2-1. Transect distribution per habitat unit**

| ***Habitat Unit*** | ***Transect*** |
|---|---|
| Pool | CK1,13 (at high flow) |
| Riffle | CK2, 3, 4, 5, 9, 14, 15 |
| Glide | CK6, 7, 8, 10, 11, 12, 13 |

### 2.2.2 Habitat Types

Three habitat types: pool, riffle, and glide, were chosen for analysis based on their importance to Kokanee in Cranberry Creek. Pools were found sporadically within the study area in Cranberry Creek. Pools are hydraulic units where the water surface slope is zero degrees. They are normally deeper and wider than the aquatic habitat immediately above and below. Riffles were found throughout the study area and are characterized by shallow (less than 0.30 m depth) broken surface water over mixed cobble or gravel substrates with channel gradient within the 1% to 3% range. Glides were found in the lower gradient sections (less than 1%) of Cranberry Creek and were characterized by shallow (i.e., depth less than or equal to 5% of the average stream width), uniform flow, and unbroken surface water over primarily homogenous gravel substrates (Armantrout, 1998).

### 2.2.3 Field Data Collection

Transect selection was based on presence of Kokanee spawning habitat (e.g., low velocities with small gravels). Transects were marked and geo-referenced to allow re-location in the field. Geo-coordinates (Universal Transverse Mercator - UTM) were collected with a handheld GPS unit using the NAD83 map datum. Each transect was identified with a simple numerical system and benchmarks (stakes) were installed at each transect on both stream banks so that water level measurements could be referenced to the same fixed point for each site visit.

Hydrometric data was collected at a minimum of 20 sampling stations along each transect. The distributions of the sampling stations across each transect were uniform and measured from the established benchmarks. Channel bed and water level elevation data were collected using standard surveying techniques. At each transect, measurements of habitat characteristics (i.e., depth, velocity, and substrate) were collected. Velocity was measured using a horizontal axis Swoffer model 2100 single propeller current meter. The channel and wetted widths were also measured and discharge (Q) in the creek was then calculated for each transect.

The equation is: $Q = \sum_i^n (W_i * D_i * V_i)$

where '$\mathbf{W_i}$' is the width of cell '$\boldsymbol{i}$' on the transect, '$\mathbf{D_i}$' is water depth at cell '$\boldsymbol{i}$', '$\mathbf{V_i}$' is the water velocity at cell '$\boldsymbol{i}$', and '**n**' is the number of cells across the transect.

Substrate was visually estimated as the percentage of each size class (Table 2-2) to the nearest 25% at each station along the transect. Digital photographs in each of four directions (upstream, downstream, left bank, and right bank) were obtained at each transect and archived.

Habitat surveys were also conducted in September 2011 when Kokanee spawning activity was observed. The goal was to assess the accuracy of transect location and collect HSI data at active redd sites. Nosepoint velocity and depth were recorded for each redd using a Swoffer model 2100 current meter. Velocity was recorded at 5 cm above the substrate, as this was representative of velocities experienced by spawning Kokanee. The size of the redd was measured based on the area of disturbed substrate, when possible. Redd structure was often not readily observable due to small fish size, and their inability to create structured redds; however some disturbance indicators were evident. Each observed redd was geo-referenced and the habitat unit (i.e., pool, riffle, or glide) were also recorded.

## 2.3 Data Compilation and Analysis

Project-specific data forms were developed to ensure consistent data collection at each sampling site. All data collected was entered into a Microsoft Excel spreadsheet for analysis. To answer the overarching question regarding the effects at minimum flow, transects with data collected at low and moderate stages (i.e., discharge of 0.13 $m^3s^{-1}$ and 0.56 $m^3s^{-1}$ respectively) were used. Where data was also collected at the high stage (discharge 1.67 $m^3s^{-1}$) it was included in the analysis. Data was grouped by habitat unit (e.g., pool, riffle, glide) and each was analyzed separately across the three flow levels.

### 2.3.1 Habitat Suitability Index (HSI)

HSI curves relate the relative preference of fish for each parameter. Three parameters were used to determine the physical habitat suitability of Cranberry Creek for Kokanee: water depth, water velocity, and substrate composition. The HSI curves for Kokanee spawning habitat were calculated using empirical data collected at each observed redd location. Data collected at 38 observed Kokanee redds were incorporated to develop HSI curves for depth and velocity specific to Cranberry Creek. Data were grouped into bins to provide a frequency distribution for each parameter. The percent use for each bin was determined by dividing the frequency of each bin by the total number of redds. The probability of use or habitat suitability (HS), is the percent use of each bin divided by the greatest percent use.

The equation is: $HS_p = \%\ Use_b / \%\ Use_B$

Where '***p***' is the parameter being considered (i.e., depth or velocity), '***b***' is the bin or category, and '***B***' is the bin or category with the greatest percent use. The habitat suitability rating was based on the frequency distribution. These curves are presented in Section 3.2.

HSI scores for substrate were derived from the RISC standards (RIC, 1999) and Triton (2009) and are presented in Table 2-2. Stream bed substrate is a key component in Kokanee spawning habitat suitability, as it is a major factor in spawning site selection and provides the medium for egg incubation. Cranberry Creek Kokanee are small (adult fork-length approximately 20 cm) and therefore are restricted to the velocities they can tolerate (0.05 $ms^{-1}$ to 0.24 $ms^{-1}$), and substrate they can mobilize (2 mm to 16 mm).

**Table 2-2 HSI scores for stream bed substrate**

| Substrate | Substrate Size* (mm) | HSI – Kokanee Spawning Habitat* |
|---|---|---|
| Rock | Greater than 4,000 | 0.0 |
| Boulder | 256 – 4,000 | 0.0 |
| Large Cobble | 128 – 256 | 0.0 |
| Small Cobble | 64 – 128 | 0.0 |
| Large Gravel | 16 – 64 | 0.0 |
| Small Gravel | 2 – 16 | 1.0 |
| Sand/Silt | Less than 2 | 0.0 |
| Detritus | Organic material | 0.0 |

*Taken from RISC – Site Card Field Guide, 1999; Triton, 2009.

### 2.3.2 Weighted Usable Width

The weighted usable width (WUW) indicates how much of the wetted channel width is suitable for a life history stage based on HSI criteria for that particular species. The methods used follow instream flow guidelines designed to describe changes in suitable fish habitat for the species and life history stage of management concern. The approach uses empirical data (from field measurements) to the extent possible to avoid errors inherent to hydraulic modelling of streams with complex channels. Another aspect of the approach uses At-a-Station Hydraulic Geometry (AHG) developed by Reid (2005) using channel cross-section, depth, and average velocity measurements (empirical data) at various flows to define hydraulic relationships in representative habitat types.

The WUW was calculated for each of the 15 transects using HSI values for suitability for mean depth and velocity, and the dominant bed substrate in each segment.

The equation is: $WUW_{dvs} = \sum_i^n (W_i * D_i * V_i * S_i)$;

where '$\mathbf{W_i}$' is the width of cell '$\boldsymbol{i}$' on the transect, '$\mathbf{D_i}$' is the suitability of depth at cell '$\boldsymbol{i}$', '$\mathbf{V_i}$' is the suitability of velocity at cell '$\boldsymbol{i}$', '$\mathbf{S_i}$' is the suitability of substrate at cell '$\boldsymbol{i}$' (Hatfield et al., 2007).

WUW values were plotted against discharge for each habitat unit, and a polynomial regression was fitted to each habitat type. The use of biased site selection precluded the ability to expand the WUW calculations to provide an estimate of total change of habitat over the range of flows analyzed.

# 3.0 Results

Field crews completed four visits to Lower Cranberry Creek to collect data over a range of flows. The dates for each visit are listed in Table 3-1. Tabular summaries of general habitat characteristics as well as plots of transect profiles are included in Appendix 1.

**Table 3-1. Schedule of field visits, Triton2012.**

| Date | Discharge ($m^3s^{-1}$) | Stage | Comments |
|---|---|---|---|
| September 7, 2010 | - | High | Initial reconnaissance. |
| September 12, 2010 | 1.13 | High | Install staff gauge and continuous monitoring device. Hydrometric data collection. |
| November 5, 2010 | 0.78 | Moderate | Hydrometric data collection. |
| August 31, 2011 to September 1, 2011 | 0.13* | Low | Habitat and hydrometric data collection at transects. |
| October 26 to 27, 2011 | 0.56* | Moderate | Habitat and hydrometric data collection at transects. |
| September 21 to 22, 2011 | 1.67* | High | Habitat and hydrometric data collection at transects. |

*mean value derived from data collected at all transects during that sample period

## 3.1 Hydraulic Changes with Change in Discharge

### 3.1.1 Change in Depth

A HOBO continuous recording stage monitoring device installed at Transect 14 recorded data from September 14, 2010 until November 5, 2010, when it was displaced by high flows. There was a high variability in depth (Figure 3-1), reflecting rapid changes in discharge. In general, flows during the spawning period were elevated beyond base flow conditions and were highly variable. The depths measured from the data logger (Transect 14) were plotted against discharges (Figure 3-2).

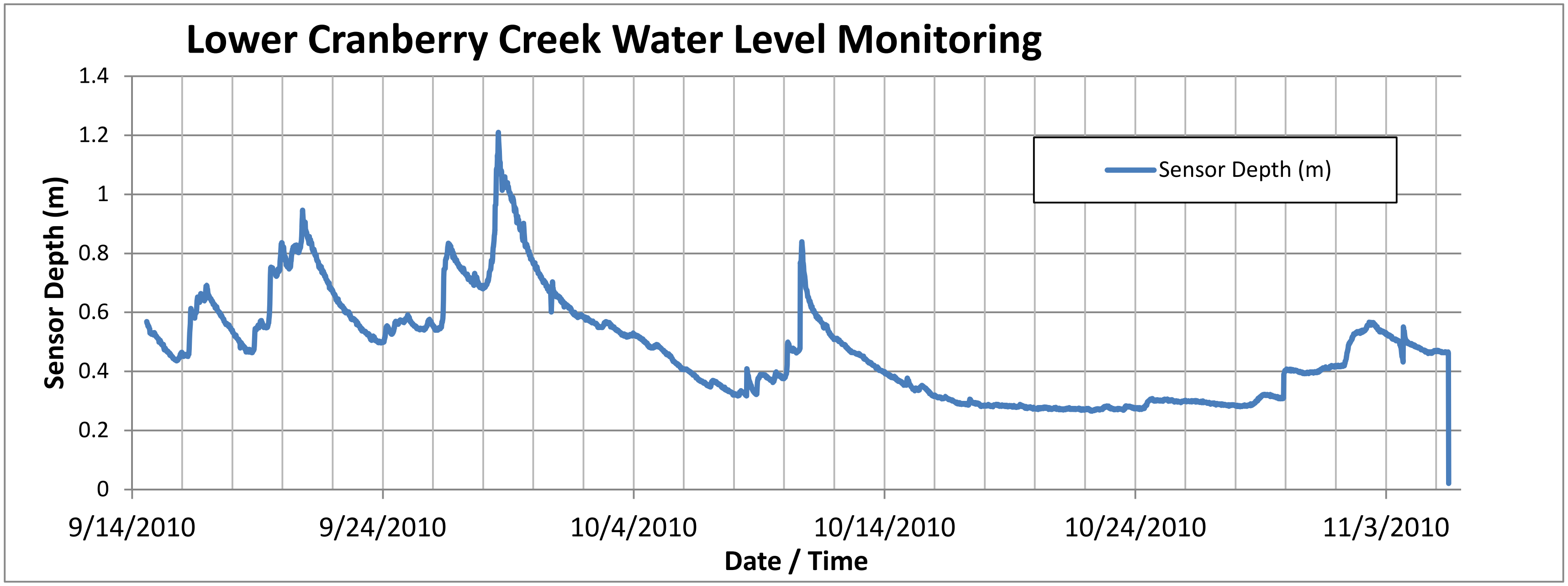



**Figure 3-1. Water levels (m) from lower Cranberry Creek from September 14th to November 5th, 2010.**

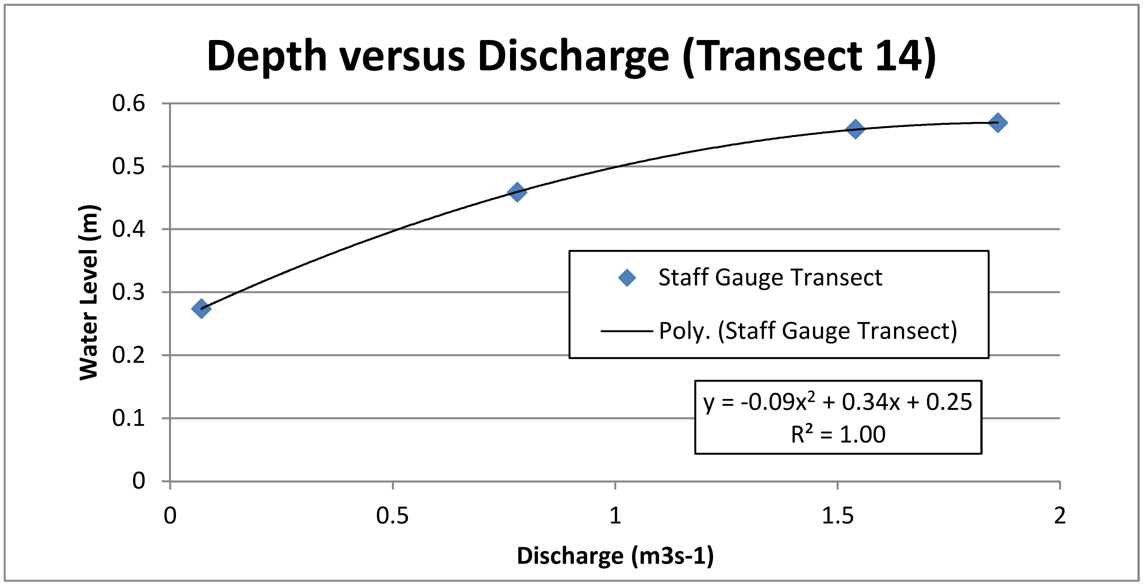



**Figure 3-2. Relationship between sensor depth and discharge, Triton, 2012**

Depth increased with increasing discharge (Figure 3-2 and Table 3-2). Within pools the mean depth increased from 0.09 m at low flow to 0.70 m at the highest observed flow. Mean depth also changed noticeably in riffle and glide habitat units. The mean riffle depth increased from 0.16 m to 0.29 m and in glides from 0.20 m to 0.41 m during the same period.

**Table 3-2. Mean hydraulic measurements per habitat unit, Triton, 2012**

| Habitat Unit | Stage | Discharge ($m^3s^{-1}$) | Mean Depth (m) | Mean Velocity ($ms^{-1}$) |
|---|---|---|---|---|
| **Pool** | **Low** | 0.15 | 0.09 | 0.09 |
| | **Moderate** | 0.56 | 0.14 | 0.23 |
| | **High** | 1.61 | 0.70 | 0.36 |
| **Riffle** | **Low** | 0.10 | 0.16 | 0.08 |
| | **Moderate** | 0.54 | 0.25 | 0.22 |
| | **High** | 1.71 | 0.29 | 0.39 |
| **Glide** | **Low** | 0.13 | 0.20 | 0.07 |
| | **Moderate** | 0.57 | 0.28 | 0.22 |
| | **High** | 1.69 | 0.41 | 0.28 |

### 3.1.2 Change in Velocity

Velocities measured at each transect also increased with increased discharge (Table 3-2). The change in velocity with discharge was linear within each habitat unit. In general, with every 0.1 $m^3s^{-1}$ increase in discharge, the velocity increased approximately 0.1 $m{\cdot}s^{-1}$ (Figure 3-3).

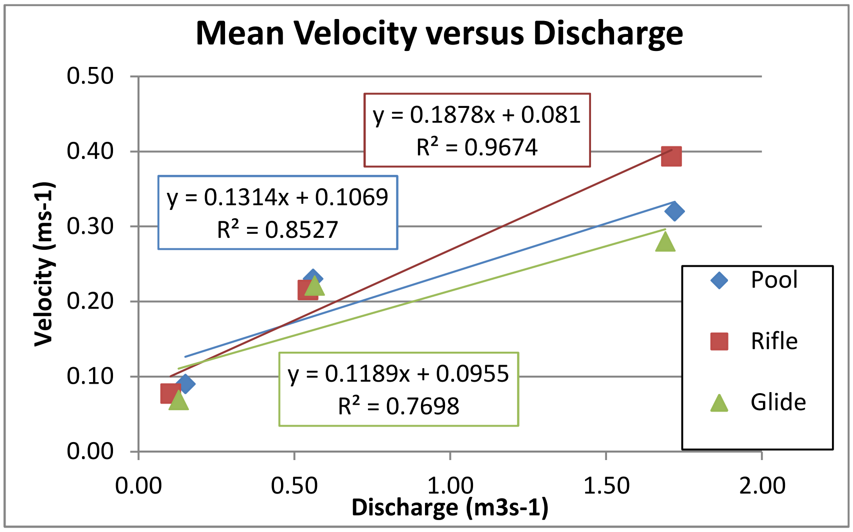



**Figure 3-3. Relationship between velocity and discharge.**

## *3.2 Analysis of Redd Data to Produce HSI Curves*

Redds were observed clumped within the study area as the amount of suitable spawning substrate was limited within the channel. Redds were observed in gravel substrate at the tailout of two identified pools as well as in pockets in lower velocity areas associated with larger substrate elements. Contributing factors included accumulation of gravel to the system, and substrate mobilization associated with elevated flows and high velocities. All redds are influenced by localized hydraulic conditions. Spawning activity was concentrated in pools at elevated flows, when fish were forced to seek out refuge habitats from high velocities. The probability of use calculated from empirical data shows the preferred depths and velocities for Kokanee redds (Figure 3-4 and Figure 3-5).

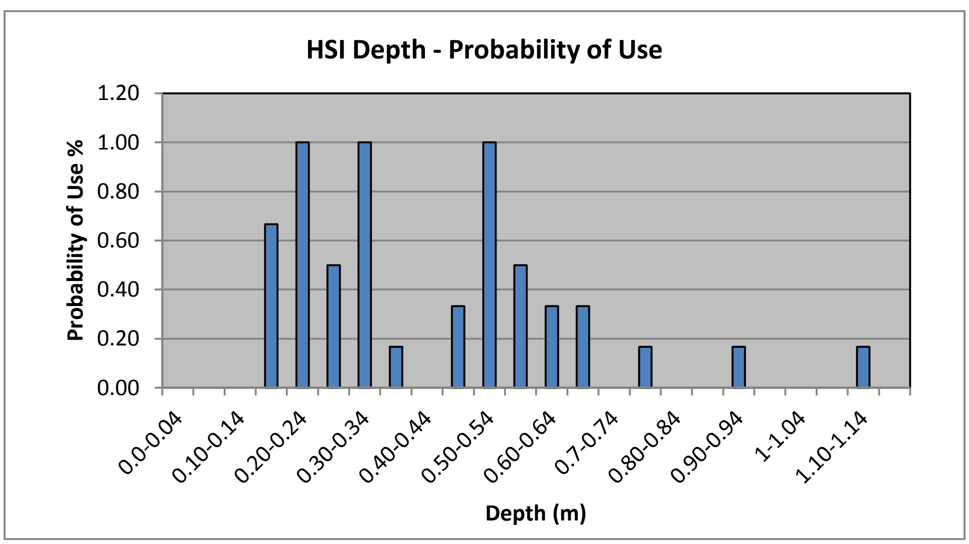



**Figure 3-4. Lower Cranberry Creek HSI depth for Kokanee spawning**

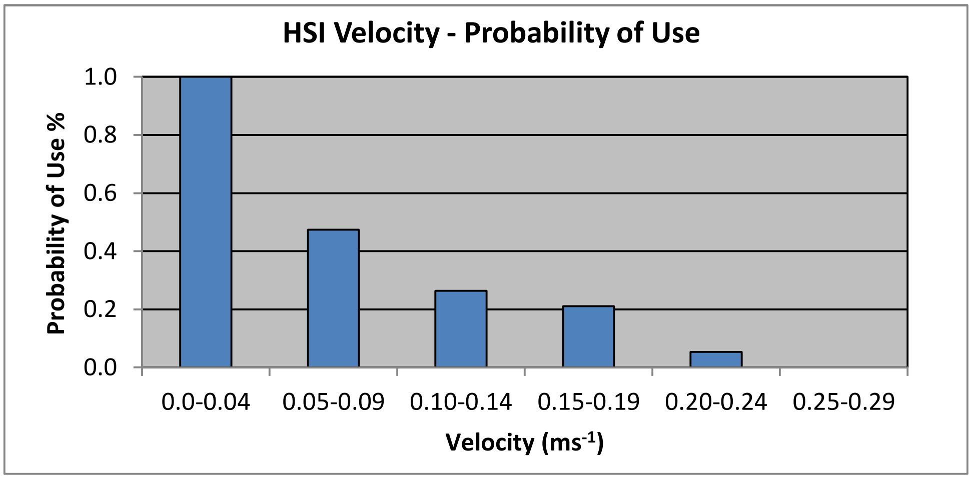



**Figure 3-5. Lower Cranberry Creek HSI velocity for Kokanee spawning**

Habitat suitability curves were generated using the empirical data (frequency of use) as shown in Figure 3-6**Error! Reference source not found.**. A tabular summary of the data is provided in Appendix 2. Mean transect depths ranged from 0.09 m to 0.72 m, and the derived HSI depth curve reflects Kokanee usability throughout that depth range. The deeper values are associated with pools, reflective of the use of this type of habitat during the elevated flows seen throughout the survey period.

HSI velocity criteria show a preference for low to negligible velocity in spawning locations. The majority of spawning activity was associated with water velocities ranging from negligible flow to 0.2 $ms^{-1}$. These velocities are associated with pools and low velocity pockets in riffles and glides. These velocities are also required to recruit the small gravels suitable for redd building by Kokanee.

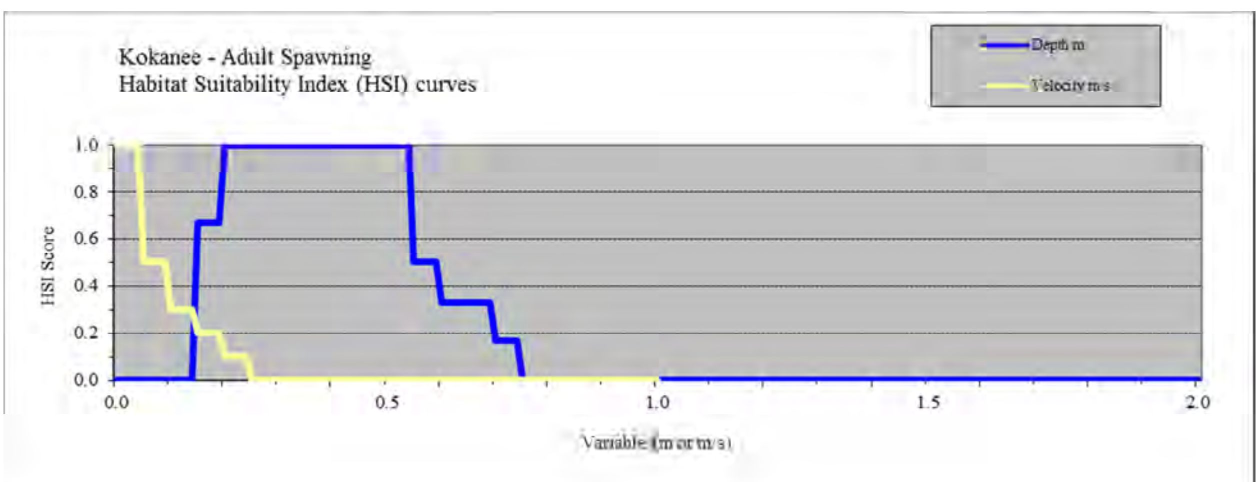



**Figure 3-6. Habitat suitability index (HSI) curves for Kokanee spawning habitat**

### 3.3 Weighted Usable Width

The HSI data was applied to the hydrometric data for each transect to calculate the weighted useable width (WUW). A summary of the calculated WUW per transect at three stages of flow is provided in Appendix 3.

Each habitat unit responded slightly differently to the increase in discharge which affected the available suitable habitat. Figures 3-7 to 3-9 show the WUW values against the measured discharge for each habitat unit. The points represent the WUW calculated from empirical data, and the fitted line (Figure 3-8 and 3-9) shows the relationship between discharge and WUW. A polynomial regression was used because the relationship between discharge and usable habitat is not linear.

WUW increased with discharge in pool habitat units (Figure 3-7). For example from low discharge (approximately 0.13 $m^3s^{-1}$) to moderate discharge (approximately 0.56 $m^3s^{-1}$) each 0.1 $m^3s^{-1}$ increase in discharge, resulted in an increase of 0.17 m in WUW. Alternatively increase from moderate to high (greater than 1.0 $m^3s^{-1}$) showed an increase of 0.05 m per 0.1 $m^3s^{-1}$ of discharge.

At low water levels, an increase in discharge was shown to increase the WUW for each transect within riffle habitats (Figure 3-8). However, as discharge increased further (greater than 1.0 $m^3s^{-1}$), WUW was shown to decrease in riffles. WUW decreased in glide habitat at low flows (less than 0.56 $m^3s^{-1}$) but increased slightly as discharge increased above 1.0 $m^3s^{-1}$ (Figure 3-9).

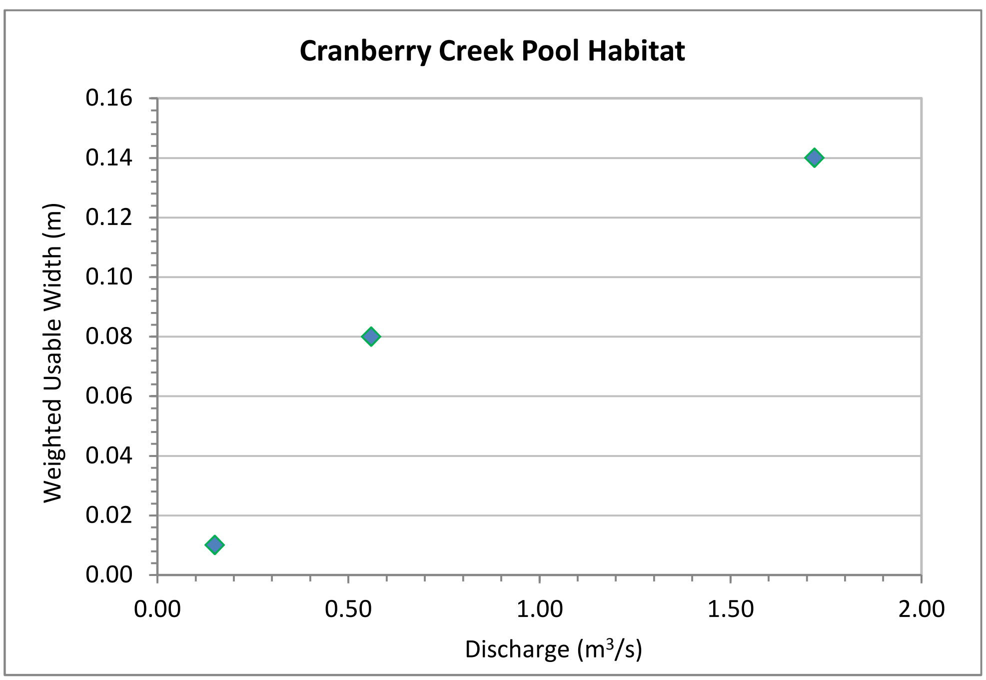



**Figure 3-7. Data correlation curve for pool hydraulic unit in Cranberry Creek, Triton, 2012**

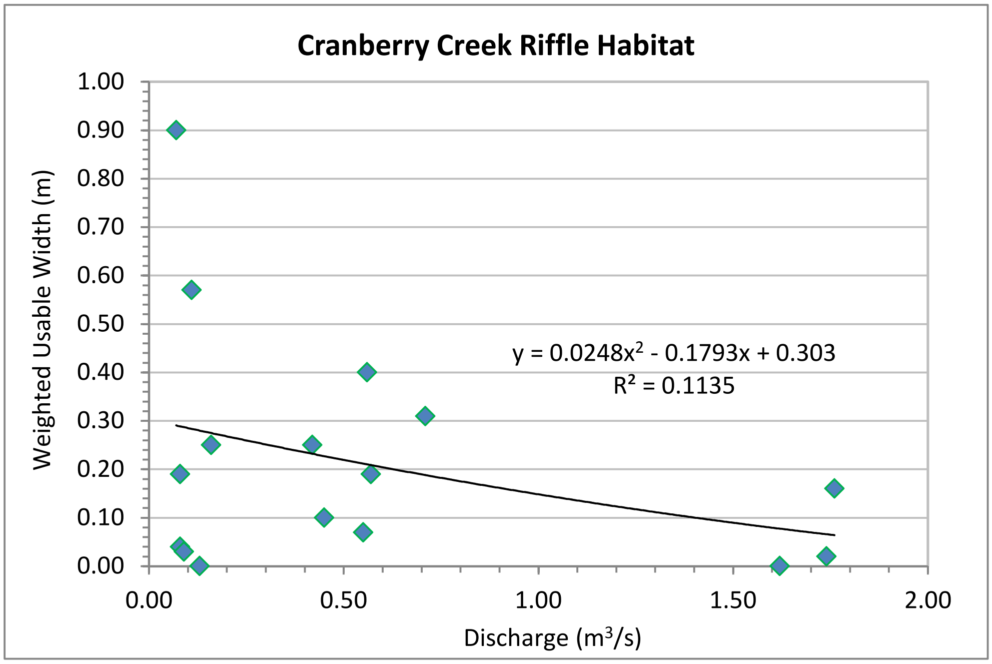



**Figure 3-8. Data correlation curve for riffle hydraulic unit in Cranberry Creek, Triton, 2012**

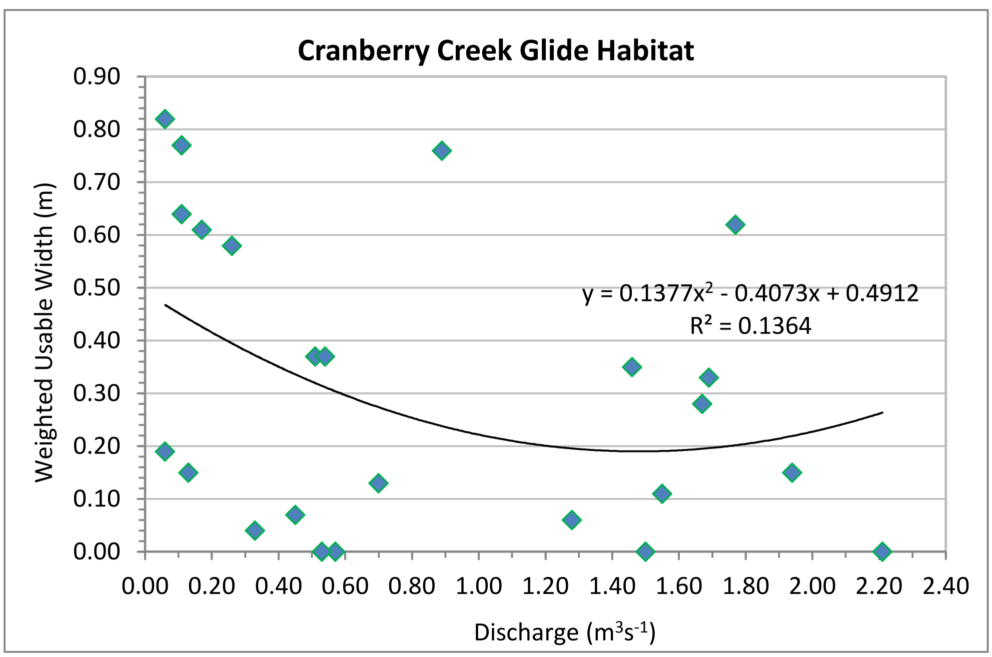



**Figure 3-9. Data correlation curve for glide hydraulic unit in Cranberry Creek, Triton, 2012**

# 4.0 Discussion

Cranberry Creek displayed highly variable flows throughout the project timelines, which made it difficult to collect data at targeted flows. Additionally, flows often changed during data collection trips. Diversion bypass flows during the study were estimated to be less than 0.01 $m^3s^{-1}$, or an order of magnitude below design flows, and approximated pre-diversion low flows. Overtopping of the diversion dam occurred during high flows in upper Cranberry Creek and as a result of gate adjustments at the Walter Hardman Reservoir. As there is no flow gauge in lower Cranberry Creek, the timing of field visits was best-guess, relying on weather forecasts and previous day images of the diversion dam. Several trips were cancelled on arrival due to elevated river flows.

## 4.1 Effects of 0.1 $m^3s^{-1}$ Minimum Flow on Depth in Key Spawning Locations

Depth increased with increased flow. As the depths increased and the wetted width expanded, more areas of the channel became accessible to fish. Kokanee prefer depths in the range of 0.2 m to 0.54 m (HSI at 95%; Appendix 1) for spawning but will spawn in suitable substrates in depths ranging from 0.15 m to 0.74 m (HSI greater than 5%; Appendix 1). Mean depth increased in all habitat units with increased discharge. These results therefore support the first sub-hypothesis that the release of a 0.1 $m^3s^{-1}$ minimum flow will result in an increase in the depth of flow in key Kokanee spawning locations. Kokanee were shown to select spawning locations within a wide range of depths (Figure 3-6), therefore the effect of depth on Kokanee spawning capacity may not be limiting. Factors other than water depth appear to be the bottlenecks to the availability of Kokanee spawning habitat.

## 4.2 Effects of 0.1 $m^3s^{-1}$ Minimum Flow on Velocity in Key Spawning Locations

Discharge in Cranberry Creek reached base flow values (approximately 0.13 $m^3s^{-1}$) in late August prior to Kokanee spawning. At this stage, mean velocities fell within the preferred ranges for Kokanee spawning and Kokanee were observed throughout the channel. However, as flows increased, visual observations indicated that the ability for Kokanee to stage in riffle and glide habitats was diminished.

Our results showed that mean velocity increased with increasing discharge. We determined the suitable velocity range for Kokanee in Cranberry Creek is less than 0.24 $m \cdot s^{-1}$ (Figure 3-6) and an increase in 0.1 $m^3s^{-1}$ will result in an approximate increase in water velocity of 0.1 $ms^{-1}$ (for each habitat unit). These data indicate that the release of 0.1 $m^3s^{-1}$ will result in an unsuitable increase in velocity in key spawning locations. The overall effect this would have on the Cranberry Kokanee population is unclear. This would require an assessment of the total available Kokanee spawning habitat and whether this value would limit Kokanee production in this system. This assessment was beyond the scope of this study. It would also need to be assessed relative to the effect of highly variable flows that take place during the Kokanee spawning period.

## 4.3 Effects of 0.1 $m^3s^{-1}$ Minimum Flow on Suitable Habitat area in Key Spawning Locations

Kokanee behaviour and distribution changed with increase in discharge. At base flows Kokanee were distributed throughout the channel, but as discharge increased, Kokanee distribution was restricted to lower velocity refuge areas (e.g., the tailout of pools). At flows in excess of 0.50 $m^3s^{-1}$ Kokanee were found concentrated in two main pools: one located at Transect 1 at km 1.7 and a second Transect 14 located at km 0.32. Fish presence in riffle and glide habitats was minimal as flows reached and exceeded 0.50 $m^3s^{-1}$.

Our results showed that mean velocity increased with increasing discharge and the resultant increase in velocity reduced the spawning habitat values (measured as WUW) for Kokanee. There was a positive effect of flow increase of 0.1 $m^3s^{-1}$ for pools but a negative trend associated with glides and riffles, through the range of flows assessed. Excluding the high flow data points the trend was less clear particularly for riffle habitats. Given the low velocity (less than 0.2 $m\cdot s^{-1}$) requirement (HSI greater than 5%) for Kokanee to spawn, these data indicate that the release of 0.1 $m^3s^{-1}$ flow will result in an increase in mean velocity of approximately 0.1 $ms^{-1}$ in key spawning locations which results in a decrease in habitat preference.

The magnitude of change (with 0.1 $m^3s^{-1}$ increase in discharge) within riffle and glide habitats was small, less than 5-10% in weighted useable width. As there was no attempt to quantify the total amount of available Kokanee spawning habitat, the significance of this reduction is unclear. Additionally, the magnitude of daily variation in natural flows is greater than the incremental change in discharge studied.

WUW declined from 0.1 $m^3s^{-1}$ to 0.5 $m^3s^{-1}$. When discharge reached 0.5 $m^3s^{-1}$ the mean velocities exceeded preferred Kokanee spawning velocities (i.e., greater than 0.2 $m\cdot s^{-1}$). In addition to the negative relationship of WUW vs. flow, Kokanee behaviour and distribution changed. Kokanee distribution was restricted to lower velocity refuge areas (e.g., the tailout of pools). At flows in excess of 0.50 $m^3s^{-1}$ Kokanee were found concentrated in two main pools: one located at Transect 1 at km 1.7 and a second Transect 14 located at km 0.32. Fish presence in riffle and glide habitats was minimal as flows reached and exceeded 0.50 $m^3s^{-1}$.

Riffle and glide habitat units in Cranberry Creek exhibited high variability in velocity and substrate composition and only provided pockets of suitable conditions for spawning. Kokanee have a range of preferred depths, but require low velocities and small gravels to spawn. These small substrates are found in tailouts of pools or are associated with deposition areas in proximity to large instream structural elements. Further, they are easily mobilized and their distribution may change with stream discharge. Useable spawning habitat was limited in all transects mainly because of the limited availability of suitable gravel within the channel. Additionally the variation in velocity (which changes with discharge) over pockets of suitable substrate will result in localized change in suitability of a redd location. In order to predict the amount of spawning habitat within these habitat units and the change in the areal extent of these suitable pockets these areas would have to be mapped out at different flow levels. This type of assessment and analysis was beyond the scope of the study.

Kokanee distribution was affected by elevated flows which precluded staging in and from effectively using riffles and glides. Increased discharges during the spawning period resulted in the majority of Kokanee selecting spawning locations in two pools and abandoning potential spawning areas in riffles and glides. It is unclear whether this had any bias on data used to generate the HSI curves. Modelling of pocket spawning used by Kokanee tends to be problematic because the model results lack the resolution to accurately assess the microhabitat inputs. Observational data on Kokanee distribution at higher flows suggest that the modelling results may overestimate WUW. The calculated WUW (in riffle and glides) decreased overall as flows increased, reflecting the reduction in use related to increases in velocity. While WUW increased in pools, and fish were observed using the pools, pool habitat other than tailout areas is not typically a hydraulic habitat type used by spawning salmonids. This suggests that this might be a habitat of necessity rather than choice. Based on the data collected and the relationship of WUW versus flow, the third sub-hypothesis that the release of 0.1 $m^3s^{-1}$ minimum flow will result in a significant increase in the suitable (depth and velocity integrated) habitat area in key Kokanee spawning locations is not supported by the data collected to date.

Based on the two-year study of Cranberry Creek, flows during the spawning period exceeded base flow conditions for the majority of the spawning period. Discharge levels were generally at or above the upper diversion flows (i.e., greater than 0.1 $m^3s^{-1}$). The diversion in its present condition does not consistently deliver the target flow 0.1 $m^3s^{-1}$. Even if it functioned as designed, the discharge in lower Cranberry Creek appears to exceed the base flows for which diversion flow benefits were directed.

It is unclear how effective Kokanee spawning activity is, given the flow variability and magnitude. Flow fluctuations could result in dewatering of redds if spawning occurs along stream margins during high water. Spawning that takes place at low flows (i.e., 0.1 $m^3s^{-1}$), may be at risk of mobilization of substrates during high flow events. Kokanee appear to aggregate in pools and use tailout gravels when flows are high. However, even these substrates are prone to disturbance at high flows as witnessed by the removal and downstream mobilization of a pressure sensor anchored with a cinder block that was flushed from the pool located at km 0.32. Additionally the high variability of flows means channel bathymetry is likely in a state of regular flux. It is possible that habitat units are often reshaped and distribution of habitat types along the channel may change from year to year. However the effects of changes in habitat unit distribution on the quality and quantity of Kokanee spawning habitat is beyond the scope of this study. Habitat modelling and visual observations confirm that the highest spawning values are when flows are at or near base flow conditions. These flows appear to be rare during the Kokanee spawning period. As long as Cranberry flows during the Kokanee spawning period continue to be highly variable, it is likely that Kokanee production will show high annual variability.

# 5.0 Conclusions

Base flows in Cranberry Creek provide suitable depth and velocity for Kokanee spawners. Habitat limitation appears to be driven by availability of suitably sized substrate. Increase in flows resulted in increases in mean water velocity and wetted width. WUW in riffles and glides declined with increases in flows above base levels. An increment of 0.1 $m^3 \cdot s^{-1}$ resulted in a decline in WUW of <10%. WUW continued to decline as flows increased. WUW in pools increased with flows from base flows up to and beyond maximum design diversion flows. At low flows Kokanee were able to stage throughout the channel but as discharge increased, velocities surpassed the upper limit at which Kokanee could hold. At flows that exceeded 0.5 $m^3 \cdot s^{-1}$ fish were forced into refuge areas including limited pool habitats. Based on this behaviour, the WUW calculations for available spawning habitats likely overestimated availability at elevated flows locations.

The high variability of stream flow in Cranberry Creek had some implications on data collection but also was the key factor affecting Kokanee spawning potential. The small substrates required are easily mobilized and distribution often changed with stream discharge. Changing velocities resulted in the majority of Kokanee selecting spawning locations associated with pools, and abandoning potential spawning areas in riffles and glides. Fluctuations in flow could result in dewatering of redds along stream margins or mobilization of eggs and substrates at higher flows. While a diversion flow of 0.1 $m^3s^{-1}$ may have a slight negative effect (under current channel morphology) on Kokanee spawning capacity, it is likely minimal. The main constraint to production appears to be the high variability of flows during the Kokanee spawning period.

## 6.0 References

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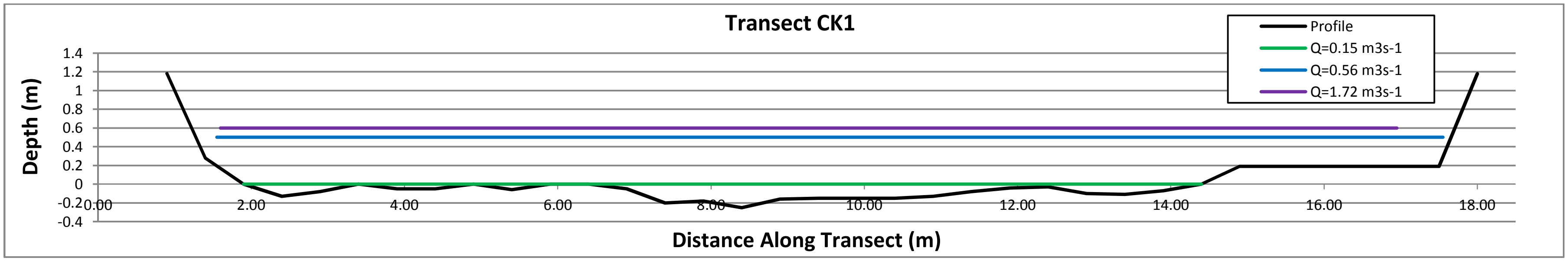
# APPENDIX 1

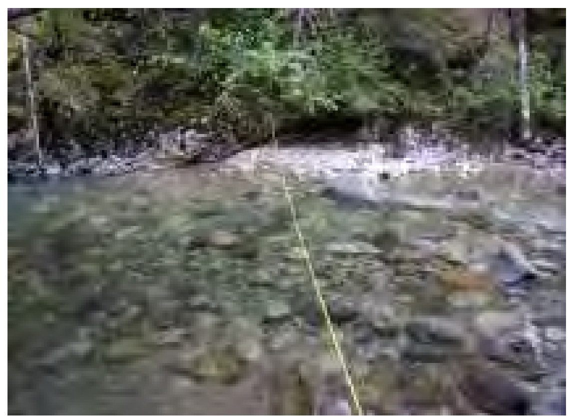
# COMPILATION OF FIELD DATA PER TRANSECT

## Cranberry Creek - Transect 1

| Date | Hydraulic Unit | Discharge ($m^3/s$) | WUW (m) | Wetted Width (m) | Channel Width (m) | Mean Depth (m) | Max Depth (m) | Mean Velocity (m/s) | Max Velocity (m/s) |
|---|---|---|---|---|---|---|---|---|---|
| 31-Aug | Pool | 0.15 | 0.01 | 12.00 | 12.50 | 0.09 | 0.25 | 0.09 | 0.42 |
| 26-Oct | Pool | 0.56 | 0.08 | 15.25 | 15.30 | 0.14 | 0.27 | 0.23 | 0.60 |
| 22-Sep | Pool | 1.72 | 0.14 | 16.10 | 16.10 | 0.27 | 0.45 | 0.39 | 0.90 |




View upstream from right bank with spawning Kokanee present (August 31, 2011).

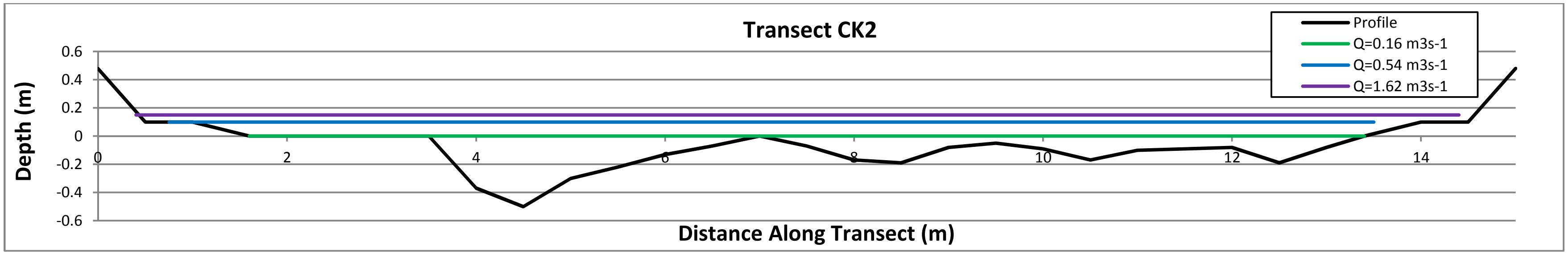


View of left bank at tail-out of pool (August 31, 2011)

View upstream from left bank (September 22, 2011)

## Cranberry Creek - Transect 2

| Date | Hydraulic Unit | Discharge ($m^3/s$) | WUW (m) | Wetted Width (m) | Channel Width (m) | Mean Depth (m) | Max Depth (m) | Mean Velocity (m/s) | Max Velocity (m/s) |
|---|---|---|---|---|---|---|---|---|---|
| 31-Aug | Riffle | 0.16 | 0.25 | 9.50 | 22.00 | 0.15 | 0.50 | 0.15 | 0.64 |
| 26-Oct | Riffle | 0.56 | 0.40 | 13.15 | 13.90 | 0.17 | 0.50 | 0.22 | 0.72 |
| 22-Sep | Riffle | 1.62 | 0.00 | 13.50 | 14.40 | 0.30 | 0.46 | 0.35 | 1.13 |

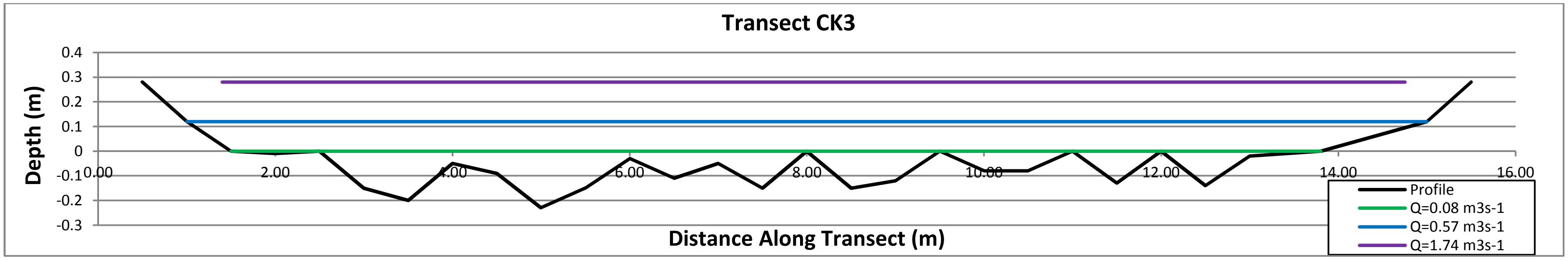



View upstream (September 22, 2011)

View of right bank (September 22, 2011)

## Cranberry Creek - Transect 3

| Date | Hydraulic Unit | Discharge ($m^3/s$) | WUW (m) | Wetted Width (m) | Channel Width (m) | Mean Depth (m) | Max Depth (m) | Mean Velocity (m/s) | Max Velocity (m/s) |
|---|---|---|---|---|---|---|---|---|---|
| 31-Aug | Riffle | 0.08 | 0.04 | 12.30 | 15.50 | 0.08 | 0.23 | 0.08 | 0.41 |
| 26-Oct | Riffle | 0.57 | 0.19 | 13.50 | 14.00 | 0.19 | 0.50 | 0.24 | 0.65 |
| 22-Sep | Riffle | 1.74 | 0.02 | 12.85 | 14.10 | 0.29 | 0.47 | 0.45 | 0.80 |

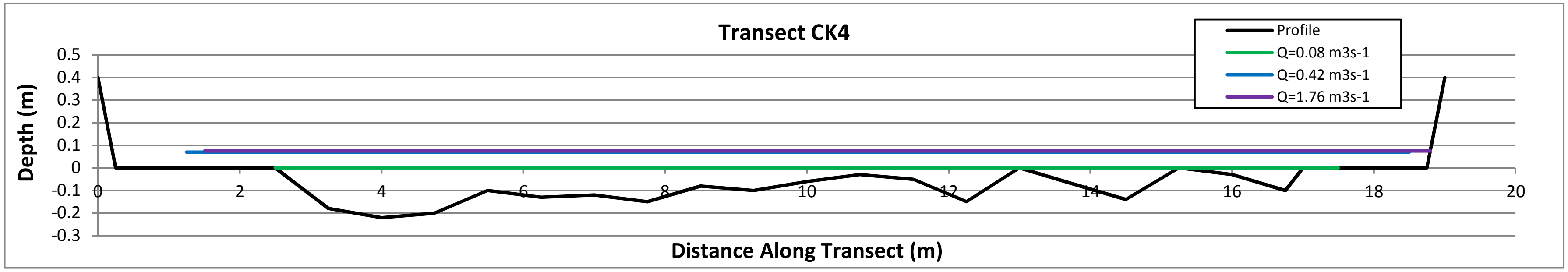



View downstream (September 22, 2011)

View of right bank (September 22, 2011)

## Cranberry Creek - Transect 4

| Date | Hydraulic Unit | Discharge ($m^3/s$) | WUW (m) | Wetted Width (m) | Channel Width (m) | Mean Depth (m) | Max Depth (m) | Mean Velocity (m/s) | Max Velocity (m/s) |
|---|---|---|---|---|---|---|---|---|---|
| 31-Aug | Riffle | 0.08 | 0.19 | 14.50 | 17.50 | 0.10 | 0.22 | 0.06 | 0.18 |
| 26-Oct | Riffle | 0.42 | 0.25 | 16.50 | 16.50 | 0.12 | 0.25 | 0.20 | 0.41 |
| 22-Sep | Riffle | 1.76 | 0.16 | 17.30 | 17.50 | 0.27 | 0.41 | 0.38 | 0.84 |

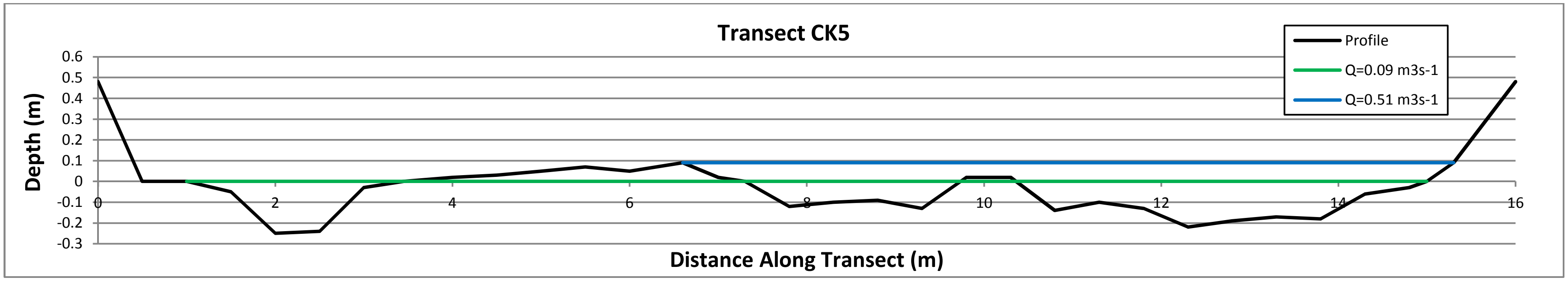



View downstream (September 22, 2011)

View of right bank (September 22, 2011)

## Cranberry Creek - Transect 5

| Date | Hydraulic Unit | Discharge ($m^3/s$) | WUW (m) | Wetted Width (m) | Channel Width (m) | Mean Depth (m) | Max Depth (m) | Mean Velocity (m/s) | Max Velocity (m/s) |
|---|---|---|---|---|---|---|---|---|---|
| 31-Aug | Riffle | 0.09 | 0.03 | 10.65 | 15.00 | 0.11 | 0.25 | 0.06 | 0.33 |
| 26-Oct | Glide | 0.51 | 0.37 | 8.30 | 9.10 | 0.21 | 0.32 | 0.32 | 0.62 |



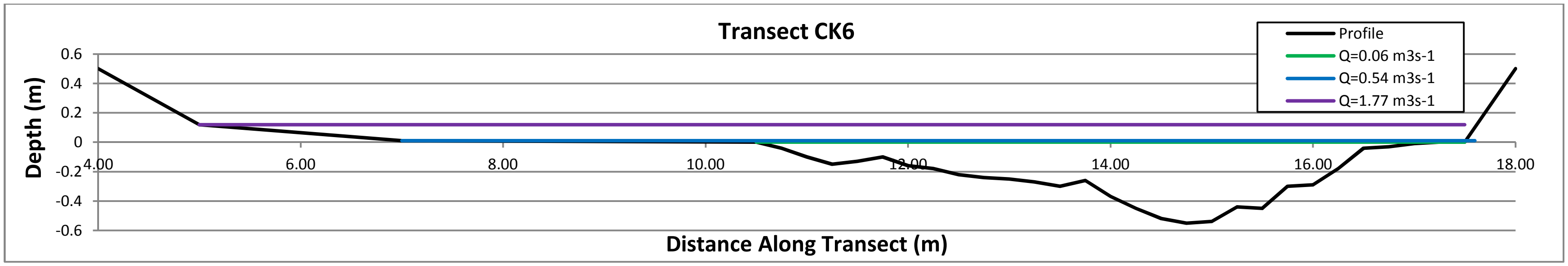

View downstream from transect 5.
(October 26, 2011)

View across transect 5 towards left bank
(October 26, 2011)

View of left bank
(August 31, 2011)

## Cranberry Creek - Transect 6

| Date | Hydraulic Unit | Discharge ($m^3/s$) | WUW (m) | Wetted Width (m) | Channel Width (m) | Mean Depth (m) | Max Depth (m) | Mean Velocity (m/s) | Max Velocity (m/s) |
|---|---|---|---|---|---|---|---|---|---|
| 31-Aug | Glide | 0.06 | 0.82 | 7.00 | 17.50 | 0.24 | 0.55 | 0.03 | 0.13 |
| 26-Oct | Glide | 0.54 | 0.37 | 9.60 | 10.60 | 0.25 | 0.65 | 0.16 | 0.52 |
| 22-Sep | Glide | 1.77 | 0.62 | 12.00 | 12.50 | 0.36 | 0.82 | 0.26 | 0.89 |





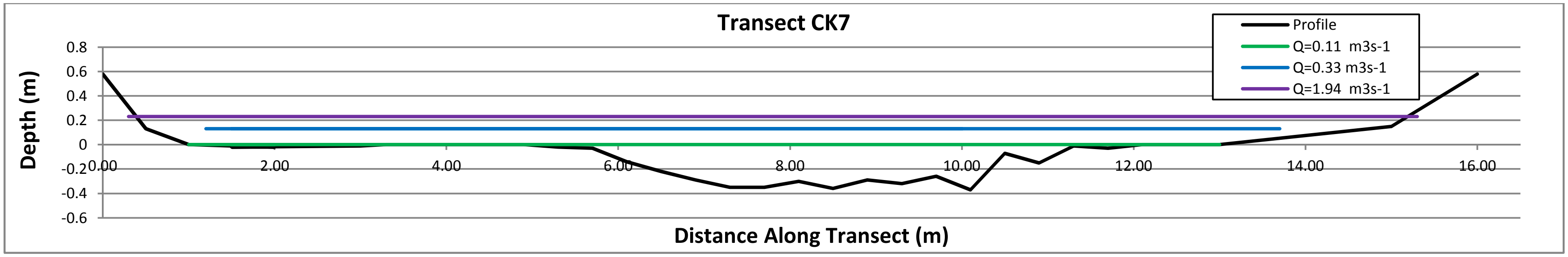
View downstream from transect 6 (October 26, 2011)


View across transect 6 towards right bank. (October 26, 2011)


View downstream from transect 6 (September 22, 2011)

## Cranberry Creek - Transect 7

| Date | Hydraulic Unit | Discharge ($m^3/s$) | WUW (m) | Wetted Width (m) | Channel Width (m) | Mean Depth (m) | Max Depth (m) | Mean Velocity (m/s) | Max Velocity (m/s) |
|---|---|---|---|---|---|---|---|---|---|
| 31-Aug | Glide | 0.11 | 0.64 | 7.20 | 15.30 | 0.20 | 0.37 | 0.06 | 0.24 |
| 26-Oct | Glide | 0.33 | 0.04 | 11.30 | 12.50 | 0.29 | 0.80 | 0.07 | 0.47 |
| 22-Sep | Glide | 1.94 | 0.15 | 14.70 | 14.70 | 0.34 | 0.72 | 0.23 | 1.05 |



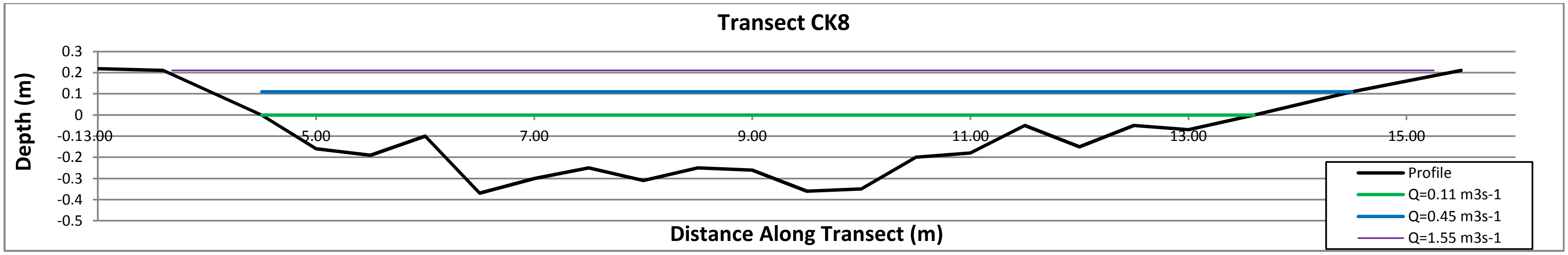

View downstream from transect 7. (October 26, 2011)

Kokanee observed spawning behind boulder near left bank (September 9, 2011).

View downstream from transect 7 (September 22, 2011)

## Cranberry Creek - Transect 8

| Date | Hydraulic Unit | Discharge ($m^3/s$) | WUW (m) | Wetted Width (m) | Channel Width (m) | Mean Depth (m) | Max Depth (m) | Mean Velocity (m/s) | Max Velocity (m/s) |
|---|---|---|---|---|---|---|---|---|---|
| 31-Aug | Glide | 0.11 | 0.77 | 9.10 | 15.30 | 0.20 | 0.37 | 0.06 | 0.21 |
| 26-Oct | Glide | 0.45 | 0.07 | 9.00 | 10.00 | 0.26 | 0.46 | 0.17 | 0.54 |
| 22-Sep | Glide | 1.55 | 0.11 | 11.57 | 11.57 | 0.39 | 0.75 | 0.31 | 0.86 |



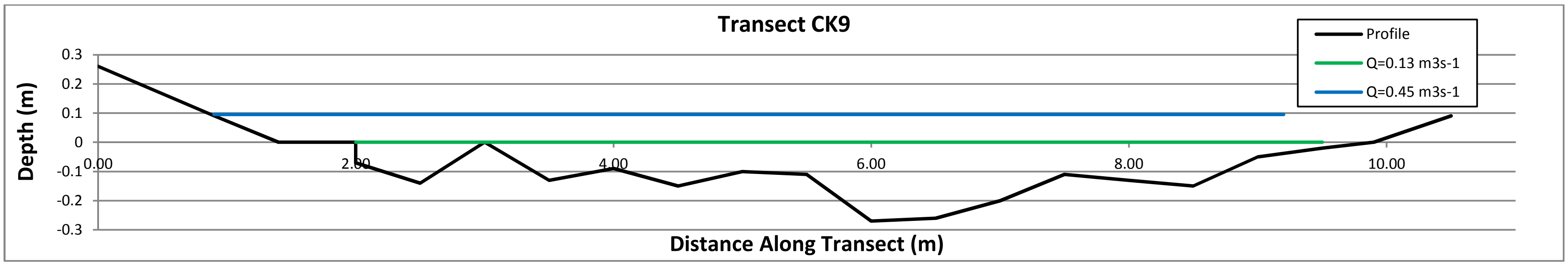

View upstream from transect 8 (October 26, 2011)

View across transect 8 towards right bank (October 26, 2011)

View upstream from transect 8 (September 22, 2011)

## Cranberry Creek - Transect 9

| Date | Hydraulic Unit | Discharge ($m^3/s$) | WUW (m) | Wetted Width (m) | Channel Width (m) | Mean Depth (m) | Max Depth (m) | Mean Velocity (m/s) | Max Velocity (m/s) |
|---|---|---|---|---|---|---|---|---|---|
| 01-Sep | Riffle | 0.13 | 0.00 | 7.90 | 9.90 | 0.12 | 0.27 | 0.10 | 0.34 |
| 26-Oct | Riffle | 0.45 | 0.10 | 8.20 | 8.20 | 0.22 | 0.40 | 0.25 | 1.14 |

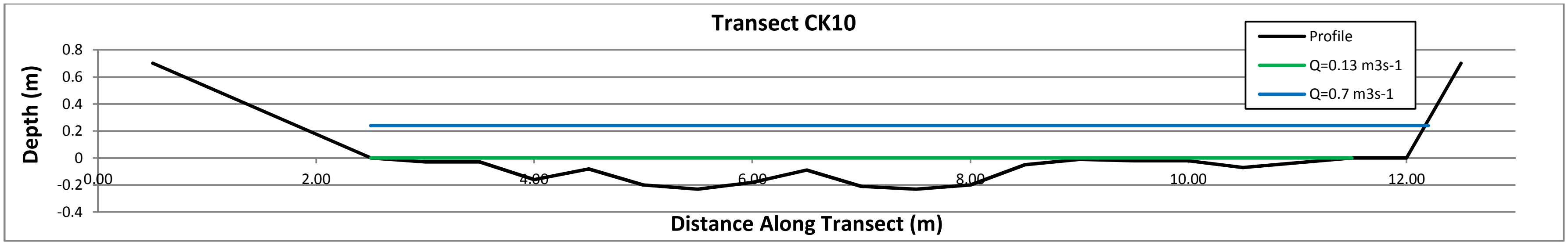



View downstream from transect 9 (October 26, 2011)

View across transect 9 towards left bank (October 26, 2011)

## Cranberry Creek - Transect 10

| Date | Hydraulic Unit | Discharge ($m^3/s$) | WUW (m) | Wetted Width (m) | Channel Width (m) | Mean Depth (m) | Max Depth (m) | Mean Velocity (m/s) | Max Velocity (m/s) |
|---|---|---|---|---|---|---|---|---|---|
| 01-Sep | Glide | 0.13 | 0.15 | 9.00 | 13.00 | 0.11 | 0.23 | 0.10 | 0.48 |
| 26-Oct | Glide | 0.70 | 0.13 | 9.00 | 9.70 | 0.22 | 0.38 | 0.27 | 0.81 |
| 22-Sep | Glide | 1.46 | 0.35 | 11.50 | 11.50 | 0.33 | 0.66 | 0.23 | 0.79 |



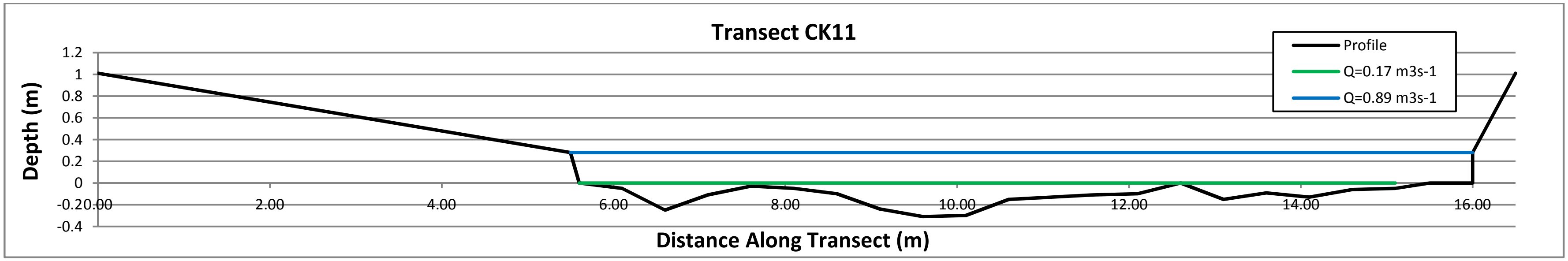

Upstream through transect 10.
(October 26, 2011)

Downstream view of glide through transect.
(October 26, 2011)

Upstream through transect 10
(September 22, 2011)

## Cranberry Creek - Transect 11

| Date | Hydraulic Unit | Discharge ($m^3/s$) | WUW (m) | Wetted Width (m) | Channel Width (m) | Mean Depth (m) | Max Depth (m) | Mean Velocity (m/s) | Max Velocity (m/s) |
|---|---|---|---|---|---|---|---|---|---|
| 01-Sep | Glide | 0.17 | 0.61 | 9.90 | 15.50 | 0.12 | 0.31 | 0.10 | 0.81 |
| 27-Oct | Glide | 0.89 | 0.76 | 10.50 | 10.50 | 0.20 | 0.40 | 0.39 | 1.74 |
| 22-Sep | Glide | 1.69 | 0.33 | 11.40 | 14.90 | 0.41 | 0.83 | 0.33 | 1.35 |



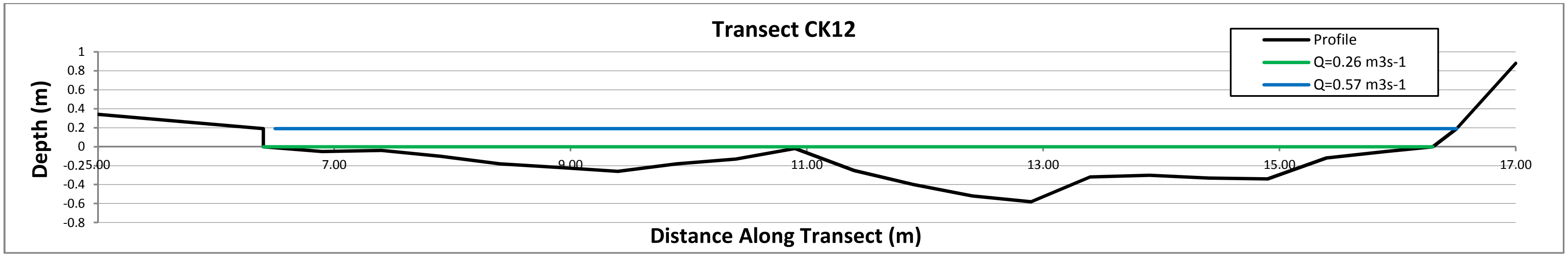

View downstream through transect. (October 27, 2011)

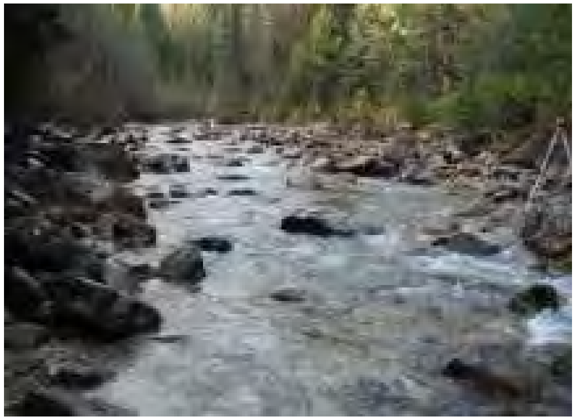
Upstream view of channel through transect. (October 27, 2011)

View downstream through transect. (September 22, 2011)

## Cranberry Creek - Transect 12

| Date | Hydraulic Unit | Discharge ($m^3/s$) | WUW (m) | Wetted Width (m) | Channel Width (m) | Mean Depth (m) | Max Depth (m) | Mean Velocity (m/s) | Max Velocity (m/s) |
|---|---|---|---|---|---|---|---|---|---|
| 01-Sep | Glide | 0.26 | 0.58 | 9.90 | 16.40 | 0.22 | 0.58 | 0.10 | 0.30 |
| 27-Oct | Glide | 0.57 | 0.00 | 9.50 | 10.00 | 0.34 | 0.70 | 0.21 | 0.63 |
| 22-Sep | Glide | 1.28 | 0.06 | 12.00 | 13.00 | 0.44 | 0.88 | 0.25 | 1.05 |



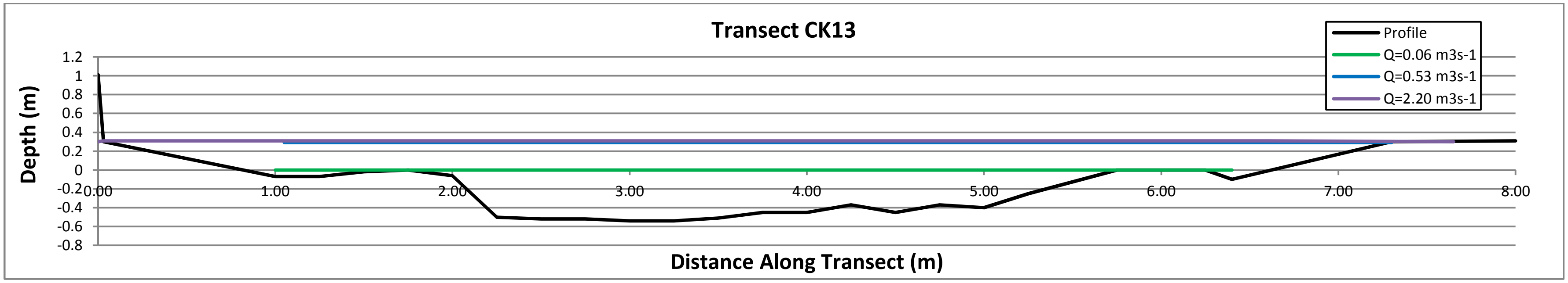
View upstream through transect.
(October 27, 2011)

Downstream view of channel through transect.
(October 27, 2011)

View downstream through transect.
(September 22, 2011)

## Cranberry Creek - Transect 13

| Date | Hydraulic Unit | Discharge ($m^3/s$) | WUW (m) | Wetted Width (m) | Channel Width (m) | Mean Depth (m) | Max Depth (m) | Mean Velocity (m/s) | Max Velocity (m/s) |
|---|---|---|---|---|---|---|---|---|---|
| 01-Sep | Glide | 0.06 | 0.19 | 4.90 | 7.30 | 0.32 | 0.54 | 0.03 | 0.11 |
| 27-Oct | Glide | 0.53 | 0.00 | 6.25 | 6.30 | 0.43 | 0.75 | 0.18 | 0.47 |
| 22-Sep | Pool | 1.50 | 0.00 | 7.30 | 8.30 | 0.53 | 0.94 | 0.32 | 0.89 |



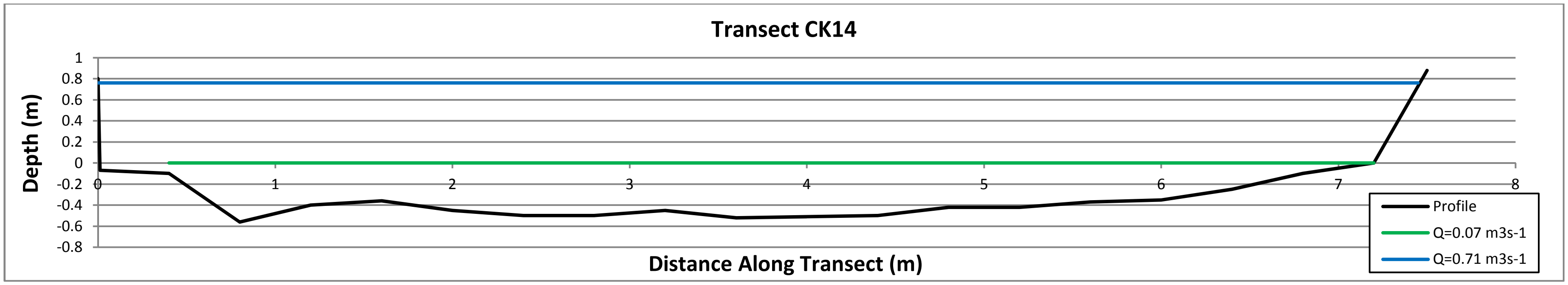

View upstream through transect.
(October 27, 2011)

View downstream through transect.
(October 27, 2011)

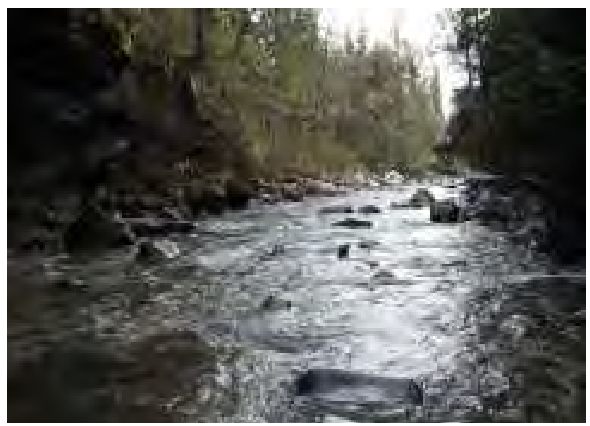
View downstream through transect.
(September 22, 2011)

## Cranberry Creek - Transect 14

| Date | Hydraulic Unit | Discharge ($m^3/s$) | WUW (m) | Wetted Width (m) | Channel Width (m) | Mean Depth (m) | Max Depth (m) | Mean Velocity (m/s) | Max Velocity (m/s) |
|---|---|---|---|---|---|---|---|---|---|
| 01-Sep | Riffle | 0.07 | 0.90 | 7.20 | 7.20 | 0.38 | 0.56 | 0.02 | 0.09 |
| 27-Oct | Riffle | 0.71 | 0.31 | 7.50 | 7.50 | 0.48 | 0.67 | 0.18 | 0.51 |
| 22-Sep | Glide | 2.21 | 0.00 | 7.40 | 7.40 | 0.72 | 0.93 | 0.33 | 0.92 |




View of left bank across transect.
(October 27, 2011)

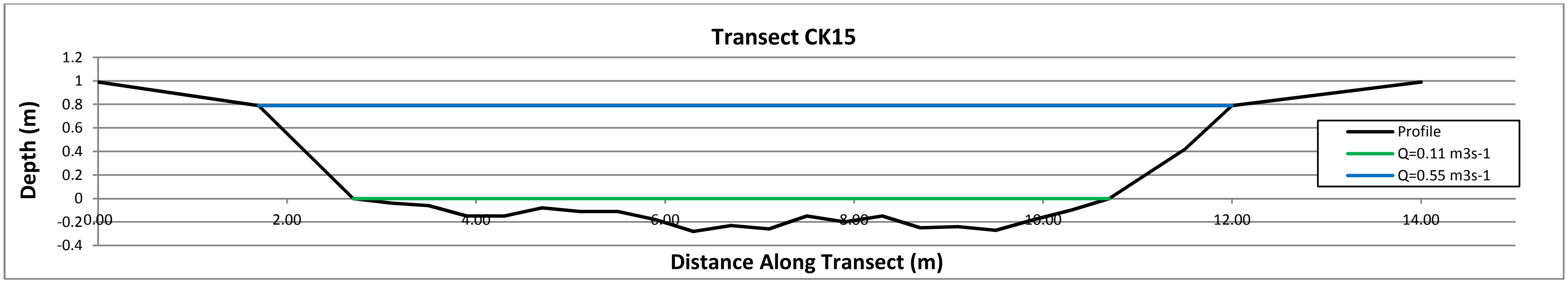


View upstream from transect.
(October 27, 2011)

View upstream from transect.
(September 22, 2011)

## Cranberry Creek - Transect 15

| Date | Hydraulic Unit | Discharge ($m^3/s$) | WUW (m) | Wetted Width (m) | Channel Width (m) | Mean Depth (m) | Max Depth (m) | Mean Velocity (m/s) | Max Velocity (m/s) |
|---|---|---|---|---|---|---|---|---|---|
| 01-Sep | Riffle | 0.11 | 0.57 | 8.30 | 11.00 | 0.16 | 0.28 | 0.07 | 0.37 |
| 27-Oct | Riffle | 0.55 | 0.07 | 9.80 | 10.30 | 0.31 | 2.00 | 0.20 | 0.61 |
| 22-Sep | Glide | 1.67 | 0.28 | 10.85 | 10.90 | 0.37 | 0.7 | 0.37 | 1.24 |




View downstream from transect 15 (October 27, 2011).

View downstream from transect 15 (September 21, 2011).

View upstream from transect 15. (September 21, 2011)

# APPENDIX 2

# CALCULATED HSI VALUES FOR DEPTH AND VELOCITY AT KOKANEE REDDS IN CRANBERRY CREEK

| DV (cm) | DV (m) | Depth | Velocity |
|---|---|---|---|
| 0 | 0.00 | 0.00 | 1.00 |
| 1 | 0.01 | 0.00 | 1.00 |
| 2 | 0.02 | 0.00 | 1.00 |
| 3 | 0.03 | 0.00 | 1.00 |
| 4 | 0.04 | 0.00 | 1.00 |
| 5 | 0.05 | 0.00 | 0.50 |
| 6 | 0.06 | 0.00 | 0.50 |
| 7 | 0.07 | 0.00 | 0.50 |
| 8 | 0.08 | 0.00 | 0.50 |
| 9 | 0.09 | 0.00 | 0.50 |
| 10 | 0.10 | 0.00 | 0.30 |
| 11 | 0.11 | 0.00 | 0.30 |
| 12 | 0.12 | 0.00 | 0.30 |
| 13 | 0.13 | 0.00 | 0.30 |
| 14 | 0.14 | 0.00 | 0.30 |
| 15 | 0.15 | 0.67 | 0.20 |
| 16 | 0.16 | 0.67 | 0.20 |
| 17 | 0.17 | 0.67 | 0.20 |
| 18 | 0.18 | 0.67 | 0.20 |
| 19 | 0.19 | 0.67 | 0.20 |
| 20 | 0.20 | 1.00 | 0.10 |
| 21 | 0.21 | 1.00 | 0.10 |
| 22 | 0.22 | 1.00 | 0.10 |
| 23 | 0.23 | 1.00 | 0.10 |
| 24 | 0.24 | 1.00 | 0.10 |
| 25 | 0.25 | 1.00 | 0.00 |
| 26 | 0.26 | 1.00 | 0.00 |
| 27 | 0.27 | 1.00 | 0.00 |
| 28 | 0.28 | 1.00 | 0.00 |
| 29 | 0.29 | 1.00 | 0.00 |
| 30 | 0.30 | 1.00 | 0.00 |
| 31 | 0.31 | 1.00 | 0.00 |
| 32 | 0.32 | 1.00 | 0.00 |
| 33 | 0.33 | 1.00 | 0.00 |
| 34 | 0.34 | 1.00 | 0.00 |
| 35 | 0.35 | 1.00 | 0.00 |
| 36 | 0.36 | 1.00 | 0.00 |
| 37 | 0.37 | 1.00 | 0.00 |
| 38 | 0.38 | 1.00 | 0.00 |
| 39 | 0.39 | 1.00 | 0.00 |
| 40 | 0.40 | 1.00 | 0.00 |
| 41 | 0.41 | 1.00 | 0.00 |
| 42 | 0.42 | 1.00 | 0.00 |
| 43 | 0.43 | 1.00 | 0.00 |
| 44 | 0.44 | 1.00 | 0.00 |

| DV (cm) | DV (m) | Depth | Velocity |
|---|---|---|---|
| 45 | 0.45 | 1.00 | 0.00 |
| 46 | 0.46 | 1.00 | 0.00 |
| 47 | 0.47 | 1.00 | 0.00 |
| 48 | 0.48 | 1.00 | 0.00 |
| 49 | 0.49 | 1.00 | 0.00 |
| 50 | 0.50 | 1.00 | 0.00 |
| 51 | 0.51 | 1.00 | 0.00 |
| 52 | 0.52 | 1.00 | 0.00 |
| 53 | 0.53 | 1.00 | 0.00 |
| 54 | 0.54 | 1.00 | 0.00 |
| 55 | 0.55 | 0.50 | 0.00 |
| 56 | 0.56 | 0.50 | 0.00 |
| 57 | 0.57 | 0.50 | 0.00 |
| 58 | 0.58 | 0.50 | 0.00 |
| 59 | 0.59 | 0.50 | 0.00 |
| 60 | 0.60 | 0.33 | 0.00 |
| 61 | 0.61 | 0.33 | 0.00 |
| 62 | 0.62 | 0.33 | 0.00 |
| 63 | 0.63 | 0.33 | 0.00 |
| 64 | 0.64 | 0.33 | 0.00 |
| 65 | 0.65 | 0.33 | 0.00 |
| 66 | 0.66 | 0.33 | 0.00 |
| 67 | 0.67 | 0.33 | 0.00 |
| 68 | 0.68 | 0.33 | 0.00 |
| 69 | 0.69 | 0.33 | 0.00 |
| 70 | 0.70 | 0.17 | 0.00 |
| 71 | 0.71 | 0.17 | 0.00 |
| 72 | 0.72 | 0.17 | 0.00 |
| 73 | 0.73 | 0.17 | 0.00 |
| 74 | 0.74 | 0.17 | 0.00 |
| 75 | 0.75 | 0.00 | 0.00 |
| 76 | 0.76 | 0.00 | 0.00 |
| 77 | 0.77 | 0.00 | 0.00 |
| 78 | 0.78 | 0.00 | 0.00 |
| 79 | 0.79 | 0.00 | 0.00 |
| 80 | 0.80 | 0.00 | 0.00 |
| 81 | 0.81 | 0.00 | 0.00 |
| 82 | 0.82 | 0.00 | 0.00 |
| 83 | 0.83 | 0.00 | 0.00 |
| 84 | 0.84 | 0.00 | 0.00 |
| 85 | 0.85 | 0.00 | 0.00 |
| 86 | 0.86 | 0.00 | 0.00 |
| 87 | 0.87 | 0.00 | 0.00 |
| 88 | 0.88 | 0.00 | 0.00 |
| 89 | 0.89 | 0.00 | 0.00 |

| DV (cm) | DV (m) | Depth | Velocity |
|---|---|---|---|
| 90 | 0.90 | 0.00 | 0.00 |
| 91 | 0.91 | 0.00 | 0.00 |
| 92 | 0.92 | 0.00 | 0.00 |
| 93 | 0.93 | 0.00 | 0.00 |
| 94 | 0.94 | 0.00 | 0.00 |
| 95 | 0.95 | 0.00 | 0.00 |
| 96 | 0.96 | 0.00 | 0.00 |
| 97 | 0.97 | 0.00 | 0.00 |
| 98 | 0.98 | 0.00 | 0.00 |
| 99 | 0.99 | 0.00 | 0.00 |
| 100 | 1.00 | 0.00 | 0.00 |
| 101 | 1.01 | 0.00 | 0.00 |
| 102 | 1.02 | 0.00 | 0.00 |
| 103 | 1.03 | 0.00 | 0.00 |
| 104 | 1.04 | 0.00 | 0.00 |
| 105 | 1.05 | 0.00 | 0.00 |
| 106 | 1.06 | 0.00 | 0.00 |
| 107 | 1.07 | 0.00 | 0.00 |
| 108 | 1.08 | 0.00 | 0.00 |
| 109 | 1.09 | 0.00 | 0.00 |
| 110 | 1.10 | 0.00 | 0.00 |
| 111 | 1.11 | 0.00 | 0.00 |
| 112 | 1.12 | 0.00 | 0.00 |
| 113 | 1.13 | 0.00 | 0.00 |
| 114 | 1.14 | 0.00 | 0.00 |
| 115 | 1.15 | 0.00 | 0.00 |
| 116 | 1.16 | 0.00 | 0.00 |
| 117 | 1.17 | 0.00 | 0.00 |
| 118 | 1.18 | 0.00 | 0.00 |
| 119 | 1.19 | 0.00 | 0.00 |
| 120 | 1.20 | 0.00 | 0.00 |
| 121 | 1.21 | 0.00 | 0.00 |
| 122 | 1.22 | 0.00 | 0.00 |
| 123 | 1.23 | 0.00 | 0.00 |
| 124 | 1.24 | 0.00 | 0.00 |
| 125 | 1.25 | 0.00 | 0.00 |
| 126 | 1.26 | 0.00 | 0.00 |
| 127 | 1.27 | 0.00 | 0.00 |
| 128 | 1.28 | 0.00 | 0.00 |
| 129 | 1.29 | 0.00 | 0.00 |
| 130 | 1.30 | 0.00 | 0.00 |
| 131 | 1.31 | 0.00 | 0.00 |
| 132 | 1.32 | 0.00 | 0.00 |
| 133 | 1.33 | 0.00 | 0.00 |
| 134 | 1.34 | 0.00 | 0.00 |

| DV (cm) | DV (m) | Depth | Velocity |
|---|---|---|---|
| 135 | 1.35 | 0.00 | 0.00 |
| 136 | 1.36 | 0.00 | 0.00 |
| 137 | 1.37 | 0.00 | 0.00 |
| 138 | 1.38 | 0.00 | 0.00 |
| 139 | 1.39 | 0.00 | 0.00 |
| 140 | 1.40 | 0.00 | 0.00 |
| 141 | 1.41 | 0.00 | 0.00 |
| 142 | 1.42 | 0.00 | 0.00 |
| 143 | 1.43 | 0.00 | 0.00 |
| 144 | 1.44 | 0.00 | 0.00 |
| 145 | 1.45 | 0.00 | 0.00 |
| 146 | 1.46 | 0.00 | 0.00 |
| 147 | 1.47 | 0.00 | 0.00 |
| 148 | 1.48 | 0.00 | 0.00 |
| 149 | 1.49 | 0.00 | 0.00 |
| 150 | 1.50 | 0.00 | 0.00 |
| 151 | 1.51 | 0.00 | 0.00 |
| 152 | 1.52 | 0.00 | 0.00 |
| 153 | 1.53 | 0.00 | 0.00 |
| 154 | 1.54 | 0.00 | 0.00 |
| 155 | 1.55 | 0.00 | 0.00 |
| 156 | 1.56 | 0.00 | 0.00 |
| 157 | 1.57 | 0.00 | 0.00 |
| 158 | 1.58 | 0.00 | 0.00 |
| 159 | 1.59 | 0.00 | 0.00 |
| 160 | 1.60 | 0.00 | 0.00 |
| 161 | 1.61 | 0.00 | 0.00 |
| 162 | 1.62 | 0.00 | 0.00 |
| 163 | 1.63 | 0.00 | 0.00 |
| 164 | 1.64 | 0.00 | 0.00 |
| 165 | 1.65 | 0.00 | 0.00 |
| 166 | 1.66 | 0.00 | 0.00 |
| 167 | 1.67 | 0.00 | 0.00 |
| 168 | 1.68 | 0.00 | 0.00 |
| 169 | 1.69 | 0.00 | 0.00 |
| 170 | 1.70 | 0.00 | 0.00 |
| 171 | 1.71 | 0.00 | 0.00 |
| 172 | 1.72 | 0.00 | 0.00 |
| 173 | 1.73 | 0.00 | 0.00 |
| 174 | 1.74 | 0.00 | 0.00 |
| 175 | 1.75 | 0.00 | 0.00 |
| 176 | 1.76 | 0.00 | 0.00 |
| 177 | 1.77 | 0.00 | 0.00 |
| 178 | 1.78 | 0.00 | 0.00 |
| 179 | 1.79 | 0.00 | 0.00 |

| DV (cm) | DV (m) | Depth | Velocity |
|---|---|---|---|
| 180 | 1.80 | 0.00 | 0.00 |
| 181 | 1.81 | 0.00 | 0.00 |
| 182 | 1.82 | 0.00 | 0.00 |
| 183 | 1.83 | 0.00 | 0.00 |
| 184 | 1.84 | 0.00 | 0.00 |
| 185 | 1.85 | 0.00 | 0.00 |
| 186 | 1.86 | 0.00 | 0.00 |
| 187 | 1.87 | 0.00 | 0.00 |
| 188 | 1.88 | 0.00 | 0.00 |
| 189 | 1.89 | 0.00 | 0.00 |
| 190 | 1.90 | 0.00 | 0.00 |
| 191 | 1.91 | 0.00 | 0.00 |
| 192 | 1.92 | 0.00 | 0.00 |
| 193 | 1.93 | 0.00 | 0.00 |
| 194 | 1.94 | 0.00 | 0.00 |
| 195 | 1.95 | 0.00 | 0.00 |
| 196 | 1.96 | 0.00 | 0.00 |
| 197 | 1.97 | 0.00 | 0.00 |
| 198 | 1.98 | 0.00 | 0.00 |
| 199 | 1.99 | 0.00 | 0.00 |
| 200 | 2.00 | 0.00 | 0.00 |
| 201 | 2.01 | 0.00 | 0.00 |
| 202 | 2.02 | 0.00 | 0.00 |
| 203 | 2.03 | 0.00 | 0.00 |
| 204 | 2.04 | 0.00 | 0.00 |
| 205 | 2.05 | 0.00 | 0.00 |
| 206 | 2.06 | 0.00 | 0.00 |
| 207 | 2.07 | 0.00 | 0.00 |
| 208 | 2.08 | 0.00 | 0.00 |
| 209 | 2.09 | 0.00 | 0.00 |
| 210 | 2.10 | 0.00 | 0.00 |
| 211 | 2.11 | 0.00 | 0.00 |
| 212 | 2.12 | 0.00 | 0.00 |
| 213 | 2.13 | 0.00 | 0.00 |
| 214 | 2.14 | 0.00 | 0.00 |
| 215 | 2.15 | 0.00 | 0.00 |
| 216 | 2.16 | 0.00 | 0.00 |
| 217 | 2.17 | 0.00 | 0.00 |
| 218 | 2.18 | 0.00 | 0.00 |
| 219 | 2.19 | 0.00 | 0.00 |
| 220 | 2.20 | 0.00 | 0.00 |
| 221 | 2.21 | 0.00 | 0.00 |
| 222 | 2.22 | 0.00 | 0.00 |
| 223 | 2.23 | 0.00 | 0.00 |
| 224 | 2.24 | 0.00 | 0.00 |

| DV (cm) | DV (m) | Depth | Velocity |
|---|---|---|---|
| 225 | 2.25 | 0.00 | 0.00 |
| 226 | 2.26 | 0.00 | 0.00 |
| 227 | 2.27 | 0.00 | 0.00 |
| 228 | 2.28 | 0.00 | 0.00 |
| 229 | 2.29 | 0.00 | 0.00 |
| 230 | 2.30 | 0.00 | 0.00 |
| 231 | 2.31 | 0.00 | 0.00 |
| 232 | 2.32 | 0.00 | 0.00 |
| 233 | 2.33 | 0.00 | 0.00 |
| 234 | 2.34 | 0.00 | 0.00 |
| 235 | 2.35 | 0.00 | 0.00 |
| 236 | 2.36 | 0.00 | 0.00 |
| 237 | 2.37 | 0.00 | 0.00 |
| 238 | 2.38 | 0.00 | 0.00 |
| 239 | 2.39 | 0.00 | 0.00 |
| 240 | 2.40 | 0.00 | 0.00 |
| 241 | 2.41 | 0.00 | 0.00 |
| 242 | 2.42 | 0.00 | 0.00 |
| 243 | 2.43 | 0.00 | 0.00 |
| 244 | 2.44 | 0.00 | 0.00 |
| 245 | 2.45 | 0.00 | 0.00 |
| 246 | 2.46 | 0.00 | 0.00 |
| 247 | 2.47 | 0.00 | 0.00 |
| 248 | 2.48 | 0.00 | 0.00 |
| 249 | 2.49 | 0.00 | 0.00 |
| 250 | 2.50 | 0.00 | 0.00 |
| 251 | 2.51 | 0.00 | 0.00 |
| 252 | 2.52 | 0.00 | 0.00 |
| 253 | 2.53 | 0.00 | 0.00 |
| 254 | 2.54 | 0.00 | 0.00 |
| 255 | 2.55 | 0.00 | 0.00 |
| 256 | 2.56 | 0.00 | 0.00 |
| 257 | 2.57 | 0.00 | 0.00 |
| 258 | 2.58 | 0.00 | 0.00 |
| 259 | 2.59 | 0.00 | 0.00 |
| 260 | 2.60 | 0.00 | 0.00 |
| 261 | 2.61 | 0.00 | 0.00 |
| 262 | 2.62 | 0.00 | 0.00 |
| 263 | 2.63 | 0.00 | 0.00 |
| 264 | 2.64 | 0.00 | 0.00 |
| 265 | 2.65 | 0.00 | 0.00 |
| 266 | 2.66 | 0.00 | 0.00 |
| 267 | 2.67 | 0.00 | 0.00 |
| 268 | 2.68 | 0.00 | 0.00 |
| 269 | 2.69 | 0.00 | 0.00 |

| DV (cm) | DV (m) | Depth | Velocity |
|---|---|---|---|
| 270 | 2.70 | 0.00 | 0.00 |
| 271 | 2.71 | 0.00 | 0.00 |
| 272 | 2.72 | 0.00 | 0.00 |
| 273 | 2.73 | 0.00 | 0.00 |
| 274 | 2.74 | 0.00 | 0.00 |
| 275 | 2.75 | 0.00 | 0.00 |
| 276 | 2.76 | 0.00 | 0.00 |
| 277 | 2.77 | 0.00 | 0.00 |
| 278 | 2.78 | 0.00 | 0.00 |
| 279 | 2.79 | 0.00 | 0.00 |
| 280 | 2.80 | 0.00 | 0.00 |
| 281 | 2.81 | 0.00 | 0.00 |
| 282 | 2.82 | 0.00 | 0.00 |
| 283 | 2.83 | 0.00 | 0.00 |
| 284 | 2.84 | 0.00 | 0.00 |
| 285 | 2.85 | 0.00 | 0.00 |
| 286 | 2.86 | 0.00 | 0.00 |
| 287 | 2.87 | 0.00 | 0.00 |
| 288 | 2.88 | 0.00 | 0.00 |
| 289 | 2.89 | 0.00 | 0.00 |
| 290 | 2.90 | 0.00 | 0.00 |
| 291 | 2.91 | 0.00 | 0.00 |
| 292 | 2.92 | 0.00 | 0.00 |
| 293 | 2.93 | 0.00 | 0.00 |
| 294 | 2.94 | 0.00 | 0.00 |
| 295 | 2.95 | 0.00 | 0.00 |
| 296 | 2.96 | 0.00 | 0.00 |
| 297 | 2.97 | 0.00 | 0.00 |
| 298 | 2.98 | 0.00 | 0.00 |
| 299 | 2.99 | 0.00 | 0.00 |
| 300 | 3.00 | 0.00 | 0.00 |
| 301 | 3.01 | 0.00 | 0.00 |
| 302 | 3.02 | 0.00 | 0.00 |
| 303 | 3.03 | 0.00 | 0.00 |
| 304 | 3.04 | 0.00 | 0.00 |
| 305 | 3.05 | 0.00 | 0.00 |
| 306 | 3.06 | 0.00 | 0.00 |
| 307 | 3.07 | 0.00 | 0.00 |
| 308 | 3.08 | 0.00 | 0.00 |
| 309 | 3.09 | 0.00 | 0.00 |
| 310 | 3.10 | 0.00 | 0.00 |
| 311 | 3.11 | 0.00 | 0.00 |
| 312 | 3.12 | 0.00 | 0.00 |
| 313 | 3.13 | 0.00 | 0.00 |
| 314 | 3.14 | 0.00 | 0.00 |

| DV (cm) | DV (m) | Depth | Velocity |
|---|---|---|---|
| 315 | 3.15 | 0.00 | 0.00 |
| 316 | 3.16 | 0.00 | 0.00 |
| 317 | 3.17 | 0.00 | 0.00 |
| 318 | 3.18 | 0.00 | 0.00 |
| 319 | 3.19 | 0.00 | 0.00 |
| 320 | 3.20 | 0.00 | 0.00 |
| 321 | 3.21 | 0.00 | 0.00 |
| 322 | 3.22 | 0.00 | 0.00 |
| 323 | 3.23 | 0.00 | 0.00 |
| 324 | 3.24 | 0.00 | 0.00 |
| 325 | 3.25 | 0.00 | 0.00 |
| 326 | 3.26 | 0.00 | 0.00 |
| 327 | 3.27 | 0.00 | 0.00 |
| 328 | 3.28 | 0.00 | 0.00 |
| 329 | 3.29 | 0.00 | 0.00 |
| 330 | 3.30 | 0.00 | 0.00 |
| 331 | 3.31 | 0.00 | 0.00 |
| 332 | 3.32 | 0.00 | 0.00 |
| 333 | 3.33 | 0.00 | 0.00 |
| 334 | 3.34 | 0.00 | 0.00 |
| 335 | 3.35 | 0.00 | 0.00 |
| 336 | 3.36 | 0.00 | 0.00 |
| 337 | 3.37 | 0.00 | 0.00 |
| 338 | 3.38 | 0.00 | 0.00 |
| 339 | 3.39 | 0.00 | 0.00 |
| 340 | 3.40 | 0.00 | 0.00 |
| 341 | 3.41 | 0.00 | 0.00 |
| 342 | 3.42 | 0.00 | 0.00 |
| 343 | 3.43 | 0.00 | 0.00 |
| 344 | 3.44 | 0.00 | 0.00 |
| 345 | 3.45 | 0.00 | 0.00 |
| 346 | 3.46 | 0.00 | 0.00 |
| 347 | 3.47 | 0.00 | 0.00 |
| 348 | 3.48 | 0.00 | 0.00 |
| 349 | 3.49 | 0.00 | 0.00 |
| 350 | 3.50 | 0.00 | 0.00 |
| 351 | 3.51 | 0.00 | 0.00 |
| 352 | 3.52 | 0.00 | 0.00 |
| 353 | 3.53 | 0.00 | 0.00 |
| 354 | 3.54 | 0.00 | 0.00 |
| 355 | 3.55 | 0.00 | 0.00 |
| 356 | 3.56 | 0.00 | 0.00 |
| 357 | 3.57 | 0.00 | 0.00 |
| 358 | 3.58 | 0.00 | 0.00 |
| 359 | 3.59 | 0.00 | 0.00 |

| DV (cm) | DV (m) | Depth | Velocity |
|---|---|---|---|
| 360 | 3.60 | 0.00 | 0.00 |
| 361 | 3.61 | 0.00 | 0.00 |
| 362 | 3.62 | 0.00 | 0.00 |
| 363 | 3.63 | 0.00 | 0.00 |
| 364 | 3.64 | 0.00 | 0.00 |
| 365 | 3.65 | 0.00 | 0.00 |
| 366 | 3.66 | 0.00 | 0.00 |
| 367 | 3.67 | 0.00 | 0.00 |
| 368 | 3.68 | 0.00 | 0.00 |
| 369 | 3.69 | 0.00 | 0.00 |
| 370 | 3.70 | 0.00 | 0.00 |
| 371 | 3.71 | 0.00 | 0.00 |
| 372 | 3.72 | 0.00 | 0.00 |
| 373 | 3.73 | 0.00 | 0.00 |
| 374 | 3.74 | 0.00 | 0.00 |
| 375 | 3.75 | 0.00 | 0.00 |
| 376 | 3.76 | 0.00 | 0.00 |
| 377 | 3.77 | 0.00 | 0.00 |
| 378 | 3.78 | 0.00 | 0.00 |
| 379 | 3.79 | 0.00 | 0.00 |
| 380 | 3.80 | 0.00 | 0.00 |
| 381 | 3.81 | 0.00 | 0.00 |
| 382 | 3.82 | 0.00 | 0.00 |
| 383 | 3.83 | 0.00 | 0.00 |
| 384 | 3.84 | 0.00 | 0.00 |
| 385 | 3.85 | 0.00 | 0.00 |
| 386 | 3.86 | 0.00 | 0.00 |
| 387 | 3.87 | 0.00 | 0.00 |
| 388 | 3.88 | 0.00 | 0.00 |
| 389 | 3.89 | 0.00 | 0.00 |
| 390 | 3.90 | 0.00 | 0.00 |
| 391 | 3.91 | 0.00 | 0.00 |
| 392 | 3.92 | 0.00 | 0.00 |
| 393 | 3.93 | 0.00 | 0.00 |
| 394 | 3.94 | 0.00 | 0.00 |
| 395 | 3.95 | 0.00 | 0.00 |
| 396 | 3.96 | 0.00 | 0.00 |
| 397 | 3.97 | 0.00 | 0.00 |
| 398 | 3.98 | 0.00 | 0.00 |
| 399 | 3.99 | 0.00 | 0.00 |
| 400 | 4.00 | 0.00 | 0.00 |

# APPENDIX 3

## SUMMARY OF CALCULATED WEIGHTED USABLE WIDTH VALUES FOR EACH TRANSECT AT THREE STAGES

**Calculated weighted usable width values for Kokanee spawning locations at three stages in Cranberry Creek (Triton, 2012)**

| | ***Low Flow*** $Q_{avg} = 0.13\ m^3s^{-1}$ (Aug 31 – Sept 1) | | | ***Moderate Flow*** $Q_{avg} = 0.56\ m^3s^{-1}$ (Oct 26 – 27) | | | ***High Flow*** $Q_{avg} = 1.67\ m^3s^{-1}$ (Sept 21 – 22) | | |
|---|---|---|---|---|---|---|---|---|---|
| **Transect** | **Wetted Width (m)** | **WUW (m)** | **WUW % of Wetted Width** | **Wetted Width (m)** | **WUW (m)** | **WUW % of Wetted Width** | **Wetted Width (m)** | **WUW (m)** | **WUW % of Wetted Width** |
| CK1 | 12.0 | 0.01 | 0.08 | 15.3 | 0.08 | 0.52 | 16.1 | 0.14 | 0.87 |
| CK2 | 9.5 | 0.25 | 2.63 | 13.2 | 0.40 | 3.04 | 13.5 | 0.00 | 0.00 |
| CK3 | 12.3 | 0.04 | 0.33 | 13.5 | 0.19 | 1.41 | 12.9 | 0.02 | 0.16 |
| CK4 | 14.5 | 0.19 | 1.31 | 16.5 | 0.25 | 1.52 | 17.3 | 0.16 | 0.92 |
| CK5 | 10.7 | 0.03 | 0.28 | 8.3 | 0.37 | 4.46 | - | - | - |
| CK6 | 7.0 | 0.82 | 11.71 | 9.6 | 0.37 | 3.85 | 12.0 | 0.62 | 5.17 |
| CK7 | 7.2 | 0.64 | 8.89 | 11.3 | 0.04 | 0.35 | 14.7 | 0.15 | 1.02 |
| CK8 | 9.1 | 0.77 | 8.46 | 9.0 | 0.07 | 0.78 | 11.6 | 0.11 | 0.95 |
| CK9 | 7.9 | 0.00 | 0.00 | 8.2 | 0.10 | 1.22 | - | - | - |
| CK10 | 9.0 | 0.15 | 1.67 | 9.7 | 0.13 | 1.34 | 11.5 | 0.35 | 3.04 |
| CK11 | 9.9 | 0.61 | 6.16 | 10.5 | 0.76 | 7.24 | 11.4 | 0.33 | 2.89 |
| CK12 | 9.9 | 0.58 | 5.86 | 9.5 | 0.00 | 0.00 | 12.0 | 0.06 | 0.50 |
| CK13 | 4.9 | 0.19 | 3.88 | 6.3 | 0.00 | 0.00 | 8.6 | 0.00 | 0.00 |
| CK14 | 7.2 | 0.90 | 12.50 | 7.5 | 0.31 | 4.13 | 7.4 | 0.00 | 0.00 |
| CK15 | 8.3 | 0.57 | 6.87 | 9.8 | 0.07 | 0.71 | 10.9 | 0.28 | 2.58 |
| **Means** | **12.19** | **0.38** | **4.71** | **10.5** | **0.21** | **2.05** | **12.2** | **0.15** | **1.21** |