

Aberfeldie Project Water Use Plan

Monitoring Program Terms of Reference

- **ABFMON-1 Baseline Productivity Monitoring**
- **ABFMON-2 Primary and Secondary Productivity Monitoring**
- **ABFMON-3 Habitat Impact Monitoring**
- **ABFMON-4 Winter Flow Effectiveness Monitoring**

27 March 2008

Terms of Reference for the Aberfeldie Project Water Use Plan Monitoring Programs ABFMON#1 – ABFMON#4

1.0 OVERVIEW

This document presents Terms of Reference for the monitoring programs for the revised Aberfeldie Water Use Plan, which was completed as part of the Aberfeldie Redevelopment Project. These programs will monitor outcomes of the recommended operations for the redeveloped facility to ensure that mitigation and compensation targets associated with the Aberfeldie Redevelopment Project have been met, and will provide information on which to base future operating decisions for the redeveloped Aberfeldie facility. This document provides detailed Terms of Reference for the following programs:

- 1) ABFMON#1 – Baseline Productivity Monitoring: A two year monitoring program to establish baseline primary and secondary productivity conditions within the diversion reach of the Bull River prior to completion of the Aberfeldie Redevelopment Project. Note that this monitoring program has been completed and is included as Attachment 1 to this Terms of Reference package to provide context for ABFMON#2.
- 2) ABFMON#2 – Primary and Secondary Productivity Monitoring: A two year monitoring program commencing upon completion of the Aberfeldie Redevelopment Project to quantify changes in productivity in the diversion reach of the Bull River due to the operating regime associated with the redeveloped Aberfeldie facility.
- 3) ABFMON#3 – Habitat Impact Monitoring: a one year monitoring program designed to calibrate the flow model at the prescribed minimum instream flows, and refine estimates of residual habitat loss in the diversion reach of the Bull River due to the operating regime associated with the redeveloped Aberfeldie facility.
- 4) ABFMON#4 – Winter Flow Effectiveness Monitoring: A three year monitoring program to assess the effectiveness of the winter flow provisions in the canyon reach of the Bull River located between the dam and the first upstream barrier from the generating station.

Terms of Reference for an additional monitoring program to assess the effectiveness of fish habitat works and the Fish and Benthic Habitat Physical Works Design will be submitted at a later date.

2.0 MONITORING PROGRAM RATIONALE

Until it ceased operation in October 2006, the Aberfeldie Generating Station was a run-of-river hydroelectric facility with water flowing over the spillway about 70% of the year and minimal storage capacity. BC Hydro is currently redeveloping the Aberfeldie facility in order to replace all the facility equipment that has reached its end of life.

The old 5 MW power plant will be replaced with a new generating station with a capacity of approximately 25 MW. The redeveloped facility will provide additional power using newer, more efficient turbines and by routing more water through the penstock and the generating station rather than spilling water over the dam. The maximum diversion flows will increase from 8.5 m³/s to 40 m³/s. The number of days

within a year that there is no spill in the canyon section between the dam and generating station is expected to increase from an average of 103 days without spill to approximately 278 days per year without spill (range = 238 to 325 days; n=66). Under normal operating conditions, river levels and flows downstream of the generating station will not be altered. Refer to Figure 1 for the geographic location and layout of the redeveloped Aberfeldie Hydroelectric Generating Facility.

The Aberfeldie Consultative and Fisheries Technical committees (CC and FTC, respectively) from the original Water Use Plan (WUP) (BC Hydro 2003) were reconvened to identify issues associated with the additional diversion flows and changes in operations with the redeveloped Aberfeldie facility.

A fish habitat-flow study was commissioned to assess changes in fish habitat and pool connectivity in the diversion reach as a result of operating the redeveloped Aberfeldie Generating Station. The study focused on flows between 0.25 m³/s and 5.0 m³/s (Rodman and Cope 2005). Based on the results of this study, the reconvened WUP CC felt that increasing the period when habitat in the diversion reach is dewatered would have little cumulative impact on fish production capabilities for the lower Bull River; however the WUP CC also felt that the provision of a minimum flow designed to ensure ecological connectivity while mitigating for the majority of lost aquatic habitat productivity (*i.e.*, periphyton and benthic invertebrates) would be a risk averse strategy that would also ensure ecological integrity to other resources (*i.e.*, vegetation, wildlife) (Cope 2006).

The WUP CC therefore supported a seasonally staged minimum instream flow release to ensure ecological connectivity during the winter low flow period, mitigate for the majority of lost summer aquatic productivity, including fish rearing and primary and secondary productivity (*i.e.*, periphyton and benthic invertebrates), and ensure connectivity flows during spring and fall fish migration windows. The recommended instream flow schedule consists of the following:

- 0.5 m³/s during the spring fish movement period (1 April – 31 May);
- 2.0 m³/s summer productivity (fish plus primary and secondary productivity) flows (1 June – 30 September);
- 0.5 m³/s during the fall fish movement period (1 October – 30 November); and
- 0.25 m³/s winter flows (1 December – 31 March).

A residual habitat loss of 2,991 m², calculated using a seasonal time-step approach, will be compensated for with the construction of the equivalent “productive capacity” of aquatic habitat and primary and secondary productivity compensation works. The compensatory fish and benthic habitat works may be achieved in whole or in part with each other.

The monitoring programs will provide a quantitative assessment to verify if compensation requirements have been achieved and will provide information upon which to base future operating decisions. After three years the results from the Aberfeldie monitoring programs will be used to determine the acceptability of the recommended minimum flow regime. If there have been no significant unforeseen impacts associated with the operations of the new facility or compensatory habitat, the planned review of the Water Use Plan will occur in 15 years as recommended by the reconvened Consultative Committee. A re-opening of the WUP could be triggered if biologically significant issues occur with the recommended flow option, or

if it is shown that the goal of no-net-loss of productive capacity can be achieved with a lower summer flow release in combination with the productive capacity realized from the compensatory habitat.

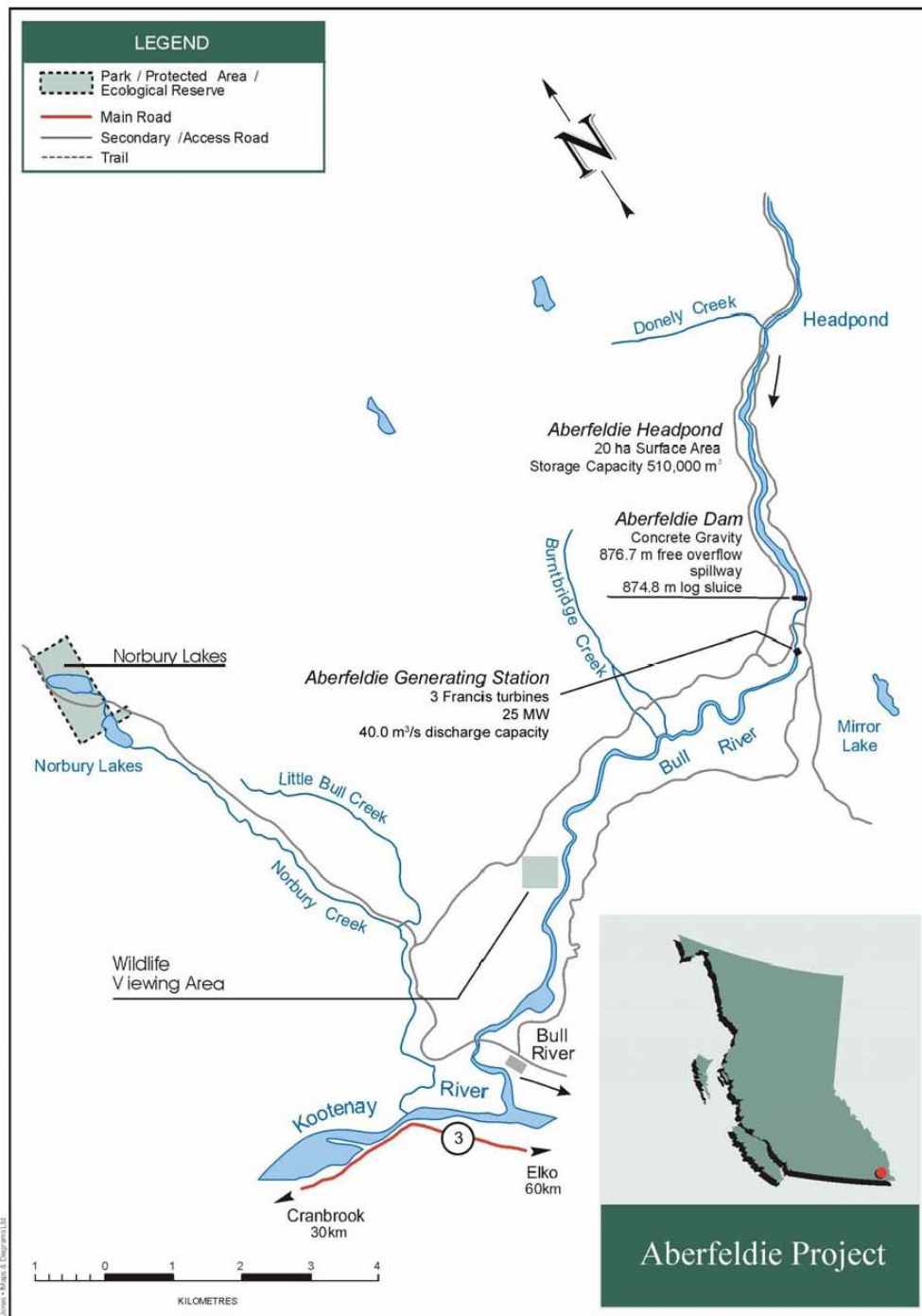


Figure 1: Map showing the layout and geographic location of Aberfeldie Hydroelectric Generating Facility.

3.0 REFERENCES

BC Hydro. 2003. Consultative Committee Report: Aberfeldie Water Use Plan.

Cope, R.S. 2006 (rev 4). Environmental Impact Assessment of the Aberfeldie Redevelopment Project, Bull River, British Columbia. Prepared by Westslope Fisheries Ltd. Prepared For BC Hydro.

Monitoring Program No. ABFMON#2 Primary and Secondary Productivity Monitoring

1.0 MONITORING PROGRAM RATIONALE

The reconvened Aberfeldie Water Use Plan Consultative Committee (CC) and Fisheries Technical Committee (FTC) identified the potential loss of productive capacity associated with the increased diversion of flows, particularly during summer months, as a concern (BC Hydro 2005a; 2005b).

The CC and FTC therefore recommended that a minimum instream flow release of 2.0 m³/s be delivered to the diversion reach from June 1 to September 30 to maintain wetted areas for benthic production, primarily in the section of the Bull River between the generating station and the first upstream barrier (Cope 2006). In addition, to meet Fisheries and Oceans Canada's (DFO) requirement of "no-net-loss" of productive capacity of fish habitat, approximately 3000 m² of aquatic physical works will be constructed to compensate for residual loss of productive capacity in the diversion reach at the recommended instream flow provision (Fisheries and Oceans Canada 2006). The physical works and associated monitoring program are addressed in separate terms of references.

This two year monitoring program is the "after" component of the Before-After-Control Impact study described in ABFMON #1 (Attachment 1). The monitoring program is intended to provide data on primary and secondary productivity at the prescribed 2.0 m³/s summer instream flow in the diversion reach of the Bull River post-redevelopment of the Aberfeldie hydroelectric facility. The data will be compared with pre-redevelopment primary and secondary productivity levels in the diversion reach, and the information will be used in addition to that from ABFMON#3 (Habitat Impact Monitoring) and ABFMON#5 (Effectiveness Monitoring Fish Habitat Works) to verify that the mitigation and compensation requirement of "no-net-loss" of productive capacity has been achieved. The baseline productivity monitoring program (ABFMON#1) was completed in 2005 and 2006 prior to decommissioning the old Aberfeldie generating station in October 2006. It is critical that the productivity monitoring component of ABFMON#5 be completed concurrently with ABFMON#2, using the same methodology, so that conclusions can be made regarding the suitability of the compensatory habitat to meet the compensation requirement of no net loss of productive capacity.

2.0 BACKGROUND

The redevelopment of the Aberfeldie facility is predicted to reduce the period of spill over the dam crest from 8 – 9 months of the year (generally from late March to late December) to 3 – 4 months of the year (primarily from late April to late July). During the new non-spill periods, river flow in the diversion reach would have decreased from current levels of 6 to 30 m³/s to between 0.05 and 1.0 m³/s (i.e., gate leakage and dam seepage). With the prescribed minimum flow requirements the actual range in flow will be between 0.25 and 2.0 m³/s. The largest decline in flow in the diversion reach is expected to occur at the peak of the freshet, typically in June.

Losses of fish habitat and of periphyton and benthic invertebrates due to increased de-watering were identified as key potential impacts. The main habitat of concern for

productivity losses is a pool-riffle sequence with a mid-channel bar that connects the generating station tailrace pool with the deep bedrock pool at the base of the first upstream barrier. Streambed in this section of the Bull River is dominated by large cobbles, boulder, rubble and bedrock. This habitat is not considered to be critical, high quality or high productivity habitat but does provide low-density summer rearing habitat for longnose dace, largescale sucker, sculpins, Westslope cutthroat trout, mountain whitefish, kokanee and possibly bull trout (Cope 2006).

2.1 Management Questions

The primary management questions to be addressed by this monitoring program are:

1. What is the net effect of the post redevelopment flow regime on the community composition, diversity, abundance, and peak biomass of periphyton in the diversion reach of Bull River?
2. What is the net effect of the post redevelopment flow regime on the community composition, diversity, biomass and abundance of benthic invertebrates in the diversion reach of Bull River?
3. If changes in the benthic community associated with post-redevelopment facility operations are detected, does the prescribed flow regime, combined with the productive capacity realized from the compensation habitat achieve the Aberfeldie Redevelopment project compensation goal of no-net-loss of productive capacity?
4. Is there an alternate minimum instream flow discharge that, in combination with the productive capacity realized from the compensation habitat, achieves the Aberfeldie Redevelopment project compensation goal of no-net-loss of productive capacity in the diversion reach of the Bull River?

It is important to note that information from ABFMON#3 (Habitat Impact Monitoring) and ABFMON#5 (Effectiveness Monitoring Fish Habitat Works) will be required in order to fully address the management questions.

2.2 Monitoring Hypothesis

The hypotheses associated with these management questions relate to potential alterations of the productive capacity of the reach of the Bull River between the generating station and the first upstream barrier stemming from changes in operations from pre to post redevelopment. These hypotheses are:

- Ho₁: The implementation of the post redevelopment 2 m³/s minimum summer flow release does not change the peak biomass of periphyton in the diversion reach of the Bull River from pre-redevelopment conditions.
- Ho₂: The implementation of the post redevelopment 2 m³/s minimum summer flow release does not change the total abundance and diversity of periphyton in the diversion reach of the Bull River from pre-redevelopment conditions.
- Ho₃: The implementation of the post redevelopment 2 m³/s minimum summer flow release does not change the total abundance, biomass and diversity of benthic invertebrates in the diversion reach of the Bull River from pre-redevelopment conditions.

2.3 Key Water Use Decision Affected

The results from this monitoring program will be integrated with the four other monitoring programs for the revised Aberfeldie Water Use Plan (Baseline Productivity Monitoring, Habitat Impact Monitoring, Winter Flow Effectiveness Monitoring, and Effectiveness Monitoring Fish Habitat Works) to:

- verify that the mitigation and compensation requirements for the Aberfeldie Redevelopment Project are met;
- support inferences about the adequacy of the recommended staged minimum flow regime; and
- support the scientific rationale for selecting a long-term flow regime for the redeveloped Aberfeldie Generating facility.

The water use decision affected specifically by the results of the productivity studies (i.e., Baseline Productivity and Primary and Secondary Productivity monitoring) is the magnitude of the summer minimum flow release of 2.0 m³/s from Aberfeldie Dam into the diversion reach of the Bull River between June 1 and September 30.

This decision has implications for ecological and power generating values. It is possible that the prescribed summer flow releases, combined with aquatic habitat compensation works may exceed the compensation objectives of no-net-loss of primary and secondary productivity; this would thus allow further reduction of the minimum flows requirements and increase the amount of water available for power generation (Cope 2006). Alternately, additional flow releases from the dam would decrease the amount of water available for power generation.

3.0 MONITORING PROGRAM PROPOSAL

3.1 Objective

The goal of the monitoring program is to quantify post-redevelopment periphyton and benthic production within the diversion reach at the prescribed minimum instream flow for comparison with baseline periphyton and benthic production.

Post redevelopment assessment of periphyton and benthic production will occur during the optimum time for growth in late summer coinciding with no spill conditions in the canyon between the dam and generating station (i.e., when headpond inflows are less than 40 m³/s).

The objectives of the monitoring program are to:

- To monitor physical and water quality parameters that may be important in determining benthos and algal biomass and composition.
- To describe periphyton community composition, and quantify diversity and peak biomass within the diversion reach under the prescribed post-redevelopment summer flow conditions.
- To describe benthic invertebrate community composition, and quantify diversity, biomass and abundance within the diversion reach under the prescribed post-redevelopment summer flow conditions.

- To determine the effect(s) of changes in summer flow conditions on biomass and abundance of benthic invertebrates and periphyton in the diversion reach on a per unit area basis.

The scope of the Primary and Secondary productivity monitoring program is:

- To assess water quality parameters at the control sites and in the diversion reach during the optimum time period for benthic production, post-redevelopment; these parameters include nitrogen and all size fractions of phosphorus (i.e. biologically active micronutrients).
- To sample water physical parameters such as water temperature, flow, current velocity, water depth, wetted width, light attenuation, turbidity, and approximate particle size distribution in the substrate at the control sites and in the diversion reach during the optimum time period for benthic production, post-redevelopment.
- To sample benthic invertebrate communities to determine post-redevelopment species richness, diversity, biomass, abundance and community composition during the optimum time period for benthic production at the control sites and in the diversion reach.
- To sample periphyton to determine post-development species richness, abundance, community composition, and peak biomass during the optimum time period for benthic production at the control sites and in the diversion reach. Note that peak biomass is a function of cell settlement during a colonization phase, actual growth, and losses associated with insect grazing, scour from suspended particles, and sloughing (Perrin 2007).
- To determine whether there is any change in productive capacity in the diversion reach due to post-redevelopment operational changes. This will be done by comparing the results of this monitoring program to those from the baseline monitoring program (ABFMON#1).

Figure 1 shows the geographic scope of the program. UBC1 is the control site located 13.6 km upstream from the Aberfeldie Dam. LBC2 is the second control site, located 1 km downstream from the generating station adjacent to the potential side channel development site. The treatment site, MBT1, is located in the diversion reach, adjacent to the mid-channel bar that connects the tailrace pool with the deep bedrock pool at the base of the first upstream barrier from the generating station (Perrin 2007).

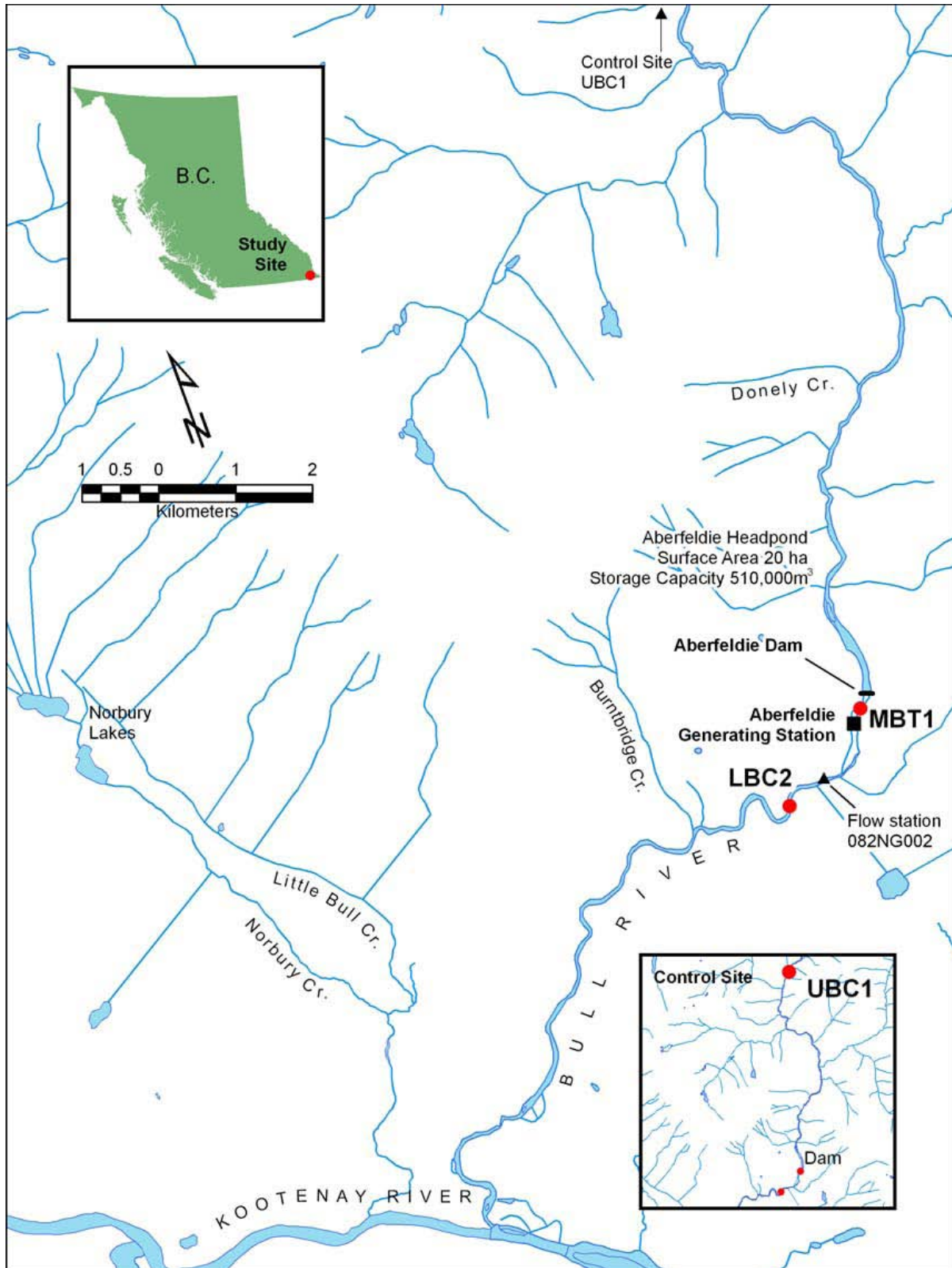


Figure 1: The Bull River study area showing the geographic location and layout of the Aberfeldie generating facilities and sampling sites. (from Perrin 2007)

3.2 Approach

A Before-After-Control-Impact (BACI) design (Perrin 2005) will be used to study the relation between benthic communities and change in post-redevelopment flows in the diversion reach. Two years of pre-redevelopment and two years post-redevelopment data will be collected. The difference between treatment and control sites will be examined before and after changes in flow. Years are the replicates in the design (n=2).

3.3 Methods

3.3.1 Task 1 Project Coordination

Project management involves the general administrative and technical oversight of the project. This task will include, but not be limited to: 1) budget management, 2) study team management, 3) logistic coordination, 4) technical oversight of field and analysis components, and 5) facilitation of data transfer among members of the reconvened WUP CC and FTC.

A safety plan must be developed and submitted to the BC Hydro contract manager for all aspects of the monitoring program involving field work, in accordance with BCH procedures and guidelines. Specific safety training may be required.

3.3.2 Task 2 Preparation of Periphyton Sampling Medium

Artificial substrate will be used to sample periphyton as recommended by Perrin (2005). The periphyton substrate will consist of open-cell sheet Styrofoam™ mounted on concrete patio blocks. Styrofoam™ is the favoured substrate since algal cells can adhere rapidly and sampling is relatively easy while holding constant variables such as substrate size or reducing the variation among field staff collection experience (Perrin 2005).

3.3.3 Task 3 Field Data Collection and Analyses

Data collection and laboratory analyses will follow methods described in Perrin (2005, 2007) and Perrin and Bennet (2006). These methods are provided below.

Replicate periphyton plates will be randomly installed at each site (i.e., 2 control sites and one test site in the diversion reach) in riffle or run flows and sampled over 35 – 46 days in August through September in 2009 and 2010. A 2 cm diameter core of the Styrofoam™ and biomass will be removed each week, and analysed for chlorophyll-a (chl-a) concentration using a fluorometer. The maximum concentration of chl-a found on a given artificial substrate sampler over the time series is considered to be the peak biomass. On the final sampling day of each series, an additional core will be removed and preserved in Lugol's solution for later taxonomic identification and enumeration in the laboratory.

Periphyton cells will be counted in the laboratory at 500x magnification after settlement in Utermohl chambers. Only cells containing cytoplasm will be enumerated. A minimum of 100 individuals of the most abundant species and a minimum of 300 cells in total will be counted. Cells of filamentous taxa will be separated from counts of unicellular taxa (Perrin 2007).

On the final day of periphyton sampling for each series, 4 replicates of benthic invertebrates will be collected at each site using a Surber sampler (surface area of

900 cm² with a 250 µm net), using methods consistent with provincial standards (BC Ministry of Environment 1997). The sampler will be placed at a randomly selected place in the river, and substrate within the sampling frame will be disturbed to a depth of 10 cm for a period of 1 minute. The sampler will then be moved upstream and the process repeated. The process will be repeated at 5 random locations. Contents accumulated in the net after completing the sampling in the 5 locations will be considered to be one complete sample (i.e., the surface area of one sample will be 4,500 cm²). Four replicate samples will be collected at each of the three sites, for a total of 12 samples. Samples will be preserved in 10% formalin.

Benthic invertebrates will be enumerated in the laboratory using a set count approach: All large animals >1 mm will be picked from the complete sample and in the process all twigs, clumps of algae and other debris will be removed. All small organisms adhering to debris will also be picked, leaving the bulk of the sample without large particulate matter that can affect the distribution of organisms among subsamples. All animals picked from the large debris will be considered "macrobenthos" and identified and enumerated.

The remaining sample containing (microbenthos, organisms <1 mm) will be evenly split into 4 to 16 subsamples using a plankton splitter. The number of splits will depend on the total number of organisms in the sample. A minimum of 200 individuals will be picked from one or more of those subsamples or at least one subsample will be examined in its entirety even if it contains more than 200 organisms. The total count of microbenthos in a whole sample will be extrapolated by taxa. The total sample count will be the sum of macrobenthos and microbenthos. All benthic animals retained on a 250 µm sieve will be identified to the lowest reliable taxonomic level.

One water sample will be collected from each location at the start and the finish of the six weeks sampling program. Water samples will be analyzed for soluble reactive phosphorus (SRP), total P (TP), total dissolved P (TDP), and particulate P (PP), at a lab with detection capabilities below 1 µg/L. Water samples will also be analyzed for nitrogen components NH⁴⁺ and NO³⁻.

Physical measurements will be made on each weekly sampling day at each location, including light attenuation, measured in photosynthetically active radiation (PAR), current velocity and water depth. Water temperature will be measured continuously using a temperature logger installed at each site.

3.3.4 Task 4 Reporting

Detailed technical reports outlining field and analytical methods, results of field measurements, and data analyses and interpretation will be prepared by June 30 of each year following the field work. The report for the final year of the primary and secondary productivity monitoring program will contain detailed analyses of the net effect of flow changes in the diversion reach by comparing the data collected during this program to the data collected during the baseline productivity monitoring program (ABFMON#1). The final report will also include an analysis of the measured and predicted wetted area (ABFMON#3) in relation to the productive capacity of the diversion reach, and effectiveness of the compensation habitat (ABFMON#5) (in concert with the prescribed minimum flow requirements) to achieve no-net-loss of productive capacity in the diversion reach of Bull River.

3.4 Interpretation of Monitoring Program Results

Data from the baseline monitoring program will be compared with those from the pre-redevelopment monitoring program. Statistical significance may indicate that post-redevelopment changes in flow have an effect on benthic community attributes. The magnitude of such effect may be determined from the data, and may help refine compensation requirement estimates to achieve no net loss of aquatic productivity in the diversion reach of the Bull River.

3.5 Schedule

The periphyton and benthic monitoring program is scheduled to occur in two successive summers once the post-redevelopment flow regime has been implemented. Based on the currently scheduled redevelopment completion date of August 2008, the periphyton and benthic monitoring program will start in August-September 2009 and finish in 2010. In such case the final report will be submitted by June 30, 2011.

The baseline primary productivity monitoring program (ABFMON#1) was completed in August – September 2005 and 2006 (Perrin 2007).

3.6 Budget

The total estimated budget for the monitoring program, including the integration of study results from ABFMON#1, 2, 3 and 5 to allow for conclusions to be reached with respect to meeting the compensation requirement of no-net-loss of productive capacity is estimated to be \$100,503. A 2% annual rate of inflation (based on 2004\$) and 5% contingency has been assumed.

3.7 References

BC Hydro. 2005a. Aberfeldie Re-Development Project – Revising the Water Use Plan (WUP) Consultative Committee Meeting #1 Final Meeting Notes.

BC Hydro. 2005b. Aberfeldie Re-Development Project – Operations-Related Impacts Fish Technical Committee Meeting #3 Final Meeting Notes.

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Fisheries and Oceans Canada. 2006. AUTHORIZATION FOR WORKS OR UNDERTAKINGS CAUSING THE HARMFUL ALTERATION, DISRUPTION OR DESTRUCTION OF FISH HABITAT. DFO Referral 05-HPAC-PA7-000-000188

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Perrin, C.J. 2005. Report on review of sampling options to examine benthic invertebrate composition and abundance due to redevelopment of the Aberfeldie Generating Station. Memo report prepared for Aberfeldie Fisheries technical Committee c/o: BC Hydro, Environment and Sustainability Engineering. Prepared by Limnotek Research & Development Inc. 10 pp.

Perrin, C.J. and S. Bennet. 2006. Periphyton and benthic invertebrate monitoring in the Bull River near the Aberfeldie Dam, 2005. Report prepared by Limnotek Research and Development Inc. for BC Hydro. 37 p.

Perrin, C. 2007 Periphyton and benthic invertebrate monitoring in the Bull River near the Aberfeldie Dam, 2006. Report prepared by Limnotek Research and Development Inc. for BC Hydro. 42 p.

Rodman, R. and R.S. Cope. 2005. Habitat flow relationships within the Bull River canyon between the Aberfeldie Dam and the powerhouse. Implications for minimum flow provisions. Report prepared for BC Hydro and Power Authority, Burnaby, B.C. Prepared by Klohn Crippen, Nelson, B.C.,

Monitoring Program No. ABFMON#3 Habitat Impact Monitoring

1.0 MONITORING PROGRAM RATIONALE

1.1 Background

The DFO Policy for the Management of Fish Habitat addresses the productive capacity rather than the net area, and the guiding principle is for no net loss of productive capacity of fish habitat. The Aberfeldie Redevelopment project will divert additional water through the penstock and powerhouse, thereby reducing the number of days per year where water spills from the headpond into the canyon between the dam and powerhouse and resulting in a possible loss of fish habitat in this reach of Bull River. BC Hydro therefore initiated a study to develop a flow-habitat model to provide appropriate minimum flow recommendations and to derive estimates of residual habitat loss for off-site habitat compensation (Rodman and Cope 2005).

The model required estimates of fish habitat quality and quantity in the diversion area. The canyon reach between the dam and first barrier upstream from the generating station was surveyed by foot and bankfull area estimates were derived for step-pool habitat. In addition, habitat units in the canyon were qualitatively assessed for habitat quality and for their vulnerability to impacts from post-operational flows.

Two cross-sectional transects were surveyed for loss of productive capacity in the pool-riffle habitat unit and in the bedrock plunge pool at the base of the first upstream barrier. Transects in this area were supplemented by other measurements such as bankfull and water elevations, wetted widths, flow depths, and roughness calibrations. The flow model was calibrated with surveyed water surface elevations at three flows: 11.0 m³/s, 6.4 m³/s and 4.4 m³/s. The calibrated flow-habitat model was then interpolated to five flows (0.25 m³/s, 0.5 m³/s, 1.0 m³/s, 2.0 m³/s, and 3.0 m³/s) to estimate usable habitat area, water depths, and water velocities at this range.

The qualitative assessment of the diversion reach habitat quality showed that:

- The habitat was not considered critical or of high quality, nor with high productivity;
- The reach may support spawning habitat for mountain whitefish, longnose dace, largescale sucker and sculpins;
- Habitat in the canyon section provides connectivity to over-wintering pools for isolated Westslope cutthroat trout and Rocky Mountain whitefish displaced over the dam; and
- The lower site (between the tailrace pool and first upstream barrier; provides little kokanee holding habitat, summer rearing habitat for Westslope cutthroat trout, mountain whitefish, longnose dace, largescale sucker, sculpins and possibly bull trout (Cope 2006).

Although members of the reconvened Water Use Plan Fisheries Technical Committee (WUP FTC) and Consultative Committee (WUP CC) agreed that the instream habitat to be impacted was relatively simple and only marginally productive, it was recognized that provision of a minimum flow would be a risk averse strategy to

ensure ecological connectivity while mitigating for the majority of the aquatic habitat productivity, including primary (periphyton) and secondary (benthic invertebrates) productivity. The provision of such minimum flow was also assumed in the determination of the net benefits of the redevelopment proposal on wildlife resources.

The Aberfeldie Consultative Committee therefore recommended an operating regime consisting of the following minimum instream flows to the diversion reach:

- 0.5 m³/s during the spring fish movement period (1 April – 31 May);
- 2.0 m³/s summer productivity (fish plus primary and secondary productivity) flows (1 June – 30 September);
- 0.5 m³/s during the fall fish movement period (1 October – 30 November); and
- 0.25 m³/s winter flows (1 December – 31 March).

The residual habitat loss at the prescribed instream flow was predicted to be 2,991 m², calculated from a seasonal time-step approach (Cope 2006). This habitat loss will be compensated by the construction of the equivalent “productive capacity” of aquatic habitat. If the compensation habitat is judged to be more productive than the impacted habitat, an experimental reduction of the minimum flow requirements may be permitted and agreed upon based on consultation with members of the reconvened WUP FTC and CC.

1.2 Management Questions

The key management questions addressed by this monitoring program are:

1. How does the implementation of the seasonally staged minimum flow releases from Aberfeldie Dam affect the mean annual area of river channel in the diversion reach?
2. Does the flow-habitat model accurately predict the wetted area within the diversion reach at each of the prescribed minimum flow releases?

1.3 Monitoring Hypotheses

Ho₁: There is no significant difference between predicted and measured habitat area at each of the prescribed minimum instream flow rates (0.25, 0.5 and 2.0 m³/s).

1.4 Key Water Use Decision Affected

The results from this program

- will be integrated with four other monitoring programs for the revised Aberfeldie Water Use Plan (Baseline Productivity Monitoring, Primary and Secondary Productivity Monitoring, Winter Flow Effectiveness monitoring, and Effectiveness Monitoring Fish Habitat Works) to verify that mitigation and compensation requirements for the Aberfeldie Redevelopment Project are met;
- will support inferences about the adequacy of the recommended staged minimum flow regime for fish and benthic productivity; and
- will support the scientific rationale for selecting a long-term flow regime for the redeveloped Aberfeldie Generating facility.

The water use decisions affected specifically by the results of this monitoring program are the magnitudes of the minimum flow releases from Aberfeldie Dam into the diversion reach of the Bull River when headpond inflows are less than 40 m³/s. These decisions have implications for ecological and power generating values.

The mean annual habitat loss with the prescribed flow release is estimated to be 2,991 m², based on a seasonal time-step approach. Although the equivalent area of 2,991 m² of aquatic habitat compensation works has been estimated for compensation area requirements, the primary objective of the compensation works is to ensure a “no-net-loss” of aquatic primary and secondary productivity. In the event that the compensation habitat is more productive than the impacted habitat the minimum flow requirements may be reduced, which would increase the amount of water available for power generation (Cope 2006). In the event that the compensation habitat is less productive than the impacted habitat, further mitigation or compensation measures and monitoring would be required. Additional flow releases from the dam would decrease the amount of water available for power generation.

2.0 MONITORING PROGRAM PROPOSAL

2.1 Objective

The flow-habitat model was used by the CC and FTC to determine the recommended minimum flow regime, but was never calibrated for the new, lower, flows. This monitoring program quantifies the area of wetted habitat at the prescribed instream flows and determines if the original wetted area predictions are valid.

2.2 Approach

The approach to meeting the program objective is to ground truth the flow-habitat model.

2.3 Methods

A survey will be completed in the step-pool section of the canyon between the dam and the first upstream barrier at each of the prescribed instream flow rates (0.25, 0.5 and 2.0 m³/s) during a period of no spill. The original cross-sections measured by Cope (2006) in the section of the diversion reach between the generating station and the first upstream barrier will also be revisited. Wetted width will be measured, and resulting dewatered area will be calculated. The calculated dewatered area will be compared to the dewatered area predicted by the dynamic flow model and compensation targets will be adjusted accordingly to ensure that no-net-loss has been realized. The monitoring program has three main tasks as outlined below.

2.3.1 Task 1 Project Coordination

Project management involves the general administrative and technical oversight of the project. This task will include, but not be limited to: 1) budget management, 2) study team management, 3) logistic coordination, 4) technical oversight of field and analysis components, and 5) facilitation of data transfer among members of the reconvened Fisheries Technical Committee and the Consultative Committee.

2.3.2 Task 2 Field Data Collection

The measurements will be made at each of the prescribed flow levels, at times when inflow to the headpond is less than or equal to 40 m³/s (i.e., when there is no spill over the dam). Wetted width measurements will be collected at the two cross sections surveyed by Rodman and Cope (2005) in the section of the Bull River between the generating station and the first upstream barrier, and in the step-pool habitat within the canyon between the dam and first upstream barrier.

2.3.3 Task 3 Reporting

A technical report will be submitted by June 30 of the year following completion of the monitoring program. The report will include an analysis of predicted vs. actual dewatered area at each of the prescribed flow levels, and will refine wetted area estimates for the mean annual habitat loss at the post-redevelopment flow regime.

2.4 Interpretation of Monitoring Program Results

Observations and measurements collected as part of the Habitat Impact Monitoring program will be used to verify compensation habitat area requirements.

2.5 Schedule

The habitat impact monitoring program will be implemented during the first year post redevelopment, currently scheduled for August 2008.

2.6 Budget

The total estimated budget for the monitoring program is \$20,908. A 2% annual rate of inflation (based on 2004\$) and 5% contingency has been assumed.

2.7 References

Cope, R.S. 2006 (rev 4). Environmental Impact Assessment of the Aberfeldie Redevelopment Project, Bull River, British Columbia. Prepared by Westslope Fisheries Ltd. Prepared For BC Hydro.

Rodman, R. and R.S. Cope. 2005. Habitat flow relationships within the Bull River canyon between the Aberfeldie Dam and the powerhouse. Implications for minimum flow provisions. Report prepared for BC Hydro and Power Authority, Burnaby, B.C. Prepared by Klohn Crippen, Nelson, B.C.,

Monitoring Program No. ABFMON#4 Winter Flow Effectiveness Monitoring

1.0 MONITORING PROGRAM RATIONALE

1.1 Background

The reconvened Aberfeldie Consultative Committee identified ecological connectivity and possible freezing of refuge habitat in the canyon between the dam and generating station during the winter months as an issue that could impact overwintering fish entrained into this section of the Bull River.

Two studies were undertaken as part of the original WUP to better address the uncertainty surrounding the adequacy of winter flows on fish survival in the canyon between the dam and the generating station (Cope 2003a, Bisset and Cope 2003). These studies suggested that leakage flows of approximately 0.05 m³/s, combined with deep pool refuge habitat, were sufficient to support the mountain whitefish and Westslope cutthroat trout overwintering between the dam and the first barrier upstream from the generating station (Figure 1). It was felt, however, that there was very little margin for safety, given the limited flows and restricted habitat connectivity. Accordingly, a fish habitat-flow study was commissioned by BC Hydro as part of the planning for the Aberfeldie Redevelopment Project to assess fish habitat and pool connectivity at flows between 0.25 m³/s and 5.0 m³/s (Rodman and Cope 2005). These flows were selected as the possible range of potential instream flow recommendations. Based on the outcome of that study, the reconvened Aberfeldie WUP CC recommended the provision of a minimum flow of 0.25 m³/s to be delivered to the Bull River between the dam and generating station between December 1 and March 31 of each year. The WUP CC recognized, however, that additional field observations would be required to confirm the effectiveness of these flows for habitat maintenance during sustained periods of cold weather and recommended implementation of additional monitoring during winter.

The winter effectiveness monitoring program will consist of winter observations during three years, beginning in the winter after the redeveloped facility is commissioned.

1.2 Management Questions

The fundamental goal of the monitoring program is to reduce uncertainty related to the effects of sustained sub-zero air temperatures on the adequacy of the 0.25 m³/s minimum flow as a habitat maintenance flow during winter. As such, the primary management question for the monitoring program is:

- will a minimum flow discharge of 0.25 m³/s, in addition to dam leakage, be sufficient to prevent total freeze-up of pool habitat and maintain habitat connectivity (i.e., prevent habitat isolation and dewatering) in the canyon between the Aberfeldie Dam and generating station during sustained periods of cold weather, under no-spill conditions?

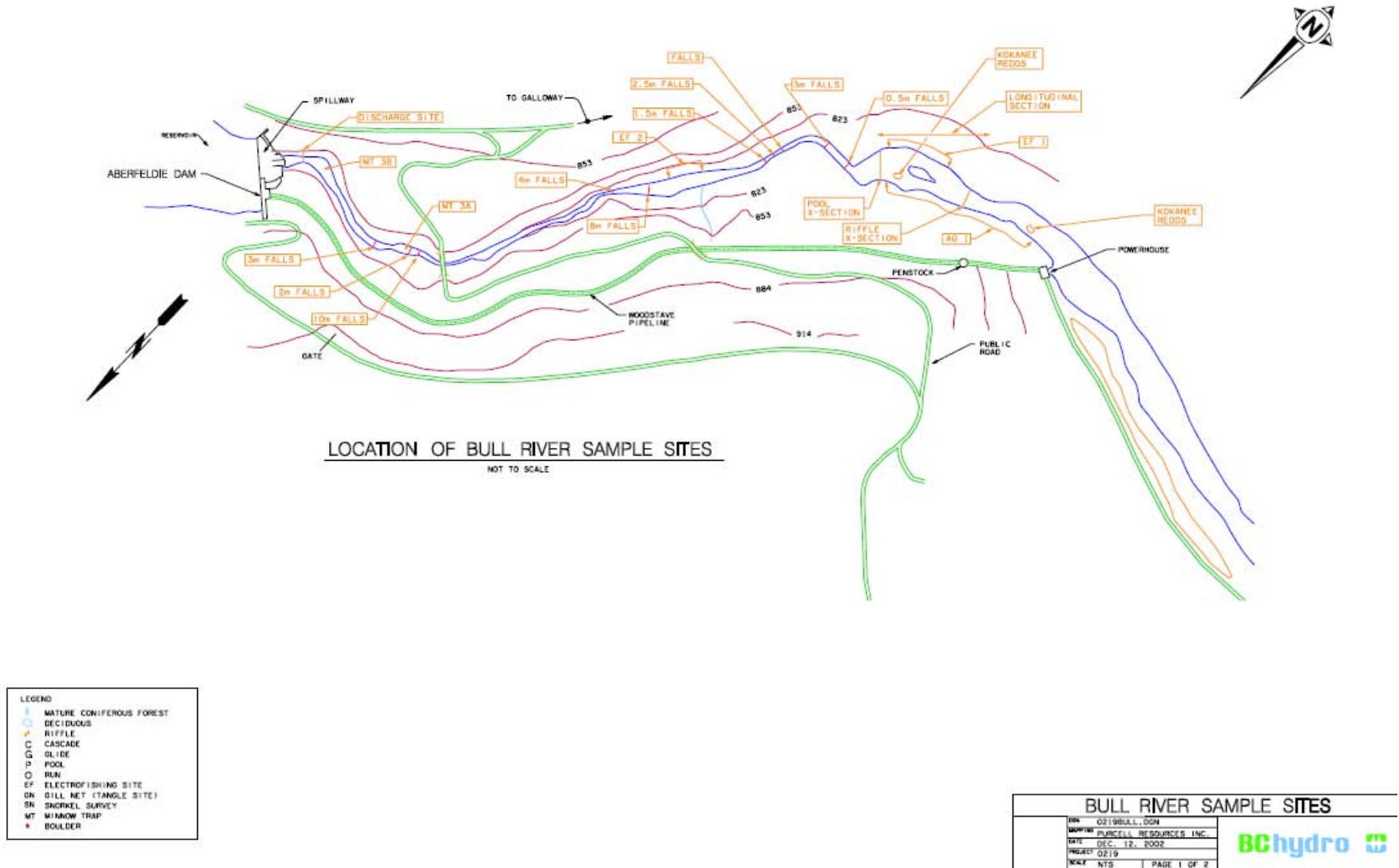


Figure 1: Bull River fish and habitat sampling sites in the canyon section between the dam and powerhouse. Winter effectiveness sample sites are labeled EF1 (25-150 m upstream from the powerhouse), EF 2 (approximately 500 m downstream from the dam), and Discharge Site (approximately 100 m downstream from the dam) (from Bisset and Cope 2003)

1.3 Monitoring Hypothesis

The primary management hypothesis to be tested by the monitoring program is:

H₀: The minimum instream flow release of 0.25 m³/s plus leakage flow from Aberfeldie Dam is adequate to maintain flow connectivity and prevent complete ice build up in pool habitat within the canyon between the Aberfeldie dam and generating station.

1.4 Key Water Use Decision Affected

The results from this program will

- evaluate the effectiveness of the 0.25 m³/s winter instream flow for maintaining ecological connectivity and habitat to support overwintering fish in the diversion reach; and
- provide data to help select a long-term flow regime for the redeveloped Aberfeldie Generating facility.

The key water use decision affected by results of this monitoring program is the magnitude of the minimum flow release into the canyon channel downstream from Aberfeldie Dam between December 1 and March 31. This decision has implications for ecological and power generating values. The canyon section is viewed as providing some overwintering and rearing habitat for mountain whitefish and Westslope cutthroat trout that have been entrained over the dam. Dam leakage flows in combination with the minimum winter instream flow release of 0.25 m³/s are suspected to support these ecological values.

Alternatively, additional flow release from the dam during winter months will decrease the amount of water available for power generation when total inflows to the river above the dam are less than 40 m³/s.

2.0 MONITORING PROGRAM PROPOSAL

2.1 Objective

The objective of the monitoring program is to confirm the effectiveness of the prescribed winter minimum flow release of 0.25 m³/s from the Aberfeldie Dam in combination with leakage flow (under no-spill conditions), for prevention of complete freeze-up of refuge habitat, and maintain habitat connectivity for overwintering fish in the canyon between the Aberfeldie Dam and Aberfeldie Generating Station during sustained periods of cold weather.

2.2 Approach

The monitoring program will consist of three opportunistic field surveys, including observations and measurements of fish habitat and ice conditions in the canyon channel downstream from Aberfeldie Dam during sustained periods of sub-zero air temperature (defined as five consecutive days with a daytime high of -7.5°C or colder with no continuous spilling from Aberfeldie Dam). The recommended approach is to monitor local weather conditions and to conduct field inspections when ice formation is likely to occur. It is possible that these conditions will not occur within a given year but highly probable that they will happen at least once within the three year period. If

possible, multiple surveys will be conducted in a given year following ice formation to study ice development.

The monitoring program will involve assessing fish habitat conditions and focus on measuring ice thickness and areas of open water at three sampling sites established during the winter 2002/2003 fish habitat study (Figure 1)(Bisset and Cope 2003).

2.3 Methods

2.3.1 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; and 5) facilitation of data transfer amongst members of the reconvened WUP CC and FTC.

2.3.2 Task 2 Field Data Collection

Three field activities are required to implement this monitoring program: 1) continuous monitoring of air and water temperature; 2) assessment of ice development; and 3) photographic documentation of habitat conditions during periods of cold weather and ice formation.

Note that this field environment is very hostile and specialized training, equipment and experience in implementing safety measures for working on and around ice in a remote location will be required.

Temperature and Discharge Monitoring

Local daily weather reports and forecasts from Cranbrook (air temperature) will be monitored to guide field surveys but will not be sufficient to accurately document physical conditions where the ice formation is anticipated. BC Hydro will therefore install an air temperature sensor and data logger at Aberfeldie to help determine when the monitoring trigger has been achieved. Long term air and water temperature monitoring locations will also be selected at the beginning of the monitoring program. Daily river discharge estimates for the canyon will be derived from: 1) Water Survey of Canada Station Bull River near Wardner (Station 08NG002), and 2) B.C. Hydro Power Records.

Assessment of Ice Development

Three surveys are recommended to document changes in river ice following periods of winter conditions (5 days with maximum hourly average air temperature less than -5°C , with no continuous spilling from Aberfeldie Dam). These surveys may be conducted consecutively in a single calendar year if an extended period of low air temperature greatly exceeding the minimum threshold for cold weather conditions is observed (13 days or more at $<-7.5^{\circ}\text{C}$; i.e., three full survey periods).

Alternatively, if weather conditions only marginally exceed the minimum threshold for cold weather then surveys may be completed in different years. Depending on ice conditions, field surveys to document physical conditions and ice development (spatial and water column coverage) within the canyon are expected to last three days. The spatial extent of ice cover will be mapped during each survey. If practical, index locations for repeated measurements of ice thickness (Bisset and Cope 2003)

will be used. Spot measurements of oxygen concentration and water temperature will be collected throughout the study area and profiling will be done in deep pools.

Spatial extent and ice thickness will also be photographed at reference locations and documented throughout the study area.

2.3.3 Task 3 Reporting

Written annual progress reports will be required by June 30 of the year following the previous winter's monitoring program, and a detailed technical report outlining the findings from the complete monitoring program will be submitted on or before June 30, 2011.

2.4 Interpretation of Monitoring Program Results

These data collected will be used to support a decision regarding the acceptability of the prescribed winter minimum flow release. If the 0.25 m³/s flow is found to be unsatisfactory for the protection of overwintering fish habitat, the flow may be increased to 0.5 m³/s or to some other level as suggested by the results of the monitoring program. If the recommended flow is judged to be sufficient to protect fish habitat, the planned review of the water use plan will occur in 15 years as recommended by the reconvened Consultative Committee.

2.5 Schedule

The monitoring program will be conducted opportunistically during low air temperature, non-spill periods, while the winter minimum instream flow release is in effect (December 1 to March 31). Three field surveys in total are planned when air temperatures drop below a threshold (refer to earlier sections). It is expected that these conditions will be met within the three-year time frame based on historical meteorological records (Environment Canada 2008) however, it is important to note that these conditions may not occur and they may not be sufficient to produce icing in the canyon.

2.6 Budget

The total estimated budget for the monitoring program is \$32,573. A 2% annual rate of inflation (based on 2004\$) and 5% contingency has been assumed.

2.7 References

Bisset, J.E. and R.S. Cope. 2003. Fish and Fish Habitat Resources in the lower Bull, Elk and Spillimacheen Rivers (between Dam and Powerhouse) during the non-spill period, 2002. Report prepared for BC Hydro, Water Use Planning by Westslope Fisheries Ltd., Cranbrook, B.C. 36p.

Cope, R.S. 2003. Fish and Fish Habitat Resources in the lower Bull and Elk Rivers (between dam and powerhouse) during the non-spill period, 2003. Report prepared for BC Hydro by Westslope Fisheries Ltd., Cranbrook, B.C. 7p.

Environment Canada 2008. Cranbrook Airport Meteorological Conditions. National Climate Archive website:

http://www.climate.weatheroffice.ec.gc.ca/climateData/canada_e.html

Attachment 1

Monitoring Program No. ABFMON#1 Baseline Productivity Monitoring

1.0 MONITORING PROGRAM RATIONALE

The reconvened Aberfeldie Water Use Plan Consultative Committee (CC) and Fisheries Technical Committee (FTC) identified the potential loss of productive capacity associated with the increased diversion of flows, particularly during summer months, as a concern (BC Hydro 2005a; 2005b).

The CC and FTC therefore recommended that a minimum instream flow release of 2.0 m³/s be delivered to the diversion reach from June 1 to September 30 to maintain wetted areas for benthic production, primarily in the section of the Bull River between the generating station and the first upstream barrier (Cope 2006). In addition, to meet Fisheries and Oceans Canada's (DFO) requirement of "no-net-loss" of productive capacity of fish habitat, aquatic physical works will be constructed to compensate for residual loss of productive capacity in the diversion reach at the recommended instream flow provision (Fisheries and Oceans Canada 2006). The physical works and associated monitoring program are addressed in separate terms of references.

This two year monitoring program is the "before" component of a Before-After-Control-Impact study, and is intended to provide baseline data on primary and secondary productivity in the diversion reach of the Bull River prior to redevelopment of the Aberfeldie hydroelectric facility. The data will ultimately be compared with post redevelopment primary and secondary productivity levels in the diversion reach at the prescribed 2.0 m³/s summer instream flow release and the information will be used to verify that the mitigation and compensation requirements of "no-net-loss" of productive capacity, in concert with the physical habitat works, have been achieved. The post redevelopment primary and secondary productivity levels will be acquired in the ABFMON #2 monitoring program.

The baseline productivity monitoring program was completed in 2005 and 2006 prior to decommissioning the old Aberfeldie generating station in October 2006.

2.0 BACKGROUND

The redevelopment of the Aberfeldie facility is predicted to reduce the period of spill over the dam crest from 8 – 9 months of the year (generally from late March to late December) to 3 – 4 months of the year (primarily from late April to late July). During the new non-spill periods, river flow in the diversion reach will decrease from current levels of 6 to 30 m³/s to between 0.05 and 1.0 m³/s (i.e., gate leakage and dam seepage). The largest decline in flow in the diversion reach will occur at the peak of the freshet, typically in June.

Losses of fish habitat and of periphyton and benthic invertebrates due to increased de-watering were identified as key potential impacts. The main habitat of concern for productivity losses is a pool-riffle sequence with a mid-channel bar that connects the generating station tailrace pool with the deep bedrock pool at the base of the first upstream barrier. Streambed materials in this section of the Bull River are dominated

by large cobbles, boulder rubble and bedrock. This habitat is not considered to be critical, high quality or high productivity habitat; however, the area does provide low-density summer rearing habitat for longnose dace, largescale sucker, sculpins, Westslope cutthroat trout, mountain whitefish, kokanee and possibly bull trout (Cope 2006).

2.1 Management Questions

The key management questions addressed by this monitoring program are:

1. What is the benthic community composition, diversity, biomass and abundance in the section of the Bull River located between the generating station and the first upstream barrier and in the control sites, pre-redevelopment?
2. What is the predicted change in productivity in the section of the Bull River located between the generating station and the first upstream barrier due to the change in operations associated with the redeveloped facility?
3. What is the habitat area required to compensate for loss of productivity in the diversion reach of the Bull River due to the post redevelopment operating regime?

2.2 Monitoring Hypothesis

n/a

2.3 Key Water Use Decision Affected

The results from this program will be integrated with the four other monitoring programs for the revised Aberfeldie Water Use Plan (Primary and Secondary Productivity Monitoring, Habitat Impact Monitoring, Winter Flow Effectiveness Monitoring, and Effectiveness Monitoring Fish Habitat Works) to

- evaluate the effectiveness of the 2.0 m³/s summer instream flows for maintaining a wetted area in the diversion reach. This area is needed to support benthic production.
- verify that mitigation and compensation requirements for the Aberfeldie Redevelopment Project have been met; and
- support the scientific rationale for selecting a long-term flow regime for the redeveloped Aberfeldie Generating facility.

The water use decision affected specifically by the results of the productivity monitoring programs (Baseline Productivity and Primary and Secondary Productivity monitoring) is the magnitude of the summer minimum flow release of 2.0 m³/s from Aberfeldie Dam into the diversion reach of the Bull River between June 1 and September 30.

This decision has implications for ecological and power generating values. It is possible that the prescribed summer flow releases, combined with aquatic habitat compensation works, may exceed the compensation objectives of no-net-loss of primary and secondary productivity; this would thus allow further reduction of the minimum flow requirements and increase the amount of water available for power generation (Cope 2006). Alternately, additional flow releases may be required and thus decrease the amount of water available for power generation.

3.0 MONITORING PROGRAM PROPOSAL

3.1 Objective

The goal of the program is to establish a benthic productivity baseline within the diversion reach for comparison with post-construction monitoring at the prescribed instream flow.

Assessment of periphyton and benthic production was scheduled to occur in late August and early September to coincide with the optimum time for growth in late summer when it was predicted that there would be no spill conditions in the canyon between the dam and generating station post-redevelopment (i.e., when headpond inflows are expected to be less than 40 m³/s).

The objectives are:

- To establish a baseline of physical and chemical parameters that may be important in determining benthos and algal biomass and composition.
- To describe benthic community composition, and quantify diversity, biomass and abundance under pre-redevelopment flow conditions.
- To describe periphyton community composition, and quantify diversity and peak biomass under pre-redevelopment flow conditions.
- To develop a model that relates an in-stream community parameter to changes in wetted area. The model, in combination with the two years of baseline data, will help define compensation requirements.

The scope of the baseline productivity assessment program is:

1. To assess water quality parameters at control sites and in the diversion reach during the optimum time period for benthic production, pre-redevelopment; these parameters include nitrogen and all size fractions of phosphorus (biologically active micronutrients).
2. To sample water physical parameters such as water temperature, flow, current velocity, water depth, wetted width, light attenuation, turbidity, and approximate particle size distribution in the substrate at the control sites and in the diversion reach during the optimum time period for benthic production, pre-redevelopment.
3. To sample benthic invertebrate communities to determine pre-redevelopment species richness, diversity, biomass and abundance and community composition during the optimum time period for benthic production at the control sites and in the diversion reach.
4. To sample periphyton to determine pre-redevelopment species richness, abundance, community composition, and peak biomass during the optimum time period for benthic production at the control sites and in the diversion reach. Note that peak biomass is a function of cell settlement during a colonization phase, actual growth, and losses associated with insect grazing, scour from suspended particles, and sloughing (Perrin 2007).
5. To develop a model to relate changes in relevant community parameters with changes in wetted area within the diversion reach.

Figure 1 shows the geographic scope of the program. UBC1 is the control site located 13.6 km upstream from the Aberfeldie Dam. LBC2 is the second control site, located 1 km downstream from the generating station adjacent to the potential side channel development site. The treatment site, MBT1, is located in the diversion reach, adjacent to the mid-channel bar that connects the tailrace pool with the deep bedrock pool at the base of the first upstream barrier from the generating station (Perrin 2007).

3.2 Approach

A Before-After-Control-Impact (BACI) design (Perrin 2005) will be used to study the relation between benthic communities and change in post-redevelopment flows in the diversion reach. Two years of pre-redevelopment and two years post-redevelopment data will be collected. The difference between treatment and control sites will be examined before and after changes in flow. Years are the replicates in the design ($n = 2$).

A model will be developed to predict changes in the periphyton and benthic communities by correlating relevant biological parameters with predicted changes in wetted area. The flow-habitat model developed earlier by Rodman and Cope (2005) to predict the wetted area over a range of water releases from the dam will be used to provide wetted area estimates.

3.3 Methods

3.3.1 Task 1 Project Coordination

Project management involves the general administrative and technical oversight of the project. This task will include, but not be limited to: 1) budget management, 2) study team management, 3) logistic coordination, 4) technical oversight of field and analysis components, and 5) facilitation of data transfer among members of the reconvened WUP CC and FTC.

A safety plan must be developed and submitted to the BC Hydro contract manager for all aspects of the study involving field work, in accordance with BCH procedures and guidelines. Specific safety training may be required.

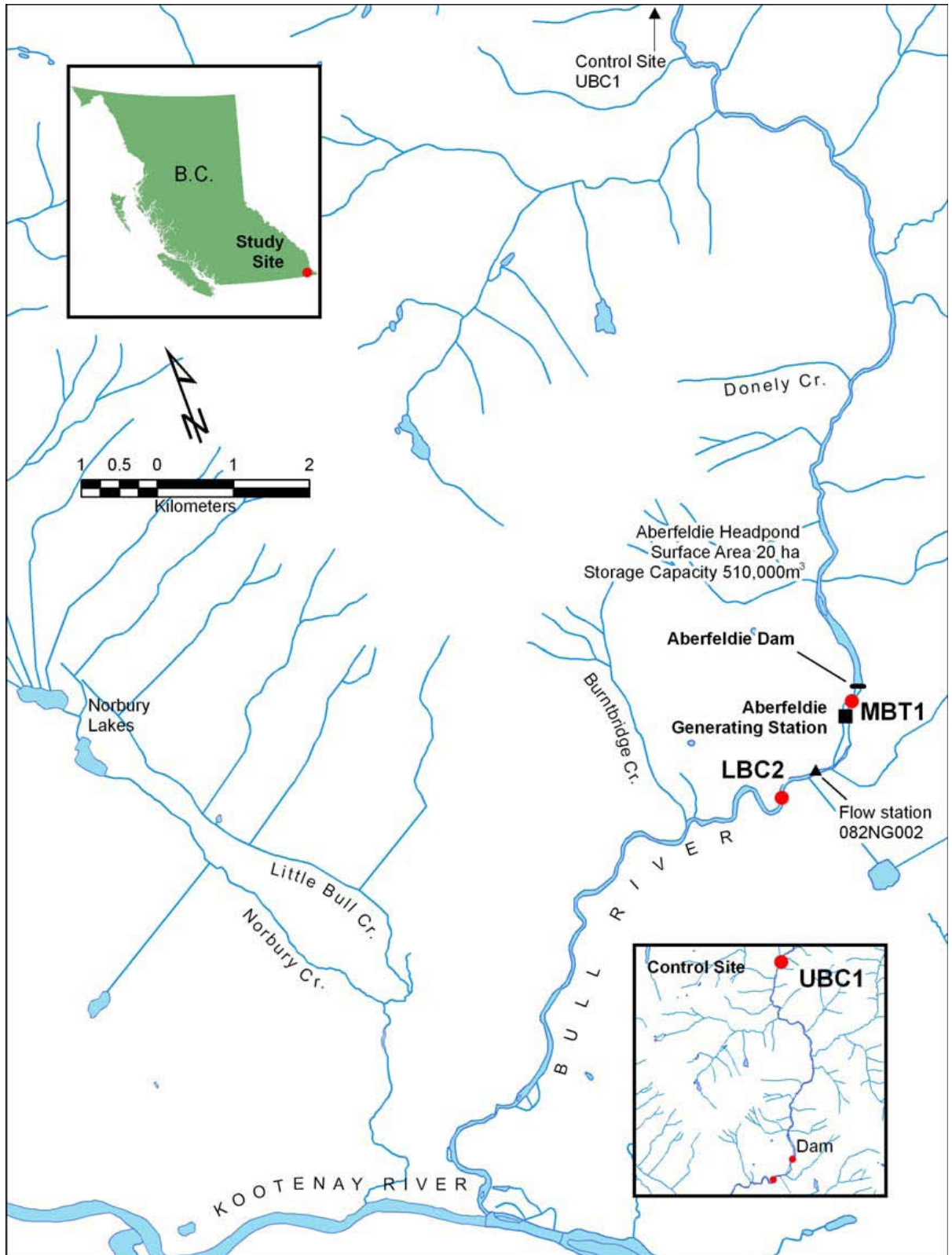


Figure 1: The Bull River study area showing the geographic location and layout of the Aberfeldie generating facilities and sampling sites. (from Perrin 2007)

3.3.2 Task 2 Preparation of periphyton sampling medium

Artificial substrate will be used to sample periphyton. The periphyton substrate will consist of open-cell sheet Styrofoam™ mounted on concrete patio blocks. Styrofoam™ is the favoured substrate since algal cells can adhere rapidly and sampling is relatively easy while holding constant variables such as substrate size or reducing the variation among field staff collection experience (Perrin 2005).

3.3.3 Task 3 Field Data Collection and Laboratory Analyses

Data collection and laboratory analyses shall follow methods described in Perrin (2005, 2007) and Perrin and Bennet (2006). These methods are provided below.

Replicate periphyton plates will be randomly installed at each site (i.e., 2 control sites and one test site in the diversion reach) in riffle or run flows and sampled over 35 – 46 days in August through September in 2005 and 2006. A 2 cm diameter core of the Styrofoam™ and biomass will be removed each week, and analysed for chlorophyll-a (chl-a) concentration using a fluorometer. The maximum concentration of chl-a found on a given artificial substrate sampler over the time series is considered to be the peak biomass. On the final sampling day of each series, an additional core will be removed and preserved in Lugol's solution for later taxonomic identification and enumeration in the laboratory.

Periphyton cells will be counted in the laboratory at 500x magnification after settlement in Utermohl chambers. Only cells containing cytoplasm will be enumerated. A minimum of 100 individuals of the most abundant species and a minimum of 300 cells in total will be counted. Cells of filamentous taxa will be separated from counts of unicellular taxa (Perrin 2007).

On the final day of periphyton sampling at each site, 4 replicates of benthic invertebrates will be collected with a Surber sampler (surface area of 900 cm² with a 250 µm net), using methods consistent with provincial standards (BC Ministry of Environment 1997). The sampler will be placed at a randomly selected place in the river, and substrate within the sampling frame disturbed to a depth of 10 cm for a period of 1 minute. The sampler will then be moved upstream and the process repeated. The process will be repeated at 5 random locations. Contents accumulated in the net after completing the sampling in the 5 locations will be considered to be one complete sample (i.e., the surface area of one sample will be 4,500 cm²). Four replicate samples will be collected at each of the three sites, for a total of 12 samples. Samples will be preserved in 10% formalin.

Benthic invertebrates will be enumerated in the laboratory using a set count approach: All animals >1 mm will be picked from the sample and twigs, clumps of algae and other debris will be removed. All small organisms adhering to debris will also be picked, leaving the bulk of the sample without large particulate matter. All animals picked from the large debris will be considered "macrobenthos" and will be identified and enumerated.

The remaining sample (microbenthos, organisms <1 mm) will be evenly split into 4 to 16 subsamples using a plankton splitter, depending on the number of organisms within the overall sample. A minimum of 200 individuals will be picked from one or more of those subsamples or at least one subsample will be examined in its entirety even if it contains more than 200 organisms. The total count of microbenthos in a whole sample will be extrapolated by taxa. The total sample count will be the sum of

macrobenthos and microbenthos. All benthic animals retained on a 250 µm sieve will be identified to the lowest reliable taxonomic level.

One water sample will be collected from each location at the start and the finish of the six weeks sampling program. Water samples will be analyzed for soluble reactive phosphorus (SRP), total P (TP), total dissolved P (TDP), and particulate P (PP) at a lab with detection capabilities below 1 µg/L. Water samples will also be analyzed for nitrogen components NH⁴⁺ and NO³⁻.

Physical measurements will be made on each weekly sampling day at each location, including light attenuation, measured in photosynthetically active radiation (PAR), current velocity and water depth. Water temperature will be measured continuously using a temperature logger installed at each site.

3.3.4 Task 4 Reporting

Detailed technical reports outlining field and analytical methods, results of field measurements, and data analyses and interpretation have been prepared for the 2005 and 2006 primary and secondary baseline productivity monitoring programs (Perrin and Bennett 2006; Perrin 2007). Perrin (2007) summarizes the findings from both years of the monitoring program.

3.4 Interpretation of Monitoring Program Results

Data from the baseline monitoring program will be compared with those from the post-redevelopment monitoring program. Statistical significance, may entail that post-redevelopment changes in flow have an effect on benthic community attributes. The magnitude of such effect may be determined from the data, and help refine compensation requirement estimates to achieve no net loss of aquatic productivity.

3.5 Schedule

Baseline primary productivity monitoring in the Bull River between the generating station and the first upstream barrier to quantify primary productivity and the equivalent loss in “productive capacity” for compensation works was completed in 2005 and 2006. The draft summary report has been prepared (Perrin 2007).

3.6 Budget

The total estimated budget for the monitoring program is \$82,621. A 2% annual rate of inflation (based on 2004\$) and 5% contingency has been assumed.

3.7 References

BC Hydro. 2005a. Aberfeldie Re-Development Project – Revising the Water Use Plan (WUP) Consultative Committee Meeting #1 Final Meeting Notes.

BC Hydro. 2005b. Aberfeldie Re-Development Project – Operations-Related Impacts Fish Technical Committee Meeting #3 Final Meeting Notes.

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