Cheakamus Project Water Use Plan

Cheakamus River Channel Morphology (Year 1)

Reference: CMSMON-8

*Cheakamus River Channel Morphology*

Study Period: 2008

Northwest Hydraulic Consultants
30 Gostick Place
North Vancouver, BC  V7M 3G3

November 2009
CHEAKAMUS RIVER MONITORING PROGRAM # 8
CHEAKAMUS RIVER CHANNEL MORPHOLOGY
YEAR 1 FINAL REPORT

NOVEMBER 2009
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Year 1 Final Report

Prepared for:
BC Hydro
333 Dunsmuir Street
Vancouver, BC, V6B 5R3

Prepared by:
Northwest Hydraulic Consultants
30 Gostick Place
North Vancouver, BC
V7M 3G3

November 2009
3-4730
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ABSTRACT

Following implementation of a new WUP flow regime in February 2006, the Consultative Committee expressed concern regarding the potential effects of changes to salmonid habitat quality and availability. As a consequence, baseline and post-WUP monitoring was recommended as a means of examining the effects of more frequent, modest flows that distribute sediment introduced by large floods, and of minimum releases from Daisy Lake Dam in altering access to sidechannel habitats. In addition, it was recommended to reduce the uncertainty associated with the contribution of tributary streams to the total flow by measuring this contribution over a period of five years.

Cheakamus River extends a length of 25 km from Daisy Lake Dam to the confluence of Squamish River. The channel can be broadly characterized by four distinct sections, including Rubble Creek landslide deposits, a bedrock canyon, a broad alluvial section and Cheakamus River fan. These sections were divided into 13 distinct reaches above Cheakamus fan (which is not included in the current monitor) that reflect differences in slope, morphologic characteristics, sediment supply, and discharge. Within each reach, a baseline map was prepared from orthophoto mosaics produced from 1:5000 colour aerial photographs obtained during low water conditions in April, 2008. The primary features mapped include channels, banks, bars, islands, and sidechannels. Secondary features include woody debris jams and bank protection structures which are common near Paradise Valley.

The wetted low flow channel dominates the areal fraction of most reaches, and represents the available overwinter habitat for salmonids. Unvegetated bars are the second most common morphologic feature and combined with the low flow wetted channel represent more than 90% of total reach area for 9 reaches in total. The low flow wetted channel was further divided into 3 habitat units which include pools, riffles, and rapids with riffles dominant in mainly unconfined reaches, and rapids dominant in steeper, confined lengths of channel. This classification is well established in the geomorphic literature and is known to represent distinct habitat types. Significant changes in the areal fraction of these units (which will be determined in Year 5 of the monitor) are expected to correlate to fish productivity indices.

In order to determine the incremental effects of tributary streams on the total river discharge, a series of hydrometric stations has been established along the mainstem channel (4 sites) with 2 additional sites on tributary streams. Equipment problems and a lack of significant flow variability during the past winter (which was colder and drier than typical) resulted in a reduced number of points to complete the rating curves. Nevertheless, preliminary curves exhibit little scatter at most sites, and encompass much of the range of low flows that are intended to be monitored. Summation of incremental downstream contribution from the tributaries reveals that they appear to supply more than half the total discharge of Cheakamus River.
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INTRODUCTION

1.1 BACKGROUND

Cheakamus River flows southward from Daisy Lake reservoir to the confluence of Squamish River, roughly 25 km downstream (Figure 1). The river has been regulated since 1957 following completion of Daisy Lake Dam. Part of the water stored in the reservoir is released into Cheakamus River and some is diverted into an 11 km long tunnel to the 157 MW Cheakamus Powerhouse located in the Squamish River Valley. BC Hydro owns and operates all of the Cheakamus facilities.

During the development of the water use plan (WUP) for the project, the Cheakamus River Fisheries Technical Committee (FTC) created a set of impact hypotheses related to fish and fish habitat. These included whether dam operations altered channel morphology, affecting the quality and quantity of available fish habitat, thereby limiting the carrying capacity for wild salmon. A study completed by NHC (2001) found that since regulation, Cheakamus River has become narrower with a simplified morphologic character, and there has been a corresponding reduction of sidechannel habitats. While the FTC accepted these conclusions, the hypothesis that dam operations were responsible for explaining changes to channel morphology was rejected since dam operations had little impact on the magnitude and frequency of very large channel-shaping floods. In addition, it was found that a variety of other factors unrelated to dam operations also influence channel morphologic development.

The FTC further expressed uncertainty regarding the role of Daisy Lake Dam operations on the frequency, magnitude and duration of more modest flows that redistribute sediment introduced by larger events, their affect on reshaping channel and side-channel habitats that are important to biota. In particular, there was considerable uncertainty regarding the importance of substrate quality and quantity for salmonids throughout the river and the factors that influence their distribution. In addition, recent implementation of the 45% previous day’s flow rule means that base releases from Daisy Lake Dam may affect the availability and utility of side-channel habitats. The concerns and uncertainty identified by the FTC have been adopted in the current WUP, and are to be address by the current monitor (CHEAKMON#8).

Final results of this study (upon completion of year 5 monitoring) are unlikely to result in significant changes to the operational regime of Daisy Lake Dam unless a dramatic operations impact is clearly detected. Such an impact would result in a review of the entire WUP since a major operational shift would be required to alter the impact. It is more likely that identified impacts be mitigated with instream physical works which would require continued monitoring to evaluate effectiveness. It is further intended that final results of this monitor will reduce uncertainty regarding impacts of Daisy Lake Dam operations under the current WUP, and may therefore increase the potential for reaching CC consensus in future WUPs.
1.2 **OBJECTIVES AND APPROACH**

The objective of the current monitor is to address the uncertainty expressed by the FTC within the context of recent (February 2006) WUP operations. The channel morphology monitoring program is expected to address shortcomings in our knowledge of how the current flow regime impacts channel morphology and the consequences to the availability and quality of fish habitat. The program seeks to address the following management questions as outlined in the Cheakamus Project WUP Terms of Reference:

1. Following implementation of the WUP, has there been a change in accessible substrate for salmonid spawning from the present state, and if so, can this change be clearly attributed to Daisy Lake Dam operations or to other environmental or anthropogenic factors?

2. Following implementation of the WUP, has there been a change in the total length, diversity and access of natural sidechannel habitat from the present state, and if so, can this change be clearly attributed to Daisy Lake Dam operations or to other environmental or anthropogenic factors? and

3. To what extent does the hydrology of major tributaries contribute to the general hydrology of lower Cheakamus River and how does it attenuate the effects of Daisy Lake Dam operations.

The management questions will be addressed by evaluating a set of impact hypotheses that test whether the morphology – hence aquatic habitat – has been significantly altered since implementation of the WUP. In order to address the first question, the following impact hypothesis is to be tested:

\[ H_{01}: \text{Total area (ha) of accessible substrate suitable for salmonid spawning has not changed since implementation of the WUP.} \]

The second management question is to be addressed by evaluating the following two impact hypotheses:

\[ H_{02}: \text{Total length (km) of connected side-channel habitat wetted at typical flows has not changed since implementation of the WUP, and} \]

\[ H_{03}: \text{The diversity of side-channel habitat as measured by the number and ratio of pool, run and riffle habitats has not changed since implementation of the WUP.} \]

The third management question does not lend itself to direct hypothesis testing as it is effectively a data collection exercise, but results may be used to support testing of morphologic and side-channel hypotheses.

The hypotheses are to be tested within the context of a pre- and post-WUP comparison of channel surveys, where pre-WUP conditions are represented by the data collected during the first year of the monitor, and post-WUP conditions will be represented by data collected in the final (fifth) year of the monitor. In contrast, hydrology data are collected continuously throughout the duration of the program. This report presents a summary of data collected for
the pre-WUP component of the monitor and provides recommendations for changes to the study design in order to address the study objectives.

1.3 Scope of Work

Northwest Hydraulic Consultants Ltd. (NHC) were retained by BC Hydro to collect the necessary information required in order to address the management questions outlined in the WUP Terms of Reference. Data collected in Year 1 will be compared and contrasted with data collected in Year 5 in order to address the specific impact hypotheses outlined in Section 1.2. The data collection procedures generally follow those described in the response to the RFP.

The focus of Year 1 of this project has been to create baseline maps of channel morphologic elements in order to quantify potential changes to channel and off-channel morphology and habitat in the future. Baseline mapping of channel morphology for the Cheakamus River from the Daisy Lake Dam to Cheekye River was conducted in GIS using 1:5000 scale colour orthophotography and rectified air photos, combined with field verification. Although this project was initiated in Autumn 2007, a reconnaissance trip in November 2007 revealed significant changes to the channel morphology since the most recent (2005) aerial photography of the channel was obtained. New aerial photography was subsequently flown in April 2008 and used to complete the baseline mapping of channel morphology. This report summarizes the findings of the Year 1 mapping.

A second major component of this study is to determine the discharge of major tributary streams to determine their incremental contribution to flow along Cheakamus River. The tributary flow monitoring is effectively a data collection exercise and is not subject to hypothesis testing, though the results may be used to support the morphologic / habitat management questions. The flow monitoring consists of establishing rating curves (relation between discharge and water levels) at six sites, including four measurements on the mainstem and two on tributary streams in order to characterize the hydrology of the entire system. The hydrology monitoring will continue throughout the entire five year study.
2 METHODOLOGY

2.1 ORTHOPHOTOGRAPHY

New aerial photography covering the entire study reach from the Daisy Lake dam to the Squamish Valley Road crossing just downstream of the Cheekye River confluence was flown April 22, 2008 at 1:5000 scale during leaf-free season prior to a spring flow release from the Daisy Lake Dam. The Cheakamus River was at low-flow conditions with an approximate discharge of 21 m³/s at the WSC gauge above the Cheekye River (08GA043). Orthophoto mosaics of the aerial photography were commissioned by Triton Environmental Consultants Ltd. for another client (CN) with copies made available to NHC in late September, 2008. The commissioned orthophoto mosaics cover the majority of the study area with the exception of the upper 3.5 km of Cheakamus River to the Daisy Lake Dam. The orthophotos have a resolution of 15 cm (which roughly defines the smallest features that can be identified) and are oriented by a UTM projection (Zone 10 north) and the NAD83 datum.

2.2 AIR PHOTO RECTIFICATION

To complete coverage of the study area it was necessary to rectify contact prints of the April 22, 2008 aerial photography for the upper 3.5 km of river channel. Contact prints of the photographs covering the missing area were scanned at 600 dpi. This level of scanning resolution ensures adequate detail is retained for defining the smallest geomorphic features of interest as well as providing a manageable file size. Scaling and rectification (orientation) of the individual photographs was completed using the geo-referencing tools available in ArcGIS 9.3. The existing orthophoto mosaics (2005) were used to provide control in the rectification process since they were also defined by the same projection and datum as the 2008 orthophotos. The transformation from photo to map coordinates was completed using a second-order polynomial function.

2.3 AIR PHOTO INTERPRETATION AND MAPPING

Year 1 of this project was concentrated on preparing baseline mapping of the channel and off-channel morphology on the Cheakamus River downstream of the Daisy Lake Dam. Morphologic features were digitized directly from the digital aerial photography using tools in ArcMap GIS. The interpretation and mapping of channel features was aided by viewing the air photos in stereo under a standard mirror stereoscope with magnification.

The primary morphologic features that were mapped are distinct channel features that can be consistently delineated on aerial photography and include channel banks, bars, islands and sidechannels. Woody debris jams and bank protection structures were also digitized. Channel bars and islands were further grouped into young or recent and mature or historic age classes. Young bars represent active, mobilized deposits that are devoid of vegetation, while mature
bars can support sparse vegetation. Young islands support dense vegetation, but this consists mainly of shrubs, grasses and smaller trees. By contrast, mature islands support stands of older, taller deciduous and conifer species. Sidechannels include both engineered off-channel habitat that has been constructed along the study reach and more natural, flow-through sidechannels. Sidechannels that are located a significant distance away from the main channel, particularly the engineered sidechannels located to the west of Paradise Valley Road near the North Vancouver Outdoor School, were not included in the mapping due to the limited connectivity to the river. Sidechannels were also classified as wet or dry at the photographed discharge which is typical of low-flow levels for the river. Figure 2 illustrates typical examples of the morphologic features along the river.

Changes in the spatial extent of these morphologic features over time will provide an indication of the overall changes occurring within the river system and the possible associated implications for fish habitat within the wetted channel. The separate morphologic features also allow inferences to be made as to the underlying substrate (i.e. vegetation traps fine-grained sediment) with an increase in vegetated features (islands, mature bars) likely indicating a reduction in gravel extent along the channel. NHC (2001) reported that sediment recruitment may have been reduced by 50% between Culliton Creek and Cheekeye River following impoundment. Comparisons between the 2008 mapping and previous mapping (cf. NHC, 2001) site photographs from various consulting reports or Provincial aerial photographs could be used to help better define footprint or stochastic impacts. Comparison with Year 5 mapping will help define changes related to implementation of the WUP.

The low-flow wetted channel was further divided into three basic morphologic units: riffle, pool and rapid/cascade. These units were chosen based on their distinct habitat characteristics and the ability to consistently delineate these units on the aerial photography. The units were defined following Church (1992) who describes channel units for similar, intermediate-sized streams. Riffles are areas of relatively shallow, rapid flow with clasts remaining submerged at all but the lowest flow levels; this unit includes the glides and runs used in biological classifications and are significant habitat units. Pools are defined as areas of slow, tranquil flow with few boulders exposed at low flow and act primarily as rearing habitats. Rapids are areas of higher gradient with emergent clasts at low flow, with up to 50% of stream area can be in supercritical flow. Cascades are a higher gradient unit than rapids with tumbling, turbulent flow over large boulders with more than 50% of stream area is in supercritical flow and have comparatively low habitat value. Figure 3 illustrates typical examples of these morphologic units along the river.

The low-flow morphologic mapping is intended to provide the basis for comparisons with future (Year 5) mapping. The low-flow channel represents the available spawning and incubation habitat for salmonids (but includes rearing habitat) and changes in their extent will reflect changes to available habitat. For example, if pools are becoming filled with sediment, there may be an extension of glide (riffle) habitats. It is intended that this exercise will permit the evaluation of management question #1, though it may be difficult to isolate changes related to Daisy Lake dam operations from other factors. It is also acknowledged that relations between morphology and habitat are highly complex given that they involve various life stages of many species (Kellerhals and Miles, 1996). It will be necessary to
compare any significant changes in morphology to fish productivity indices and benthic community surveys to determine impacts.

Upon completion of the preliminary mapping, site visits were conducted on March 10 and 27, 2009 using both road and boat access to ground truth the characterization and boundaries of delineated polygons. The sites could not be visited earlier in the year because of extensive snow cover on the bars. Flows on these dates were very comparable to the photographed flow at 22 and 23 m$^3$/s respectively at the WSC gauge above Cheekye River (08GA043). The ground truthing focused on those features which were noted during map production to have a high uncertainty in either boundary position or morphologic classification. Boundaries and morphologic classifications were checked visually and deviations from the preliminary maps were recorded and used to modify the database. Sketch maps and ground photographs were used to aid in the ground truthing. In addition to verification of the preliminary mapping, general substrate composition of exposed bar surfaces was also recorded during the site visits.

Once the preliminary maps were updated with the ground truthing data, topology was created using tools in Arc/Info GIS whereby linear boundaries between adjacent features are connected to create individual polygons for each morphologic feature class. This allows the area of the feature to be queried and summarized and creates a feature attribute table (database) that can be populated with quantitative or qualitative descriptors. Areas for each morphologic feature class and habitat classification unit were summarized by reach using the fourteen reach breaks previously defined in the Cheakamus River Water Use Plan (WUP) (Triton, 2006).
3 RESULTS

3.1 MORPHOLOGIC ELEMENTS BY REACH

Below the Daisy Lake Dam the lower Cheakamus River flows through four distinct sections before joining the Squamish River approximately 25 km downstream: the Rubble Creek landslide deposits, a bedrock canyon, a broad alluvial section, and the Cheakamus River fan (NHC, 2001). Although the following description uses the reach designations defined in Triton (2006), Reach 1 (Cheakamus Fan) is outside of the study boundary and has not been examined. Areas for each morphologic feature class are shown summarized for the 13 remaining reaches in Table 1; the baseline morphology mapping is found in Appendix A.

Between Reach 2 and 7 the Cheakamus River generally flows across a broad valley flat and has an irregular to irregular meandering pattern. Reach 2 is the start of the study area and is located immediately downstream of the Cheekye confluence. The Cheekye River drains steep, unstable terrain and occasionally provides very large quantities of coarse sediment to the Cheakamus River. Reach 2 has a proportionally high occurrence of exposed bar over its short length (approx. 800 m) and is strongly influenced by the dynamics of the Cheekye River. Above the Cheekye River the channel becomes more complex, with numerous sidechannels and locations where the channel splits around mature wooded islands. Woody debris is also common within Reach 3, 4 and 6. Sidechannels are particularly prevalent within Reach 3 and 4 where many have been built or augmented for improved fish habitat. Reach 6 is characterized by a number of islands with mature or maturing vegetation. Many of these areas are currently connected to the channel banks at low flow. The valley narrows upstream starting near the downstream end of Reach 7 and enters a relatively straight section with little deposition upstream to the Culliton Creek confluence.

Above Culliton Creek the river becomes more confined, with Reach 8 regarded as a depositional reach downstream of the bedrock canyon (there are frequent exposed bar deposits). Reach 9 and 10 are characterized by a narrow channel flowing through a bedrock canyon and occasional exposed coarse bars developed behind obstructions at the sides of the channel. From the start of the bedrock canyon upstream to the Rubble Creek confluence (Reach 11, 12 and 13) the river is flowing through re-worked Rubble Creek landslide deposits that confine the channel (NHC, 2001). The proportion of total area covered by exposed bars increases upstream through these reaches to the source of the sediment at Rubble Creek. The inclusion of the Rubble Creek fan within Reach 13 also results in a high proportion of unvegetated bar deposits. Vegetation growth on bars throughout the three reaches is quite limited, indicating these sediments are still actively re-worked. Reach 14 stretches from the Rubble Creek confluence roughly 1 km upstream to the Daisy Lake Dam. This is a confined reach with small areas of exposed bar and a coarse lag deposit immediately downstream of the dam.

Dikes and other bank protection measures are common along the lower river outside of the canyon reaches, particularly within Reach 2, 3 and 4 near the community of Paradise Valley.
3.2 **Morphologic Units by Reach**

Areas for each morphologic unit are summarized by reach in Table 2 and baseline mapping of the units are found in Appendix A. Outside of the bedrock canyon reaches the majority of the lower Cheakamus River is characterized as riffle. The riffles tend to be very long, connected features with smaller pool units located at the channel margins.

Much of the upstream section of the lower river (Reaches 9 to 12) is characterized by long sections of rapids and cascades, particularly through the bedrock canyon. Downstream of these reaches, rapids are confined to small areas of channel and at the Cheekye River and Culliton Creek confluences.

Pools are relatively limited throughout the lower river and tend to be located on the margins of the channel, rather than spanning the entire channel width. Reach 3 has the largest total area of pool at 2.12 ha with Reach 14 having the greatest proportion of pool area due to the presence of plunge pools. Pools within the alluvial section (Reach 2 to 8) are generally confined to outside bends while upstream of Reach 8 pools are more likely to be plunge pools associated with rapid/cascade morphologies.

3.3 **Bed Substrate**

Data on general substrate composition was recorded for unvegetated bars downstream of Reach 9. Upstream of Culliton Creek, bar substrate is fairly coarse but generally consists of cobble-sized material with gravel. Culliton Creek injects a large volume of boulder-sized substrate to the Cheakamus River and boulders are commonly deposited along bar edges for approximately 2 km downstream of this confluence. Over the adjacent 2 km of channel, boulder-sized substrate is still relatively common although substrate is predominately a mix of cobble and gravel. From this point downstream (approx. 4 km downstream of Culliton Creek) bar substrate is a mix of cobble and gravel up to the Cheekye River confluence which inputs boulder-sized material to the Cheakamus River.
4 HYDROMETRIC MONITORING

4.1 OVERVIEW

A total of seven locations along the Cheakamus River and tributaries are currently being gauged to provide a synoptic overview of tributary and lateral inflow contributions in the Cheakamus basin (Figure 4). The objective of this study component is to determine tributary flow contributions in the Cheakamus basin relative to Daisy Lake Dam flow releases, how this varies with season, and how this influences fish habitat. Three hydrometric locations were initially proposed this project, but additional efforts are being made to develop a better understanding of the spatial and temporal variability of flow contributions in the system.

Hydrometric monitoring stations were successfully installed at three sites during the period January 30-February 5, 2008 (Figure 4):

- Cheakamus River above Chance Creek (FSR Bridge below Daisy Lake Dam)
- Cheakamus River above Culliton Creek (Pedestrian Suspension Bridge)
- Culliton Creek above Cheakamus River

To supplement our understanding of tributary contributions to the Cheakamus system, additional tributary flow gauging has been undertaken at four extra sites (Figure 4):

- Chance Creek above Cheakamus River
- Cheakamus River above Cheekye River
- Cheekye River above Cheakamus River
- Cheakamus River below Cheekye River

An additional hydrometric station was also recently installed (April 2009) on the Cheakamus River below it's confluence with the Cheekye River (Figure 4).

Each hydrometric station consists of a pressure transducer installed in a stable, deep part of the channel, which records and logs water level (stage) and temperature data at specified intervals. Discharge measurements are made at the site under various flow conditions throughout the range of stage to capture as much of the available data as possible. NHC utilizes a range of techniques, which include: current metering, salt and dye dilution, or an Acoustic Doppler Current Profiler (ADCP).

With manual measurements, discharge is assessed by measuring depth and velocity at a minimum of 20 points across the channel cross-section, typically with a Price® AA or Swoffer® propeller-type current meter to measure velocity along the transect. With dilution or ADCP measurements, multiple measures are assessed at a single station. Dilution and ADCP measurements require thorough post-processing, and post-measurement stream water calibrations (titrations) are also required for dilution methods to determine concentration...
curves for mass balance calculations used in the estimation of flow. Stations are operated to meet Class A/B standards according to the BCMOE RIC Hydrometric Standards (1998). Stage and water level recorders and flow metering are undertaken with calibrated standardized equipment to limit measurement error to ± 10%. Stage-discharge rating curves are developed for the site by plotting individual discharge values against the corresponding stage at the time of each discharge measurement. The rating curve can then be used to transform the continuous stage record from the pressure transducer into a continuous record of discharge. Changes in channel geometry can cause the relation between stage and discharge to change over time. For example, channel erosion or deposition during storms events, or the placement of bank protection works, can affect the stage-discharge relation. To check the accuracy of the stage measurements, the offset distances from the sensor and water level back to a site benchmark is recorded. This allows for vertical adjustments in the channel section to be recorded with offset measures applied to the data to correct the record, or for alternate stage-discharge curves to be developed. Once the discharge measurements are recorded, calibrated, and verified, the data can be corroborated through examining other regional streamflow data, precipitation data within the basin, and internal gauged areas to validate flow records at a site.

4.2 Site Equipment, Installations and Gauging

NHC tests all data loggers in-house prior to field deployment to ensure functionality and manufacturer specified maximum and typical accuracies. This consists of testing each pressure transducer in a testing tank and verifying physical water levels to sensor readings for rapid short term water level fluctuations and longer term stable water levels. All flow measurement equipment is regularly tested and calibrated to minimize data errors resulting from flow measurement, and involves velocity calibrations with a known flow orifice for velocity meters, and concentration calibrations for dilution equipment.

Each hydrometric station consists of a Solinst® Levelogger which records and stores stage (water-level) and water temperature values at a 15-minute interval. Stage sensors record combined atmospheric and hydrostatic pressure. One Solinst® Barologger serves as a common barometric pressure sensor for all of the hydrometric stations compensates for the atmospheric pressure component and was installed at the Culliton Creek site.

The data loggers are housed in 2-inch steel pipes with standard lockable well caps; however, at two sites (FSR Bridge and Culliton), the potential for vandalism required the installation of more robust thick steel housings to adequately protect instrumentation. At each site, three benchmarks were established and surveyed to provide vertical reference points. The pipes are mounted on galvanized steel angle-iron and bolted into large, stable boulders. The installation of a staff gauge installation was only possible at the Culliton Creek site, but not at the other sites due to poor site conditions; instead, water level is consistently measured with reference to a specific bolt on the steel pipe, also tied in to the local survey.

As described earlier, a total of seven locations along the Cheakamus River and tributaries are currently being gauged in the Cheakamus basin (Figure 4). All mainstem transects are
gauged using an ADCP (Acoustic Doppler Current Profiler), while smaller tributaries are gauged with velocity-area or dilution methods. A summary of the seven measurement sites and field data collection efforts are described below. The sites are listed in order moving downstream from the Daisy Lake Dam.

4.2.1 **CHEAKAMUS RIVER ABOVE CHANCE CREEK**

This site is located below the Cheakamus River confluence with Rubble Creek and above the Cheakamus River confluence with Chance Creek (Figure 4). Rubble Creek flow contributions can be estimated by subtracting Daisy Lake Dam flow releases from flows measured at this site. Discharge may not be measured directly at Rubble Creek due to silt deposition in its lower reach and the unstable nature of the fan, which does not provide a stable anchor point for installation of a hydrometric station.

The hydrometric station at the FSR Bridge site is secured to the downstream side of the bridge footing on the right bank. Four flows have been measured with an ADCP over the last winter season (Table 3, Appendix B). Prior to this period, several attempts were made to measure discharge with dilution methods, but these techniques are not successful at this site due to channel characteristics that create unsuitable flow conditions.

4.2.2 **CHANCE CREEK ABOVE CHEAKAMUS RIVER**

Chance Creek is a small tributary located several hundred meters downstream of the FSR Bridge that flows into the Cheakamus River from the west (Figure 4). Gauging methods for this site vary by stage level and during low winter flows velocity-area methods are used immediately upstream of the railroad bridge, while dilution methods are preferred for higher flow periods. A total of four flow measurements have been made at this site over the past winter with water levels measured from an old staff gauge secured to the railroad bridge (Table 3, Appendix B).

4.2.3 **CHEAKAMUS RIVER ABOVE CULLITON CREEK**

This site at the pedestrian suspension bridge crossing over the Cheakamus River is located approximately 100 metres upstream of the confluence with Culliton Creek. The hydrometric station at this site is located on the right river bank just upstream of the suspension bridge. There are several minor tributaries that enter the Cheakamus River between Chance Creek and the suspension bridge, but these have minor relative flow contributions. Discharge is measured at this site with an ADCP. The steep gradient in this reach creates an extended length of riffles that make ADCP use more challenging than at other sites. Despite this challenge, however, the ADCP has proven more reliable than other methods. Five discharge measurements have been taken at this site to date (Table 3, Appendix B).
4.2.4 CULLITON CREEK ABOVE CHEAKAMUS RIVER

Culliton Creek is a main tributary to the Cheakamus River and the catchment includes Conroy Creek and half of the Brohm Ridge glacier. Discharge at this site is measured where Culliton Creek crosses Paradise Valley Road. From approximately one hundred meters upstream of the bridge to one hundred meters downstream of the bridge is a series of very turbulent riffles and step pools that are ideally suited for flow measurement using dilution methods. A total of five well-spaced discharge measurements have been made at this site (Table 3, Appendix B). Stage data is recorded at the hydrometric station located on the left river bank just downstream of the Paradise Valley Road Bridge, while barometric pressure is recorded by a Barologger located in the forest nearby.

4.2.5 CHEAKAMUS RIVER ABOVE CHEEKYE RIVER

This site is located approximately 50 metres upstream of the Cheekye Creek confluence at an inactive Water Survey of Canada (WSC) hydrometric station (Cheakamus River near Cheekye 08GA014). The conditions at this site are perfectly suited for gauging with an ADCP as the flow is slow moving and near laminar with a deep river profile and no significant steps. Stage data is available at the WSC (Cheakamus River near Brackendale 08GA043) station upstream of this site and may potentially be used to estimate flow hydrographs. A total of three discharge measurements have been made at this site (Table 3, Appendix B).

4.2.6 CHEEKYE RIVER ABOVE CHEAKAMUS RIVER

Flows have been measured on the Cheekye River in synchrony with measurements on the Cheakamus River both above and below the Cheakamus-Cheekye confluence. The purpose of measurements at this site is to verify Cheekye River flow contributions as determined by flow subtraction between gauging of flows both above and below the Cheakamus-Cheekye confluence (Table 3, Appendix B).

4.2.7 CHEAKAMUS RIVER BELOW CHEEKYE RIVER

The Cheakamus River crosses Paradise Valley Road approximately 100 meters downstream of the Cheekye River confluence. While this creates a convenient location for ADCP use, the channel at this location is shallow, fast flowing and turbulent, causing highly inconsistent results with the ADCP. As stated earlier, this has prompted measurements of Cheekye contributions to verify differences in flow measured above and below the Cheakamus-Cheekye confluence. A total of four flow measurements have been made at this site (Table 3, Appendix B). A new hydrometric station was recently added (April, 2009) at this site to monitor the flow contribution from Cheekye River on a long term basis.
4.3 **Data Handling and Storage**

Gauge data is downloaded during site visits when flow rating measurements are taken. The process involves removal of the logger, connecting to a field laptop and extracting data files. Surface water elevations and offset data are documented, and the logger set-up and battery condition are reviewed. The logger is re-initiated and returned to the gauge, and seated properly within the housing. A similar process is used to extract the barometric data, but no offsets or calibrations are required. As the Solinst® loggers are sealed units, there is no atmospheric venting and the water level data is barometrically compensated within the software using the barometric data. The corrected file is reviewed for data quality and stored in an NHC database by site and date. QA/QC procedures are critical especially if freezing water conditions were reported in the temperature logs, significant flows occurred, or anomalous readings are identified.

4.4 **Gauge Analysis**

4.4.1 **Site Rating Curves**

As described in the methodology, flow level or stage is compared to streamflow discharge at various water levels to construct a stage-discharge or rating curve. A rod and level survey is typically used to check water level and sensor elevation to one or more vertical benchmarks. Rating gauge plots typically follow the Power Law form:

\[ S = A \cdot Q^B \]

where

- \( S \) = gauge stage
- \( Q \) = flow
- \( A \) and \( B \) = coefficients determined from analysis

Each site is typically gauged during a rating, which results in a corresponding stage and discharge measurement. The timing of the rating is a function of available access to the site and streamflows. Field programs and monitoring are designed to attempt to rate the gauge over the range of interest. Typically this includes measurements over as much of the expected range of flows as possible, but with emphasis on a certain flow state required (e.g. low flow analysis).

The rating curves are subject to change and adjustment due to an increased record of gauge points that better define the rating curve, or on the basis of physical changes to the rating section. These changes are typically a result of channel or bank erosion from flood events, changes in sediment regimes, or anthropogenic alterations to the river channel. Changes to
the rating curve are assessed on the basis of regular surveys of the section relative to the benchmark to determine shifts or changes to the curve. As part of the initial assessment of gauging sites, effort is taken to locate these sections in relatively uniform stable reaches where these impacts are limited. Sections are checked during each rating, and re-surveyed if bed movement or erosion is noted, or following a significant flood. Streamflows are estimated using the rating curves and recorded stage data. Streamflows are often estimated beyond the measured bounds of ratings at the section, and these estimates are subject to change as additional rating data is collected, hence all values are considered draft and subject to change. Table 3 summarizes discharge measurements and methods to date by site, and Figures 5 through 10 present preliminary rating curves for each site (Appendix B). The extrapolation line on rating curves indicates the limit above which flow hydrograph estimates for each site are based on extrapolations from measured flows. Measurement error estimates are as follows: one standard deviation for ADCP measurements, 7% for dilution methods, and 10% for velocity-area methods.

4.4.2 Preliminary Streamflows

Using the preliminary draft rating curve data and hourly recorded stage date, estimates of daily mean streamflow were calculated for the 3 sites with hydrometric stations continuously recording stage data. Corresponding water temperature data recorded at the gauge is also presented. Figures 11 though 13 illustrate the data record at each gauge location (Appendix B). The extrapolation line indicates the limit above which data is generated from the extrapolated portion of the rating curve.
5 FUTURE WORK

Year 1 of this project has been focused on providing detailed baseline mapping of channel morphologic elements between the Daisy Lake Dam and Cheekye River. With this task complete the next step will be to repeat the mapping process in Year 5 of the project and calculate any significant changes to substrate and sidechannel habitat. Measured change in vegetation communities on the mapped features will provide an additional indication of corresponding changes in flow and sediment regimes. An important factor in the success of the project will be consistent mapping and interpretation of morphologic changes over time, as well as the ability to isolate the role of Daisy Lake Dam operations from other natural events.

Efforts in Year 2 of the project will be limited to collecting additional flow measurements to improve the existing rating curves and to check their stability over time. In Year 1, it was proposed that a minimum of six points be collected for each rating curve, and this work was scheduled to be completed by April 2009. However, there were persistent problems with the ADCP unit and we were not able to obtain a fully functional instrument until Autumn, 2008. The ADCP has been essential for gauging many of the sites necessary for this project. Previous attempts to gauge the main stem using salt dilution or rhodamine were unsuccessful due to poor lateral mixing within the channel. Consequently, we will not have gauged the higher flows (up to 50 m$^3$/s) needed to establish the upper bound of the rating curves until the upcoming freshet (usually occurring in mid to late May through June). However, this winter we were able to gauge flows during the short duration spikes in the Cheakamus hydrograph, creating the widest range of discharge values possible during an uncommonly dry winter.

Three more discharge measurements are needed to complete the rating curves at sites along the main stem, while only one or two more are needed at Culliton Creek. Water levels in the Cheakamus River are being monitored continuously and field personnel will be deployed immediately following an increase in flow. This work is expected to be complete by the middle of June 2009. Year 2 data collection efforts will further include flow measurements following the freshet, and continue through the following Autumn and Winter periods until an additional 6 measurements have been recorded at the key sites.
6 References


TABLES
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<th>Wetted Channel</th>
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<th>Bar (sparse shrub)</th>
<th>Island (young)</th>
<th>Island (mature)</th>
<th>Sidechannel (wet)</th>
<th>Sidechannel (dry)</th>
<th>Rubble Creek Fan</th>
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<td>% of Total Area</td>
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<td>a)</td>
<td>b)</td>
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<td>Sparse shrub in foreground with young island (immature trees) behind</td>
<td>Mature island (mature trees) with woody debris in foreground</td>
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<td>c)</td>
<td>d)</td>
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<td>Start of sidechannel going off to right; dry at low flow (approx. 23 m³/s)</td>
<td>Newly re-constructed sidechannel at low flow (approx. 23 m³/s)</td>
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<td>e)</td>
<td>f)</td>
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<td>Typical riprap bank protection with adjacent bar displaying sparse shrub</td>
<td>Edge of Rubble Creek alluvial fan showing water flowing over surface</td>
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**Figure 2: Morphologic features used in mapping**
Figure 3: Morphologic units of low flow channel
Figure 1: Location of hydrometric stations
Cheakamus River Flows

Figure 2: Downstream increases in discharge due to incremental tributary contributions
APPENDIX A

YEAR 1 CHANNEL MORPHOLOGY MAPPING
APPENDIX B

HYDROGRAPHS AND RATING CURVES
Legend
- Reach breaks
- Banklines
- Woody debris jam
- Riprap banks
- Bar (unvegetated)
- Bar (sparse shrub)
- Bar (submerged)
- Island (young)
- Island (old)
- Sidechannel (wet)*
- Sidechannel (dry)*

Habitat Units
- Riffle
- Rapid/Cascade
- Pool

*Dashed outline indicates engineered sidechannel
Cheakamus River
Channel Morphology - Map 5

Legend
- Reach breaks
- Banklines
- Woody debris jam
- Riprap banks
- Bar (unvegetated)
- Bar (sparse shrub)
- Bar (submerged)
- Island (young)
- Island (old)
- Sidechannel (wet)*
- Sidechannel (dry)*

Habitat Units
- Riffle
- Rapid/Cascade
- Pool

*Dashed outline indicates engineered sidechannel
Cheakamus River
Channel Morphology - Map 6

Legend
- Reach breaks
- Banklines
- Woody debris jam
- Riprap banks
- Bar (unvegetated)
- Bar (sparse shrub)
- Bar (submerged)
- Island (young)
- Island (old)
- Sidechannel (wet)*
- Sidechannel (dry)*

Habitat Units
- Riffle
- Rapid/Cascade
- Pool

*Dashed outline indicates engineered sidechannel
Legend
- Reach breaks
- Banklines
- Woody debris jam
- Riprap banks
- Bar (unvegetated)
- Bar (sparse shrub)
- Bar (submerged)
- Island (young)
- Island (old)
- Sidechannel (wet)*
- Sidechannel (dry)*

Habitat Units
- Riffle
- Rapid/Cascade
- Pool

*Dashed outline indicates engineered sidechannel
Legend

- Reach breaks
- Banklines
- Woody debris jam
- Riprap banks
- Bar (unvegetated)
- Bar (sparse shrub)
- Bar (submerged)
- Island (young)
- Island (old)
- Sidechannel (wet)*
- Sidechannel (dry)*

Habitat Units
- riffle
- Rapid/Cascade
- Pool

*Dashed outline indicates engineered sidechannel
Legend

-Reach breaks
- Banklines
- Woody debris jam
- Riprap banks
- Bar (unvegetated)
- Bar (sparse shrub)
- Bar (submerged)
- Island (young)
- Island (old)
- Sidechannel (wet)
- Sidechannel (dry)
- Rubble Creek fan

Habitat Units

- Riffle
- Rapid/Cascade
- Pool

*Dashed outline indicates engineered sidechannel

BC HYDRO

Cheakamus River
Channel Morphology - Map 11
Table 3: Summary of discharge measurements

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<td></td>
<td>May 27, '09 13:58</td>
<td>64.3 ±6.7</td>
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<td>ADCP</td>
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Cheakamus Pedestrian Suspension Bridge

<table>
<thead>
<tr>
<th>Site</th>
<th>Date-Time</th>
<th>Discharge (m$^3$/s)</th>
<th>Error (m$^3$/s)</th>
<th>Method</th>
<th>Drainage Area (km$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheakamus Pedestrian Suspension Bridge</td>
<td>Aug 12, '08 13:30</td>
<td>36.3 ±3.6</td>
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<td>Price Meter</td>
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<td>Feb 10, '09 14:00</td>
<td>13.9 ±1.7</td>
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<td>ADCP</td>
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<tr>
<td></td>
<td>Apr 13, '09 11:00</td>
<td>21.9 ±1.6</td>
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<td>ADCP</td>
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<tr>
<td></td>
<td>Apr 21, '09 09:30</td>
<td>19.4 ±1.8</td>
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<td>ADCP</td>
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<tr>
<td></td>
<td>May 27, '09 17:39</td>
<td>66.7 ±5.7</td>
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<td>ADCP</td>
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Cheakamus Pedestrian Suspension Bridge

<table>
<thead>
<tr>
<th>Site</th>
<th>Date-Time</th>
<th>Discharge (m$^3$/s)</th>
<th>Error (m$^3$/s)</th>
<th>Method</th>
<th>Drainage Area (km$^2$)</th>
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</thead>
<tbody>
<tr>
<td>Cheakamus Pedestrian Suspension Bridge</td>
<td>Jun 19, '08 12:20</td>
<td>5.3 ±0.4</td>
<td></td>
<td>Rhodamine WT Dilution</td>
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<td></td>
<td>Jun 19, '08 16:00</td>
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<td>Salt dilution</td>
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<td>Aug 12, '08 08:00</td>
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<td>Feb 3, '09 13:00</td>
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<td>Salt dilution</td>
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<td>Feb 3, '09 13:20</td>
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<td>Salt dilution</td>
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<td>Apr 13, '09 13:15</td>
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Cheakamus above Cheekye

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<tr>
<th>Site</th>
<th>Date-Time</th>
<th>Discharge (m$^3$/s)</th>
<th>Error (m$^3$/s)</th>
<th>Method</th>
<th>Drainage Area (km$^2$)</th>
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<tbody>
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<td>Cheakamus above Cheekye</td>
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<td></td>
<td>Apr 13, '09 14:30</td>
<td>27.9 ±0.7</td>
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<td>ADCP</td>
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<td>Apr 21, '09 11:50</td>
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Cheekye River

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<th>Discharge (m$^3$/s)</th>
<th>Error (m$^3$/s)</th>
<th>Method</th>
<th>Drainage Area (km$^2$)</th>
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</thead>
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<td>Cheekye River</td>
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<td>3.2 ±0.2</td>
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<td>Salt Dilution</td>
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<td>Salt Dilution</td>
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Cheakamus below Cheekye

<table>
<thead>
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<th>Site</th>
<th>Date-Time</th>
<th>Discharge (m$^3$/s)</th>
<th>Error (m$^3$/s)</th>
<th>Method</th>
<th>Drainage Area (km$^2$)</th>
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</thead>
<tbody>
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<td>Cheakamus below Cheekye</td>
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<td>ADCP</td>
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Stage = 0.3093\cdot Q^{0.4483} \\
R^2 = 0.99 \\

Figure 5: Rating curve for the Cheakamus River gauge at the Chance Creek Forest Service Road (FSR) Bridge crossing. Estimates of flow for the site hydrograph above measured flows are indicated by the extrapolation line; measurement errors are 1 standard deviation for ADCP, 7% for dilution methods, and 10% for velocity-area measurements.
Figure 6: Rating curve for Chance Creek at the railroad bridge crossing immediately upstream of the Chance Creek-Cheamamus River confluence. Measurement errors are 1 standard deviation for ADCP, 7% for dilution methods, and 10% for velocity-area measurements.
Figure 7: Rating curve for the Cheakamus River gauge at the pedestrian suspension bridge upstream of the Cheakamus River-Culliton Creek confluence. Estimates of flow for the site hydrograph above measured flows are indicated by the extrapolation line; measurement errors are 1 standard deviation for ADCP, 7% for dilution methods, and 10% for velocity-area measurements.
Figure 8: Rating curve for the Culliton Creek gauge upstream of the Culliton Creek-Cheakamus River confluence. Estimates of flow for the site hydrograph above measured flows are indicated by the extrapolation line; measurement errors are 1 standard deviation for ADCP, 7% for dilution methods, and 10% for velocity-area measurements.
Stage = 0.0952·Q^{0.696}

R^2 = 0.99

Figure 9: Rating curve for Cheekye River upstream of the Cheekye River-Chance Creek confluence. Measurement errors are 1 standard deviation for ADCP, 7% for dilution methods, and 10% for velocity-area measurements.
Figure 10: Rating curve for Cheekye River downstream of the Cheekye River-Chance Creek confluence. Measurement errors are 1 standard deviation for ADCP, 7% for dilution methods, and 10% for velocity-area measurements.
Figure 11: Preliminary hydrograph and water temperature for the Cheakamus River gauge at the Chance Creek Forest Service Road (FSR) Bridge crossing. Estimates of flow for the site hydrograph above measured flows are indicated by the extrapolation line.
Figure 12: Preliminary hydrograph and water temperature for the Cheakamus River gauge at the pedestrian suspension bridge upstream of the Cheakamus River-Culliton Creek confluence. Estimates of flow for the site hydrograph above measured flows are indicated by the extrapolation line.
Figure 13: Preliminary hydrograph and water temperature for the Culliton Creek gauge upstream of the Culliton Creek-Cheakamus River confluence. Estimates of flow for the site hydrograph above measured flows are indicated by the extrapolation line.