

Duncan Dam Project Water Use Plan Monitoring Program Terms of Reference

- **DDMMON-07 Lower Duncan River Water Quality Monitoring**

DUNCAN DAM TERMS OF REFERENCE

1.0 OVERVIEW

This document presents Terms of Reference for monitoring program and physical works for the Duncan Dam Water Use Plan (Table 1). The monitoring programs will address key questions that affected decision making throughout the consultative process. They will assess expected outcomes of operational changes recommended in the Water Use Plan and will provide improved information for future operating decisions. The physical works programs will reduce ongoing erosion to a valuable wetland area, install a boat ramp, develop an action plan to minimize stranding of kokanee spawning in Duncan River side channels, and compensate for nutrient loss to Kootenay Lake.

This document provides detailed Terms of Reference for the following programs:

- 1) DDMMON-07 Lower Duncan River Water Quality Monitoring: A 2-year project with a 1-year contingency to collect temperature and total gas pressure concentration data in the Lower Duncan River and correlate changes in data with dam operations.
- 2) DDMMON-10 Duncan Reservoir Fish Habitat Use Monitoring: a multi-year program to monitor habitat use of reservoir fish species of interest (rainbow trout, kokanee, bull trout and burbot), reservoir water quality variables, and spawning timing data on a seasonal basis. The information collected in this program will be used in future water use planning processes to assess potential effects of operating alternatives.
- 3) DDMMON-15 Lower Duncan River Protocol Development and Finalization: a multi-year program to synthesize the results of the Adaptive Stranding Protocol and Development (ASDP) monitoring program studies (DDMMON#1, DDMMON#2, DDMMON#3 and DDMMON#16), identify data gaps as studies progress, provide the basis for recommending changes to the Lower Duncan River Stranding Protocol, and communicate to stakeholders at key decision points.

Table 1: Duncan Dam Water Use Plan Physical Works and Monitoring Program Terms of Reference Submission Information

Name of Monitoring Program or Physical Works	Order Clause Fulfilled	Submitted with this Package	Previously Submitted To CWR	Submission Date	Leave to Commence
DDMMON-1 Lower Duncan River Ramping Rate Monitoring	Clause 5(e)	No	Yes	3 April 2008	Yes
DDMMON-2 Lower Duncan River Habitat Use Monitoring	Clause 5(e)	No	Yes	30 July 2008	Yes

Name of Monitoring Program or Physical Works	Order Clause Fulfilled	Submitted with this Package	Previously Submitted To CWR	Submission Date	Leave to Commence
DDMMON-3 Lower Duncan River Hydraulic Model Development	Clause 5(e)	No	Yes	3 April 2008	Yes
DDMMON-4 Lower Duncan River Kokanee Spawning Monitoring	Clause 6(a)	No	Yes	3 April 2008	Yes
DDMMON-5 Upper Duncan River Bull Trout Migration Monitoring (removed telemetry and extended study for 2 additional years)	Clause 6(b)	No	Yes	23 Jan 2008	Yes
DDMMON-6 Lower Duncan Dam Bull Trout Passage Monitoring	Clause 6(b)	No	Yes	23 Jan 2008	Yes
DDMMON-7 Lower Duncan River Water Quality Monitoring	Clause 6(c)	Yes	No	16 Dec 2008	No
DDMMON-8 Duncan Riparian Monitoring	Clause 6(d)	No	Yes	30 July 2008	Yes
DDMMON-9 Lower Duncan River Mosquito Monitoring and Management Plan Development	Clause 6(e)	No	Yes	30 July 2008	Yes
DDMMON-10 Duncan Reservoir Fish Habitat Use Monitoring	Clause 6(f)	Yes	No	16 Dec 2008	No
DDMMON-11 Duncan Reservoir Burbot Monitoring	Clause 6(g)	No	Yes	3 April 2008	Yes
DDMMON-12 Duncan Reservoir Archeological Overview Assessment	Clause 5(f)	No	No		No
DDMMON-13 Duncan Reservoir Archeological Site Erosion Monitoring	Clause 5(g)	No	No		No
DDMMON-14 Duncan Wildlife Use Monitoring	Clause 6(h)	No	Yes	30 July 2008	Yes
DDMMON-15 Lower Duncan River Stranding Protocol Development and Finalization	Clause 5(e)	Yes	No	16 Dec 2008	No
DDMMON-16 Lower Duncan River Fish stranding impact monitoring	Clause 5(e)	No	Yes	24 July 2008	Yes
DDMMON-17 Duncan Reservoir Kokanee Stock Assessment	Clause 5(e)	No	No		No
DDMWORKS-1 Argenta Slough Erosion Protection	Clause 5(a)	No	Yes	23 Jan 2008	Yes
DDMWORKS-2 Glacier Creek Boat Ramp	Clause 5(b)	No	Yes	23 Jan 2008	Yes

Name of Monitoring Program or Physical Works	Order Clause Fulfilled	Submitted with this Package	Previously Submitted To CWR	Submission Date	Leave to Commence
DDMWORKS-3 Kootenay Lake Nutrient Loading Funding	Clause 5(d)	No	Yes	23 Jan 2008	Yes
DDMWORKS-4 Action Plan to minimize stranding of kokanee stranding in Lower Duncan River Sidechannels.	Clause 5(c)	No	No		No

7.0 DDMMON#7 – Lower Duncan River Water Quality Monitoring

7.1 MONITORING PROGRAM RATIONALE

7.1.1 Background

It is known that total gas pressure (TGP) levels above certain thresholds may subject fish and other aquatic organisms to injury or mortality (Fidler and Miller, 1994). Prior to the trade-off stage of the Duncan Dam water use planning (WUP) process, limited TGP monitoring was conducted (BC Hydro data on file) on the Duncan River. The Duncan Dam WUP Consultative Committee (CC) recommended (BC Hydro 2005) that further monitoring be undertaken to better understand the relationship between low level port discharge, spill magnitude and TGP concentration at locations downstream of the spillway plunge pool. It was proposed that the Duncan River fish monitoring program fund the installation and data reporting of TGP monitoring at two stations (above the Lardeau River confluence and near the Water Survey of Canada station 08NH118). Monitoring will be opportunistic and will occur for two years during spill events, or until adequate data is collected to complete the TGP-discharge relationship required at both sites.

It is known that, at certain times of the year, there is a temperature differential associated with either discharging flows through the spillway or through the low-level outlets as water from the spillway is drawn from the surface of the Duncan Reservoir while water from the low-level outlets is drawn from depth in the Duncan Reservoir. Currently, the degree to which this temperature differential affects fish species downstream of the Duncan Dam is unknown. During the Duncan Dam water use planning process, a study (BC Hydro, 2003) confirmed that releases in 2002 did not increase water temperatures beyond levels critical to fish survival. The preferred temperature ranges for different fish species and life stages was determined using information from the provincial government's Water Quality Guidelines (year). The Duncan Dam WUP CC recommended (BC Hydro 2005) that further water temperature monitoring be undertaken to determine how operation of the Duncan Dam low-level gates and the spillway affect water temperature in the Duncan River. Monitoring will be continuous for one year and will occur at critical time periods (such as freshet or periods when the Duncan Dam spillway is used) for an additional year. Temperature monitoring is proposed to occur at approximately 12 sites, the exact number of which will be finalized to be sufficient to cover the forebay, the Lardeau River, and the Duncan River from the Duncan Dam to near Kootenay Lake.

Completing this study program will result in partial fulfillment of requirements ordered by British Columbia's Comptroller of Water Rights, and will specifically address clause 6(c) of BC Hydro's Duncan Dam Conditional Water License 27027, monitoring water quality in Lower Duncan River to determine any linkages to operations.

7.1.2 Management Questions

The primary management questions discussed regarding the effects of TGP and water temperature on Duncan River fauna were:

1. What is the relationship between water discharge through the Duncan Dam spillway and the production of TGP?
2. How does the operation of the Duncan Dam low-level gates and the spillway affect the water temperature regime in the lower Duncan River?

Monitoring of spill events at Duncan Dam indicates that spills greater than 114 m³/s with low level port discharge of approximately 142 cms (dilution) results in TGP levels above 115 per cent (BC Hydro data on file). Recent information indicates the situation is most prominent during bull trout transfers when less water is passed

through the low-level outlets and more water is discharged over the spillway (Aspen Applied Sciences, 2002 as cited in Consultative Committee Report, 2005). According to Fisheries and Oceans Canada TGP levels above 115 per cent can be harmful to fish if they are maintained for a period of 4 to 5 days while TGP levels above 130 per cent can kill fish within hours (Consultative Committee Report, 2005). A determination on how often and the length of time TGP levels rise above 115 per cent needs to be made in order that BC Hydro can refine the total gas pressure performance measure.

7.1.3 Summary of Hypotheses

The following hypotheses are to be tested in this monitoring program:

- H₁: Total gas pressure concentrations in Lower Duncan River are correlated to Duncan Dam spillway discharges.
- H₂: Temperature in the Lower Duncan River supports the productivity of fish species of interest.
- H₃: Temperature in the Lower Duncan River are correlated to Duncan Dam operations

In addition to addressing the hypotheses above, the data collected in this study will be correlated to operations to determine the key operations thresholds that impact fish species and life histories of interest. These thresholds will be compared to those assumed in the initial Water Use Planning performance measure analysis for significance, and where appropriate, will be applied in consultation with regulatory agencies either during or following the end of the review period.

7.1.4 Key Water Use Decision Affected

This monitoring program is devised to collect baseline TGP and water temperature data that will allow a determination to be made about 1) whether a relationship exists between the amount of water discharged through the Duncan Dam spillway and the TGP level in the Duncan River downstream of Duncan Dam, and 2) how operations at Duncan Dam affect water temperature downstream of the dam and if these water temperatures affect fish species of interest in the Duncan River downstream of Duncan Dam. This information will provide information to the Water Comptroller and project stakeholders to assess the benefits to the lower Duncan River from the Water Use Plan. Where operations are shown to have an impact on water quality parameters of consequence to fish species of interest, and stakeholders wish to have these impacts addressed, Duncan Dam operating protocols will be reviewed through a decision process either during or after the review period is complete.

7.2 MONITORING PROGRAM PROPOSAL

7.2.1 Objective and Scope

The objective of this monitoring program is to determine if a relationship exists between water quality parameters (TGP levels and water temperature) and Duncan Dam operations and decide if/how each of the water quality parameters affect fish species downstream of Duncan Dam using the total gas pressure as a performance measure (there is no performance measure for water temperature).

Both the TGP and water temperature components of the program will be in effect for two years, scheduled for initial implementation in Year 3 of the review period. However, as TGP monitoring is to occur opportunistically, and temperature monitoring is to coincide with TGP monitoring, it is unknown what years monitoring will occur.

7.2.2 Approach

The monitoring program has three components:

- Study preparation and Site Selection – after reviewing the existing water quality data reports for the system, refine the study terms and establish two TGP monitoring stations, several temperature monitoring fixed-stations on the lower Duncan River, one index temperature monitoring station on the Lardeau River, and one floating thermistor array station located in the Duncan Reservoir forebay
- Water Quality Monitoring – all monitoring stations will be maintained over the two-year monitoring period, with data downloading and instrument calibration occurring several times each year. Monitoring may be extended where operating conditions do not allow for a full range of water quality results.
- Analysis and Reporting – data will be analysed to determine if a relationship exists between Duncan Dam operations and temperature/TGP results. In addition, fisheries tolerances for both parameters will be evaluated to determine if operations have negative impacts on species and life histories of interest. Annual data reports will be provided for each of the two years, and for each year added to compile a comprehensive dataset for each parameter.

7.2.3 Methods

Methods for the duration of the study period are recommended below. Where field limitations require modifications to these methods, the study methodology may be adapted to ensure annual results are comparable. All efforts will be made to maintain consistent methods throughout the review period, and therefore any changes must be ratified by the study coordinator prior to the start of data collection.

7.2.3.1 Study Preparation and Site Selection

Prior to study implementation, a review of the study objectives will be conducted with the study authority and provincial regulatory agencies to confirm the focus and approach of the study, including monitoring locations and fish species and life histories of interest. A review of all water quality studies conducted on the Lower Duncan River will be performed, including those conducted for the DDM WUP, specifically to identify the data gaps and errors in existing data sets and analyses. In addition, a review of published literature for water quality guidelines related to fish health will be conducted for both parameters, to determine the critical thresholds and consequences of various ranges of conditions.

Monitoring sites will be chosen based on previous sampling work conducted by BC Hydro (BC Hydro data on file). In order to ensure all newly collected data can be compared to previously collected data, the same or comparable sampling sites should be utilized as have been utilized in past monitoring programs. Prior to the start of field work, a reconnaissance should be conducted to identify sampling sites. Once sites are chosen and stations installed, characteristics of each site will be recorded on a site summary sheet, including the datalogger settings, access conditions and location as recorded using a handheld GPS.

7.2.3.2 Water Quality Monitoring

The term of this monitoring program was set at two years, but may be extended where water quality data sets are not comprehensive enough to draw conclusions on the effect operations have on either parameter in key locations of the Lower Duncan River. Where necessary, monitoring of either parameter may be suspended to save costs for use during operations of particular interest (e.g., heavy spilling, or unusual reservoir operations).

Total Gas Pressure Monitoring

The Duncan Dam spillway is used only for a portion of the year; typically mid-July through September. The fixed station should be logging for the aforementioned time period and approximately a month before and after this time period to ensure that any spill events are captured and to collect background data. Each site will be downloaded on a frequent basis prior to, and following, spill events and on a weekly basis during spill events. At each of these times the TGP datalogger will be calibrated. One sampling site will be located at or near a site used in 2002 through 2004 TGP studies conducted by BC Hydro. This site is approximately 80 m downstream of the Water Survey of Canada station 08NH118 on the left bank. The other sampling site will be located above the Lardeau River confluence. For security reasons, this station should be placed on the left bank near the end of the Duncan Dam discharge channel.

Water Temperature Monitoring

Water temperature will be monitored year-round for one year and at critical times for an additional year. Temperature dataloggers recording continuous daily average, minimum and maximum temperatures will be installed at each of the sampling sites. Each sampling site will have two recorders to ensure data integrity and will be downloaded on a quarterly basis. Where appropriate, sampling sites will be located at or near sites used in 2002 through 2004 water temperature studies conducted by BC Hydro, to specifically meet the following requirements:

- Duncan Reservoir forebay: an array of approximately five loggers set at fixed depth intervals will be installed in consideration of both reservoir fluctuation and low level outlet intake depth throughout the year;
- Lower Duncan River: several river temperature dataloggers will be placed at a sufficient depth in the river so they are not dewatered during river level fluctuations. Sites will include a variety of habitats (e.g., sidechannels and mainstem) and placed in consideration of both major tributaries and predominant fish use; and
- Lardeau River (index site): one monitoring station will be set in the Lardeau River mainstem just above its confluence with the Lower Duncan River.

Most sampling sites are accessible only by boat; therefore, a boat will be required to conduct site reconnaissance, site set-up, and datalogger downloading. Budget has been set aside for up to 12 monitoring stations (including the reservoir array).

7.2.3.3 Analysis

A relationship between total gas pressure and flow for each outlet device and at each monitoring site will be developed based on the cumulative data sets provided throughout the monitoring period. Confidence intervals for each relationship will be defined based on observed variance in the relationship.

Analysis will be done similarly for temperature, with the inclusion of reservoir elevation and temperature profiles to define the relationship between reservoir elevation, time of year, and downstream temperature in comparison with surface or "natural" river releases. Observed differences in the comparison will be evaluated using statistical tests of significance particularly to determine if such differences are within natural variability. A brief literature review of local accumulated thermal unit (ATU) requirements for key spawning species (kokanee, rainbow trout and mountain whitefish) will be integrated with known spawning timing from DDMMON#2 study results to compare emergent timing of each species associated with a managed flow regime and the "natural" surface release scenario. The literature review will also identify key temperature thresholds for both optimal and suboptimal development of

various life stages of each key fish species, and compare them with monitored results.

A brief description of the relevance of any observed disparity between “natural” and regulated temperature monitoring, and between optimal temperature requirements and observed habitat temperatures is to be included in the final report, with particular emphasis on the reservoir operating zone that most contributes to a particular change in downstream temperature.

7.2.3.4 Reporting

There will be two levels of reporting provided over the course of the Total Gas Pressure and Water Temperature monitoring program:

- Annual Reporting: A technical report will be provided to detail the results of the total gas pressure and water temperature monitoring on an annual basis. The first annual report should identify any data gaps that exist so these can be addressed during the second year of data collection. All data to be provided in excel format
- Final Report: A detailed retrospective analysis and report will be prepared following the collection of the TGP, water temperature, and Duncan Dam discharge (to be provided by BC Hydro) data. The analysis will include a statistical analysis of variability and significance of any differences observed. This report will include illustrations that will allow the reader to decide if a relationship exists between 1) TGP levels downstream of Duncan Dam and the amount of water discharged from the Duncan Dam spillway, and 2) water temperature downstream of the dam and the amount of water discharged from the low-level outlets and the spillway. The report will also include recommendations on how each of the issues should be addressed by BC Hydro.

All reports will outline the methods used (detailing rationale for any deviations from the terms of reference), data summary (all data will be summarized in charts and tables, and discussed in text), maps summary (all maps in GIS format), and including conclusions and recommendations. An executive summary, providing the results of the critical performance measure of total gas pressure will also be included in each report. All raw data and analysis will be provided in an appendix. Reports will be provided in hard and electronic formats (in Microsoft Word and Adobe Acrobat formats), and raw data will be provided in Microsoft Excel documents.

7.2.4 Interpretation of Results

Correlation analysis will be conducted to determine the sensitivity of lower Duncan River temperatures to Duncan Dam discharge and Duncan Reservoir elevation.

Where significant effects are detected, safe reservoir operating ranges and Duncan Dam discharge ranges for typical seasonal (or monthly) lower Duncan River natural inflows will be defined according to literature based fish life history tolerances for species of interest in the river. Similarly for TGP levels, operating thresholds will be defined that incorporate provincial water quality guidelines. For both metrics, operating protocols will be suggested for review and implementation. Any recommendations for operational changes will also include recommendations for follow-up monitoring specific to the site targeted for mitigation.

Where no correlation is detected, or where correlations are not significant, recommendations for further monitoring will be made to clarify specific relationship requirements, including the necessary study period.

7.2.5 Schedule

The spill season at Duncan Dam typically occurs from mid-July through September. Although some monitoring will occur outside this seasonal window, the majority of monitoring will be conducted during this season.

- March 2010 – Contract start – meeting with BCHydro/regulators
- May 2010 – Site selection and station installation
- December 2010 – Literature (ATU and temperature threshold) review
- June 2011 – Draft Year 1 report and recommendations
- July 2011 – Final Year 1 report
- July 2012 – Draft Year 2 (program*) report
- August 2012 – Final Year 2 program report

*If operating conditions do not allow for a full range of water quality results and the monitoring program is extended, the final report due date will be adjusted accordingly. The program has contingency for up to six months in addition to the two-year program already budgeted.

7.2.6 Estimated Budget

A 5% contingency for field work and 10% administration cost for project management have been included in the budget estimate.

Budget was originally approved by the Consultative Committee for a two-year study totaling \$68K (2004\$). The budget for these terms of reference has been estimated to be \$98K (2004\$), which includes a one-half year additional contingency. Total inflated cost for this study is estimated to be \$112K assuming 2010 implementation.

7.3 REFERENCES

Aspen Applied Sciences. 2002. TGP performance measures for the Columbia River water use planning process: A review and evaluation of relevant information and data. Prepared for BC Hydro Water Use Plan, Burnaby, B.C.

BC Hydro. 2005. Duncan Dam Water Use Plan Consultative Committee Report. Prepared on behalf of: The Consultative Committee for the Duncan Dam Water Use Plan.

BC Water Quality Guidelines. 2006. British Columbia Approved Water Quality Guidelines, 2006 Edition. Available at: http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html

Fiddler, L.E. and S.B Miller. 1994. British Columbia water quality guidelines for dissolved gas supersaturation. Prepared for BC Ministry of Environment, Canada Department of Fisheries and Oceans, and Environment Canada.