Cheakamus Project Water Use Plan

Monitoring Program Terms of Reference

- Monitoring Channel Morphology in Cheakamus River

Revision 1: February 2007
1st Submission: November 2006
Terms of Reference for the Cheakamus Water Use Plan
Effectiveness Monitoring Program

Overview

This document presents Terms of Reference (TOR) for the effectiveness monitoring programs for the Cheakamus Water Use Plan (WUP). These programs will monitor outcomes of the recommended operational changes, and provide information on which to base future operating decisions.

The first submission of the TOR was in November 2006 for the Cheakamus River Juvenile salmonid outmigrant enumeration monitoring program. This document is Revision 1 and provides detailed Terms of Reference for the following programs:

1a) Cheakamus River Juvenile salmonid outmigrant enumeration monitoring: A five-year monitoring program to enumerate juvenile salmonid outmigration from the Cheakamus River mainstem and key side channels. Previously submitted to the Comptroller of Water Rights on 20 November 2006; leave to commence was received 28 November 2006.

1b) Cheakamus River chum salmon escapement monitoring and mainstem spawning groundwater survey: A five-year monitoring program to enumerate chum spawning escapement and examine groundwater in mainstem spawning areas

2) Trout abundance monitor in Cheakamus River (Daisy Lake Dam to Cheakamus canyon): A five-year monitoring program for rainbow trout in the non-anadromous section of the Cheakamus River.

3) Cheakamus River steelhead adult abundance, fry emergence-timing, and juvenile habitat use and abundance monitoring: A five-year monitoring program to examine the effects of mainstem flows on steelhead production.

4) Monitoring stranding downstream of Cheakamus generating station: A three-year monitoring program to examine stranding downstream of the Cheakamus generating station tailrace on the Squamish River.

5) Monitoring stranding downstream of Daisy Lake Dam: A one-year monitoring program to monitor fish stranding downstream of Daisy Dam.

6) Monitoring groundwater in side channels of the Cheakamus River: A five-year program to monitor the effect of Cheakamus mainstem flows on groundwater-fed side channels.

7) Cheakamus River benthic community monitoring: A three-year monitoring program and modelling exercise to examine the effects of mainstem flows on the benthic community.

8) Monitoring channel morphology in Cheakamus River: A five-year monitoring program to examine the effects of flows on channel morphology in the Cheakamus River mainstem.

9) Cheakamus River recreational angling access monitoring: A one-year monitoring program to examine the benefits to recreational angling access (available angling locations) of the 1 January to 31 March 5.0 m³·s⁻¹ minimum flow release from Daisy Lake Dam.
Cheakamus River Monitoring Program #8: Monitoring Channel Morphology in Cheakamus River

1.1 Program Rationale

1.1.1 Background

The Cheakamus River FTC developed a suite of impact hypotheses related to impacts of Daisy Lake Dam operation on downstream fish and fish habitat. One of these hypotheses was that the pattern of release from the dam causes a change in the river’s hydrology such that it alters its channel geomorphology. This in turn affects the quantity and quality of fish habitat in the system and hence, the number of wild salmon that it is capable of sustaining. Specifically, that habitat concerns were channel diversity, development and access to side channels, and the distribution and quality of substrates utilized by rearing and spawning salmonids.

To test this hypothesis, a study was carried out by Northwest Hydraulics Consulting (2000) that examined the role of Daisy Lake Dam and its historical operation on the present day morphology and sediment characteristics of the channel. The study found that channel morphology had indeed changed significantly since construction of the dam, including a general simplification of channel structure, reduction in the overall length and complexity of side channels, re-vegetation of gravel bars, and a general reduction in channel width. Coincident with these changes was a reduction in peak annual flow by roughly 20 per cent at Daisy Lake Dam. Modelling showed that operations could virtually eliminate the snowmelt freshet in a low inflow year. Though the authors concluded that the reduced freshet was most likely responsible for the rapid re-establishment of pioneer vegetation on bar surfaces, it was not the sole factor explaining the changes in channel morphology. Diking, bank protection, bridge placement, interception of large woody debris and sediments by Daisy Lake Dam, and the lost sediment supply from the Rubble Creek fan (due to bridge maintenance) were all thought to be important contributors. As a result, Northwest Hydraulics Consulting concluded that changes to Daisy Lake Dam operations alone would not be sufficient to reverse the morphological changes in the lower Cheakamus River.

Given the results of the channel morphology study, the FTC rejected the channel morphology hypothesis since Dam operations had little influence on the frequency, magnitude, or duration of very large flows that dramatically alter the channel. The FTC accepted the conclusions of the NWH study as they pertain to the general reduction in channel width, simplification of channel structure, and the vegetation of gravel bars. However, the FTC did identify uncertainties with respect to the role of Daisy Lake Dam operation on the frequency, magnitude and duration of intermediate flows that transport and re-distribute sediment input during large events, and effect other finer scale shaping of the channel and side channels; features that are important to biota. In particular, there was considerable uncertainty centred on the importance of substrate quality and quantity for salmonid species, and the effects of operation impacts, relative footprint effects and natural stochastic events (large floods), on their distribution and availability throughout the river. As well, recent changes in natural side channel access and availability since the implementation of the 45 per cent previous day’s flow rule have prompted the question of whether base releases from Daisy Lake Dam could impact their availability and utility over time.
Therefore, the FTC recommended that these uncertainties be addressed in a monitoring plan. Some CC members also expressed concerns with channel morphology and recommended monitoring to support the technical conclusions of the FTC.

Coincident with these uncertainties is the relatively poor understanding of local inflows to the lower Cheakamus River and its contribution to the river’s hydrology and hence habitat availability in the area.

It should be noted that the Northwest Hydraulics Consulting (2000) report did not address the consequences of the WUP specifically. Rather the study looked at changes in Daisy Lake Dam operations in general and as a result, the uncertainties identified by the FTC were in general as well. In this monitor however, inquiries addressing the uncertainties raised by the FTC will not be generalized in nature, but be examined solely in the context of the WUP operations. However, the results of the monitor may be extrapolated to other operating alternatives if they do not deviate dramatically from the present set of WUP constraints.

1.1.2 Management Questions

The uncertainties stemming from the Northwest Hydraulics Consulting (2000) report have lead to the following management questions:

1) Following implementation of the WUP, has there been a change in the overall availability of suitable fish spawning substrates from the present state? If so, can this change be clearly attributed to Daisy Lake Dam operations vs. other environmental or anthropogenic factor?

2) Following implementation of the WUP, has there been a change in the overall length, access and utility for fish of naturally occurring side channels from the present state? If so, can this change be clearly attributed to Daisy Lake Dam operations vs. other environmental or anthropogenic factors?

3) To what extent does the hydrology of Rubble Creek, Culliton Creek, and Swift Creek contribute to the general hydrology of lower Cheakamus River and how does it attenuate the effects of Daisy lake dam operations.

1.1.3 Summary of Impact Hypotheses

The management questions above will be examined in the context of a pre and post WUP comparison of survey data designed to test various impact hypotheses. Here, pre-WUP will be considered the first year of monitoring after implementation of the WUP flow regime in Feb 2006. Management questions #1 and 2 have an associated set of impact hypotheses that are testable with the data that is collected in the monitor, and the results of which can be used to draw inferences that collectively may answer the management question. Resolving whether changes that occur are the result of Daisy Lake Dam operations will require a further analysis and a weight of evidence approach.

In the case of the first management question, which deals with the availability of suitable substrate, the set of impact hypotheses is as follows:
H$_0$1: Total area (ha) of accessible substrate suitable for salmonid spawning has not changed since implementation of the WUP.

Tests of H1 are focused strictly on the distribution of substrate that is accessible to spawning fish at the most common flows in the system, which may be different for each species and may require separate tests. Tests of this hypothesis will use aerial estimates of suitable substrate measured at a coarse scale (i.e., predominantly gravel = suitable; predominantly large cobble = not suitable). Tests related to the utility of these substrates at different flows is the subject of monitor #1b.

For the management question related to the impacts on side channel utility, the impact hypotheses are:

H$_0$2: Total length (km) of connected side channel habitat wetted at typical flows has not changed since implementation of the WUP.

H$_0$3: 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.

Test of all hypotheses above should incorporate an inventory of potential channel altering events (e.g., flood events, in stream physical works) that could have caused the observed changes, if any are detected. This inventory of events will be important in distinguishing whether the change is the result of Daisy Lake Dam operations, or some other event.

The tributary flow component of the monitor does not lend itself to the impact hypothesis paradigm. Rather, it is a data collection exercise designed to improve the present state of knowledge on tributary inflows to the system, and hence improve the accuracy of inferences drawn from all aspects of the Cheakamus River monitor.

### 1.1.4 Key Water Use Decision Affected

Results of the present monitor will not likely result in a significant change in decisions on flow release from Daisy Dam unless a clear and dramatic, operations-related, impact is detected. If such were the case, the WUP would have to be reviewed in its entirety because it’s unlikely that subtle changes in one or more operational constraints would alter the impact. An alternative may be to use instream physical works to mitigate the impact. Results of the monitor would aid in that respect as well, particularly the collection of air photos, which has recorded all channel changes through time. The conclusions resulting from these studies would also have an impact on the likelihood of reaching CC consensus in future WUPs. It will help reduce the uncertainty associated with the extent and nature of channel morphology changes arising directly from Daisy Lake Dam operations.

Results of the tributary flow monitor will improve the present state of knowledge on tributary inflows to the system, and hence improve the accuracy of inferences drawn from all aspects of the Cheakamus River monitor.
1.2 Program Proposal

1.2.1 Objective and Scope

The objective of this monitor is to collect the data necessary to test the impact hypotheses outlined in Section 1.3 and hence, address the management questions presented in Section 1.2. The following aspects define the scope of the study:

a) The study area will encompass the entire length of Cheakamus River from Daisy Lake Dam to the confluence of Squamish River, excluding the canyon reach which is of limited value to fish and is impractical to survey.

b) The channel morphology component of the monitor will be carried out in Years 1 and 5, and will include the use of air photos, GIS technology, and a maximum of eight days of field ground truthing surveys. A data report will be prepared within one year following completion of the GIS and survey work.

c) The tributary flow component of the monitor will be carried out continuously at Rubble Creek, Culliton Creek, and Swift Creek until the next WUP review period. Each year a total of ten days will be dedicated to ensure that the resulting rating curves are appropriately calibrated. A data report will be prepared within three months of the end of each hydrological year.

d) A final report will be prepared at the end of the monitor that summarizes the results of the entire monitoring program, discusses inferences that can be drawn pertaining to the impact of WUP operations over time, and presents conclusions concerning the impact hypotheses and the management question in Section 1.2.

1.2.2 Approach

The monitoring approach is to use repeated air photo mapping and GIS analysis to monitor changes in channel morphology. This approach will provide information at resolution to detect coarse scale changes in the channel parameters of interest. This monitor will rely heavily on the use of air photographs and GIS technology to capture changes in channel morphology through time. In Years 1 and 5, at a standard discharge and time of the year, a set of air photographs will be taken at a scale of 1:5000 along the entire length of the river. These images will be scanned into computer and rectified across two dimensions (i.e., corrected for lens distortion) so as to create accurate photo mosaics. Using the original air photos, as well as ground truthing surveys, GIS tools will be used to mark the location and aerial extent of all features of interest, including the distribution of substrates and the location and character of side channels areas. The data and summary statistics gathered by GIS analysis will then be used to test the hypotheses outlined above. This approach is very similar to the approach taken to measure Rated Usable Area at different Daisy Lake Dam Discharges (Bruce 2001).

The other aspect of the monitor is the collection of hydrology data from the primary tributaries to the system. Because these tributaries are steep, comprised of coarse substrate and tend to be dynamic in nature, collection of this type of data will be difficult and prone to error. Rather than rely on standard approaches to collect such data, which rely on a stable channel shape and laminar flow condition for accurate measurement, an alternative will be used that incorporates the use of dye or salt tracers. With the recent development of portable and highly sensitive equipment, the
use of tracers for this application has become a much more feasible option, and in this case, cost effective. Its use however, still requires the selection of a stable site for installing reference gauges for continued measurement.

1.2.3 Methods

**Task 1: Project Coordination**

Project coordination involves the general administrative and technical oversight of the program. This will include but not be limited to:

1) Budget management.
2) Staff selection.
3) Logistic coordination.
4) Technical oversight in field and analysis components.
5) Liaison with regulatory agencies.

**Coordination with WUP Monitoring and Other Monitoring Programs**

To help answer high-level questions regarding the relation between Cheakamus River discharge and fish production, data from this channel morphology program will ultimately be used in combination with data from the fish population monitoring programs (Programs #1,2,3,), the Cheakamus stranding program (#4), the benthic community monitoring program (#7), and possibly other WUP monitoring programs. Therefore, it is critical that data collection is coordinated among programs.

To ensure that data collection is coordinated among the inter-related monitoring programs for the Cheakamus WUP, an important task for this program is to develop and maintain communication with project leads for the other monitoring programs. This communication could involve a workshop at the start of the field season to ensure that the sampling locations and methodologies will meet the data requirements of the other programs, and vice-versa. Logistical changes within the scope of the program may be required.

**Task 2: Field Data Collection**

**Air Photography and GIS Analysis**

Air photos at a scale of 1:5000 will be taken along the entire length of the Cheakamus River in Years 1 and 5. Only those sections between the Squamish confluence and the bottom end of the canyon, and the top end of the canyon reach and Daisy Lake Dam will be developed for analysis.

The air photos will be scanned into a computer at maximum resolution and then corrected for lens distortion using appropriate software. The individual images will then be merged into a mosaic and properly scaled so that accurate topographical measurements can be taken. Once in this format, GIS tools will be used to create
polygons of unique character based on the mosaic imagery and detailed air photo interpretation. With respect to the sediment related hypotheses, these polygons will reflect areas of similar substrate composition. For the side channel hypotheses, the polygons will reflect areas of unique character such as habitat type and will include such elements as the extent of connectivity to the mainstem and total length.

Once the initial GIS work is completed, a two person crew will be sent into the field to resolve uncertainties encountered during the air photo interpretation phase, verify the character of each polygon, and verify their boundaries. Corrections to the GIS database will then be made based on the field observations of the ground crew.

**Tributary Flow Monitoring**

Tributary flow monitoring will be carried out by flow salt tracer methodology. At each primary tributary, a site will be selected near the confluence to the Cheakamus River that is judged to be relatively stable through time – a bridge crossing would work well. At each of these sites, a staff gauge, pressure transducer and data logger will be installed in a permanently fixed housing structure. The staff gauge will be used to transform the pressure transducer measurements that are continuously recorded by data logger into a series of water depth measurements.

The depth measurements will be transformed to estimates of discharge using a flow-rating curve derived from flow measurements collected at specific intervals of water depth. Flow estimates will be obtained by salt tracer methodology where a known volume of a concentrated salt solution (salt plug) is released at a point upstream, allowed to mix thoroughly as it travels downstream, and then measured at regular intervals for salt concentration at the gauging site. The resulting sequence of salt concentration measurements is then integrated to over time (i.e., calculate the area under the curve), and then to compare it to the original salt plug concentration to estimate discharge. Details of the methodology can be obtained from several sources, including Hudson and Fraser (2005) and references therein, and in a monograph prepared by Turner Designs entitled “A Practical Guide to Flow Measurement” (available online at www.turnerdesigns.com).

Because these tributary systems are very dynamic, the flow rating curves will have to be re-calibrated every year to accommodate changes in channel morphology at the gauging site.

**Task 3: Data Analysis**

All GIS imagery and polygon data will be stored into a database in a standardized format for future retrieval and analysis. Similarly, all data related to the development of flow rating curves and their annual calibration will be stored in a common database and in a standardized format. The water level data at each site will be stored at hourly and daily average intervals. Each year, the data will be appended to the previous year’s data to create a single data sequence for use in other monitors.

Hypotheses H\(_0\)1 to H\(_0\)4 will be tested using correlation analysis where the temporal sequence of all channel morphology data is examined for a significant increasing or decreasing trend. Both parametric and non-parametric tests will be used depending on the distribution of data.
The tributary flow data will not be subject to analyses other than the descriptive statistics noted above.

**Task 4: Reporting**

Project reporting will consist of a series of annual data reports and a single final report at the conclusion of the monitor. For the channel morphology component of the monitor a data report will be prepared once every five years and be complete within one year after the air photographs have been taken. The data report will simply document the findings of the year and will include a discussion on how the year’s data compare with that collected in previous years. Included in this discussion will be the results of all pertinent hypothesis testing.

For the tributary flow monitor, the data reports will be prepared annually and will include a summary graph of daily average flow and pertinent summary statistics. These data will be incorporated into other monitors as necessary.

At the conclusion of the monitor, a final report will be prepared that collates all of the observations collected to date and:

a) Re-states the objective and scope of the monitor.

b) Presents the method of data collection.

c) Describes the compiled data set and presents the results of all analyses.

d) Discusses the consequences of these results as they pertain to the current WUP operation, and the necessity and/or possibility for future change.

**1.2.4 Interpretation of Monitoring Results**

The air photo mapping and GIS analysis should provide information at a resolution to detect coarse-scale changes in channel morphology. Rejection of any or all of the Hypotheses H$_{01}$ to H$_{03}$ would indicate some kind of change in channel morphology since implementation of the WUP. If the trend is towards increasing substrate availability and channel complexity, then the results are considered to be positive for fish. A negative trend would be interpreted as a loss of fish habitat. If a change has occurred, the next step in the interpretation is to determine whether the change is the result of Daisy Lake Dam operations or some other environmental or anthropogenic factor. Such a distinction will have to rely on a weight of evidence assessment using a database of known, potentially channel altering events in the river. If such events cannot reasonably explain the observed change in channel morphology, then the weight of evidence would default that the change is the result of Daisy Lake Dam operations. Whether the change would have occurred regardless of the WUP operations would remain uncertain.

**1.2.5 Schedule**

Monitoring is scheduled to occur for five years. The channel morphology component of the monitor will be carried out in Years 1 and 5. A data report will be completed within one year of starting the air-photo survey. The tributary flow measurements will be an ongoing component of the monitor. Annual data reports will be prepared within
three months from the end of each hydrological year. At the conclusion of the monitor, a final report will be prepared that summarizes all findings to date.

1.2.6 Budget

Total Cost: $196,562.

1.2.7 References


