Consultative Committee Report

August 2006

Prepared on behalf of:

The Consultative Committee for the Alouette Project Water Use Plan Review

Alouette Project Water Use Plan Review

A Project of BC Hydro

Library and Archives Canada Cataloguing in Publication Data
Alouette Project Water Use Plan Review Consultative Committee (Canada)
Consultative committee report : Alouette Project water use plan review

"A project of BC Hydro."
ISBN 0-7726-5596-0

1. Water use - British Columbia - Alouette Lake. 2. Water use - British Columbia - Stave Lake. 3. Water use - British Columbia - Lower Mainland - Planning. 4. Water resources development - British Columbia - Alouette Lake. 5. Water resources development - British Columbia - Stave Lake. 6. Hydroelectric power plants - British Columbia - Lower Mainland. 7. Dams - Environmental aspects - British Columbia - Alouette River Watershed. I. B.C. Hydro. II. Title. III. Title: Alouette Project water use plan review.

TD227.B7A46 2006 333.91'00971133 C2006-960145-3

BC Hydro Contact:

Charlotte Bemister

Phone: 604-528-2354

Project Manager:

James Bruce

Phone: 604-528-3293

Email: James.Bruce@bchydro.com

BC Hydro Project Team and Consultative Committee Members listed in Appendix A.

This report was prepared for and by the Alouette Water Use Plan Review Consultative Committee, in accordance with the provincial government's *Water Use Plan Guidelines*.

This report expressed the interests, values and recommendations of the Committee and is a supporting document to BC Hydro's Draft Alouette Water Use Plan that will be submitted to the Comptroller of Water Rights for review under the *Water Act*.

The technical data contained within the Report was gathered solely for the purpose of developing the aforementioned recommendations and should not be relied upon other than for the purposes intended.

EXECUTIVE SUMMARY

Water use planning was introduced in 1996 as an approach to ensure that provincial water management decisions reflect changing public values and environmental priorities. A Water Use Plan is a technical document that, once reviewed by provincial and federal agencies and First Nations, and accepted by the provincial Comptroller of Water Rights, defines how water control facilities will be operated. The overall goal of water use planning is to find a balance between competing uses of water such as domestic water supply, fish and wildlife, recreation, heritage and electrical power needs that are environmentally, socially and economically acceptable to British Columbians. Water Use Plans (WUPs) have been developed for most of BC Hydro's hydroelectric facilities. The purpose of water use planning is to understand public values and develop recommendations defining a preferred operating strategy for a facility by involving all interested parties in a meaningful, flexible and inclusive multi-stakeholder consultation process.

In 1996 an Alouette Stakeholder Committee reached agreement on an operating plan for BC Hydro's Alouette facilities (McDaniels Research Ltd. 1996). This agreement formed the basis of the *Alouette Generating Station: Water Use Plan* approved and ordered by the Comptroller of Water Rights. One of the commitments within the agreement was to review the performance of the operating plan within 10 years and, if needed, suggest additional operating changes.

In May 2005, a review of the 1996 Alouette Water Use Plan was initiated and completed in April 2006; this was referred to as the Alouette Water Use Plan Review process. The consultative process followed the steps outlined in the provincial government's *Water Use Plan Guidelines* (British Columbia, 1998). This report summarizes the consultative process and records the areas of agreement and disagreement arrived at by the Alouette Water Use Plan Review Consultative Committee. It is the basis for the Draft *Alouette Water Use Plan,* which is submitted to the Comptroller of Water Rights for review and approval.

Alouette System

The Alouette Project forms part of the Alouette-Stave-Ruskin hydroelectric development. The Alouette Lake Reservoir and Stave Lake Reservoir provide the main storage for this system.

The Alouette Lake Reservoir lies in a narrow valley and extends in a northeast direction for 17 km from the dam. When the reservoir is at the normal maximum level of El. 125.5 m, the surface area is approximately 16 km^2. The total usable live storage is about 155 000 000 m^3. Below El. 110.7 m, the reservoir separates into two.

The tunnel intake to the Alouette Powerhouse is located on the east shore near the north end of the reservoir where the Alouette basin is separated from Stave Reservoir by a narrow granite ridge.

The Alouette Dam is located at the south end of the reservoir and, downstream of the dam, the South Alouette River flows through the municipalities of Maple Ridge and Pitt Meadows before discharging into the Pitt River. The Maple Ridge area has been

intensively developed with many residences built along the river; the Pitt Meadows area is predominantly agricultural (BC Hydro, 1996).

Consultative Committee Process

The Alouette Water Use Plan Review Consultative Committee was comprised of representatives from BC Hydro Katzie First Nation, provincial and federal government agencies, municipal governments, and local stakeholders, including Fraser Regional Correctional Centre (ALCO hatchery) and Alouette River Management Society (ARMS). Membership included a broad cross-section of interests and organizations and consisted of fifteen representatives and their designated alternates (for a complete listing of members and observers participating in the process refer to Appendix A). The Consultative Committee and its three technical subcommittees – *Fisheries, Recreation, and Heritage* – held a total of twelve meetings, ultimately reaching agreement[1] on a preferred operating alternative for the Alouette Project and an associated monitoring program.

Objectives and Performance Measures

The Consultative Committee initially identified eight interest areas that were considered important: financial, recreation, fish, wildlife, cultural resources, flood control, aquatic ecosystem, and operational flexibility. The Consultative Committee and its *Fisheries, Recreation, and Heritage Technical Sub-Committees* explored these issues and interests and how they may be affected by operations at the Alouette facilities, and agreed to the following five fundamental objectives and seven performance measures to be used to assess potential operational changes for the Alouette Water Use Plan Review:

Financial

Objective: Minimize economic impacts to Alouette, Stave, and Ruskin generation.

Performance Measure 1: The Value of Electricity, representing the average annual power loss relative to current operations, in dollars.

Recreation

Objectives:

Minimize adverse impacts to waterborne recreation in the South Alouette River.

Improve waterborne recreation quality and opportunities in the Alouette Lake Reservoir.

Minimize adverse impacts associated with terrestrial recreation on environmental and cultural interests in the Alouette Lake Reservoir.

[1] Representatives from Katzie First Nation conditionally supported the alternative, but wanted a firmer commitment from BC Hydro to undertake archaeological studies.

Performance Measure 2: The waterborne recreation quality and opportunities in the Alouette Lake Reservoir, as measured by the number of weighted user days the reservoir is at preferred elevations during the appropriate season.

Fish

Objectives:

Optimize salmonid abundance in the South Alouette River and Alouette Lake Reservoir.

Performance Measure 3: The effective littoral zone, a measure of potential algae and aquatic plant growth based on the intensity of photosynthetically active radiation at depth, mortality resulting from desiccation, and mortality resulting from "light starvation".

Performance Measure 4: The Kokanee out-migration release is an indicator to show whether an operating alternative has a surficial dam release to facilitate the out-migration of Kokanee.

Cultural Resources

Objectives:

Maximize the protection of cultural resources within the Alouette system from erosion, illegal artefact collection and secondary impacts from recreationalists.

Performance Measure 5: The protection of cultural resources, as measured by the number of weighted reservoir elevation days below 122.6 m.

Flood Control

Objective: Minimize flood damage to people and property.

Performance Measure 6: The risk of a high flow event, as measured by the number of free-crest spill events into the South Alouette River over the 45-year inflow dataset.

Performance Measure 7: The risk of a high flow event, as measured by the number of days each year that reservoir levels are at or above 122.6 m in the reservoir.

Operating Alternatives

The Consultative Committee considered a total of five operating alternatives during the Alouette Water Use Plan Review process. Different alternatives suggested different elevation levels for periods of the year to extend recreational use, to provide opportunities for smolt out-migration, to mitigate flood control risks and to provide the opportunity to better explore and protect cultural resources. These alternatives were based on recommendations from the technical subcommittees and the deliberations of the Consultative Committee. A summary of the main components for each alternative is provided below.

Alternative	Description	Operating Constraints
Alternative A	Reflects the operating constraints, as they currently exist, consistent with the Operating Agreement implemented in 1996. Serves as the reference base case.	Low-level outlet fully open (70–105 cfs) Min reservoir elevation of 121.25 m for recreation from Victoria Day to Labour Day Minimum normal reservoir elevation El. 116 m Open adit gate when reservoir level reaches El. 122.6 m to mitigate flood risk
Alternative B	Alternative A plus additional constraints designed to improve waterborne recreation opportunities in the reservoir.	Minimum reservoir target elevation of El. 123 m from 15 May to 30 September
Alternative C	Alternative A plus a reservoir operation that facilitates the out-migration of sockeye each year.	Keep reservoir level high in order to maintain a flow release using the spillway sluice of 3 m^3/s for 8 weeks (1 April to 30 May) Low-level outlet is closed during this operation
Alternative D	Alternative A plus constraints to balance fisheries, recreation, cultural and flood control constraints.	Reservoir at 121.8 m from 15 April to 14 June for recreation interests and in order to provide a 3 m^3/s surface release from spillway gate 15 June to 5 September – minimum reservoir elevation of El. 122.5 m 6 September to 30 September – minimum reservoir of El. 121.25 m Minimum elevation of El. 116 m for remainder of year to better allow archaeological research work to be carried out
Alternative E	Alternative D plus reduced reservoir levels in September to further flood control.	Reservoir at 121.8 m from 15 April to 14 June for recreation interests and in order to provide a 3 m^3/s surface release from spillway gate 15 June to 5 September– minimum reservoir elevation of El. 122.5 m 6 September to 15 September – minimum reservoir of El. 121.25 m Minimum elevation of El. 116 m for remainder of year to better allow archaeological research work to be carried out

Reaching Agreement on an Operating Alternative

During the final Consultative Committee meeting held on 2 March 2006, the Consultative Committee assessed the alternatives both quantitatively and qualitatively based on the performance measure values, professional opinion, and best available information. The main trade-off was between increasing the reservoir levels to provide additional recreational and fisheries benefits, while minimizing any increase in the risk of flooding.

Alternatives C and D were initially preferred by every member of the Consultative Committee except one member who had concerns about the additional number of flood risk days over current operations. As a result, Operating Alternative E was created, which reduced the higher reservoir levels by fifteen days in late September. This alternative was reviewed, discussed and agreed upon by the Consultative Committee at their final 2 March 2006 meeting.

Mandatory Substrate Maintenance Flushing Flows

Following the selection of a preferred operating alternative, another aspect of the Consultative Committee's deliberations was whether or not there should be a prescribed flushing flow (as recommended by the Fish Technical Committee and the Alouette Management Committee). The main impetus for undertaking a flushing flow was the perceived risk that substrate quality may deteriorate over the review period of the Water Use Plan, and this may in turn adversely affect fisheries and ecosystem benefits that accrued since the 1995 operating plan agreement. Aside from costs, the main trade-off with providing a prescribed flushing flow on a mandatory basis was the corresponding increase in the number of flood risk days that may occur because the reservoir would have to be managed at higher levels through parts of the flooding season. It was also recognized that the environmental risks of poorer substrate quality on fish and the ecology of the area were not well understood. Moreover, it was felt that the current opportunistic flushing flows carried out by BC Hydro in combination with tributary inflows appeared to be working well. In the end, the Consultative Committee abandoned recommending a mandatory flushing flow in favour of opportunistic flushing flows plus more detailed substrate and biological monitoring.

Expected Outcomes of the Recommendation

The expected outcomes of the final Consultative Committee recommendations are summarized in Table 1 below.

Table 1: Expected Outcomes of the Consultative Committee's Recommended Alternative

Issue Area	Expected Impacts
Financial	An average loss of $35,000 each year as a result of reduced power generation relative to current operations (as defined by the 1996 Water Use Plan) is expected.
Fish and Aquatic Ecosystem	Significant increase in the out-migration success of Kokanee smolts leaving the reservoir down the South Alouette River. Slightly higher salmonid abundance in the South Alouette River with slightly higher minimum flows (higher reservoir levels) from April to September (most notably in August). Less predation of Kokanee smolts during their out-migration down the South Alouette River. Ecosystem benefits associated with an increased spring freshet pulse flow. No other aquatic ecosystem changes are expected. Substrate quality is not expected to change relative to current operations.
Wildlife	No changes are expected for wildlife interests.
Cultural Resources	Monitoring and opportunistic reservoir draw downs are expected to increase the archaeological inventory of cultural resources in the area. However, the Consultative Committee's preferred alternative was not associated with any change in site access relative to current operations.
Flood Control	No increase in the risk of flooding events is expected relative to current operations (as defined in the 1996 Water Use Plan).
Recreation	Recreation quality and opportunities are expected to increase significantly in the reservoir relative to current operations: an increase from 49 to 88 weighted recreation days are expected on average each year. Improvements are also expected for sport fishing, improved beach access and greater boater safety. Some minor improvements are also expected for waterborne recreational opportunities in the South Alouette River in the summer.

Monitoring Program

The recommended monitoring program is directly built into the main component of the Consultative Committee's recommended Operating Alternative E. The details of each component of the monitoring program are seen in Table 2. Costs for the monitoring program are estimated at approximately $1,612,000 (or approximately $201,500/yr) over an eight-year review period.

Table 2: Details of Monitoring Program Elements

Study	Details
#1 Smolt Enumeration Study	Assesses the system's ability to sustain current levels or improve salmonid smolt production downstream of the dam, with respect to Chum, Pink, Chinook, and Coho salmon, and steelhead and cutthroat trout. This study has three components: 1. Smolt enumeration (includes assessment for potential impacts of warm water temperatures), 2. Egg to fry survival rate (an indicator of substrate quality), and 3. Kokanee residence time in the river.
#2 Kokanee Out-migration Study	Assesses: 1. Whether or not the surface release from the Alouette Dam is adequate to promote the downstream migration of Kokanee smolts out of the Alouette Lake Reservoir, 2. Whether or not a post-surface release flush following the tail end of the out migration period encourages more smolts to leave the system, and 3. Whether or not the duration of the surface release is sufficient to ensure out-migration of all smolts prepared to leave the system.
#3 Substrate Quality Study	Assesses: 1. Whether or not the results of the Toe-Pebble count procedure reflect the general composition of bed materials within the channel downstream of the Alouette Dam, 2. Whether or not the < 20% fines is threshold adequate to distinguish a state in substrate quality that would require a prescribed flushing event, 3. Whether or not an alternative methodology is required to qualify/calibrate the results of the Toe-Pebble count procedure, and 4. Whether or not a prescribed flushing flow is necessary given the current state of substrate quality.
#4 Sockeye Adult Enumeration Study	Assesses: 1. Whether or not the Alouette Lake Reservoir Kokanee smolts are successfully adapting to an anadromous existence by returning from the ocean environment to spawn in Alouette Lake Reservoir, 2. Whether or not the adult Sockeye caught during the monitor are members of the "Alouette stock" or are strays from other coastal systems, 3. Whether or not the returning adult sockeye numbers are sufficient to create a self-sustaining population given the existence of the Alouette Lake Reservoir Fertilization Program, and the type of strategy used to get the retuning adults into the Reservoir. 4. The run timing of adult sockeye returns.

Table 2: Details of Monitoring Program Elements cont'd

Study	Details
#5 Water Temperature Study	Assesses: 1. How often water temperatures are ≥ 25°C, including the duration of each event and the frequency of occurrence, 2. Whether or not the duration of observed warm water events is less than one day, thus limiting exposure to thermal stress impacts, 3. Whether or not warm temperature events are restricted to certain sections of river, indicating the inflow of cooler waters into the system (most likely ground water), 4. Whether or not the duration and frequency of warm water events is such that it would promote a shift in fish community structure and/or reduce summer survival and growth of rearing juvenile salmonids, as indicated by a change in salmonid smolt numbers, 5. Whether or not there is an operational change that can be implemented to mitigate the occurrence of warm water events, given the extent of thermal stratification in the reservoir and the location of the Low Level Outlet.
#6 Kokanee Age Structure Study	Assesses: 1. Whether or not the existing Kokanee population in the Alouette Lake Reservoir recruitment is limited, 2. Whether or not there is evidence of a recruitment constraint to productivity that can be liked to reservoir operations, 3. What the nature of the relationship, and whether or not it can guide the development of possible mitigative reservoir operations.
#7 Archaeological Impact Assessment	This study provides a survey of the drawdown area, an inventory of archaeological sites, and monitoring of impacts (erosion monitoring system) with recommendations for mitigation.
#8 Archaeological Inventory and Evaluation	Assesses: 1. Whether or not there are archaeological resources that are impacted by river flows, 2. Whether or not an operational change would potentially lessen those impacts.

Review Period

The Consultative Committee recommended that a formal review of the Alouette Water Use Plan be undertaken eight years after its implementation to coincide with the review of the Stave Water Use Plan. It is expected that the next Alouette Water Use Plan will be undertaken on a system wide basis in combination with the review of the Stave Water Use Plan, scheduled for 2014, but may be longer depending on monitoring and operational requirements.

The Consultative Committee recommended that a Monitoring Advisory Committee be created from a core group of its members. The primary mandate of the Monitoring Advisory Committee is to meet annually to review BC Hydro's compliance with the Alouette Water Use Plan and to discuss the content and implications of monitoring study results.

TABLE OF CONTENTS

LIST OF TABLES

List of FIGURES

List of APPENDICES

1 INTRODUCTION

Water use planning was introduced by the Minister of Employment and Investment[1] and the Minister of Environment, Lands and Parks[2] in 1996 as an approach to ensure that provincial water management decisions reflect changing public values and environmental priorities. The purpose of water use planning is to understand public values and to develop a preferred operating strategy through a multi-stakeholder consultative process. The product, a Water Use Plan, is a technical document that, following review by provincial and federal agencies and approval by the provincial Comptroller of Water Rights, defines how water control facilities will be operated. The process for developing a Water Use Plan is described in the provincial government's *Water Use Plan Guidelines* (British Columbia, 1998).

The Water Use Plan is intended to accommodate other water use interests through incremental changes in how existing water control facilities store and release water. While there may be opportunities to undertake physical works as a substitute for changes in flow, water use planning focuses primarily on a better use of water at facilities as they exist today. Water Use Plans are not intended to be comprehensive watershed management plans or address water management issues associated with other activities in the watershed such as forestry or mining. First Nations' rights and title issues and historic grievances arising from the initial construction of the facilities are specifically excluded from Water Use Plans, but can be considered as part of other processes (British Columbia, 2000).

In 1996 an Alouette Stakeholder Committee reached agreement on an operating plan for BC Hydro's Alouette facilities McDaniels Research Ltd. (1996). This agreement formed the basis of the "Alouette Generating Station: Water Use Plan" approved and ordered by the Comptroller of Water Rights. One of the commitments within the agreement was to review the performance of the operating plan within 10 years and, if needed, suggest additional operating changes.

In May 2005, a review of the 1996 Alouette Water Use Plan was initiated and completed in April 2006; this was referred to as the Alouette Water Use Plan Review process. It involved a review of all data collected since implementation of the September 1996 Alouette Water Use Plan, an assessment of new knowledge in the basin, including changes in resource values, and a refinement in proposed conditions for the operation of BC Hydro's Alouette Project. The consultative process followed the steps outlined in the provincial government's

[1] The Ministry of Employment and Investment responsible for electricity policy at the inception of the Water Use Plan Program is now part of the Ministry of Energy and Mines.

[2] The Ministry of Environment, Lands, and Parks was re-organized in 2001 into the Ministry of Water, Land and Air Protection and the Ministry of Sustainable Resource Management. In 2005, the Ministry was re-organized into the Ministry of Environment.

Water Use Plan Guidelines (British Columbia, 1998).[1] This report summarizes the consultative process and records the areas of agreement and disagreement arrived at by the Alouette Water Use Plan Review Consultative Committee. It is the basis for the Draft *Alouette Water Use Plan,* which is submitted to the Comptroller of Water Rights for review and approval.

This report has been structured according to the following sections with the *italicized references to steps* indicating how a given section and topic relates to the provincial government's *Water Use Plan Guidelines:*

Section		Description
2	Description of the Alouette Project	Describes the Alouette hydroelectric facility
3	Consultative Process	Describes the Alouette Water Use Plan Review consultative process, including process initiation, Consultative Committee participants and Committee structure *(Steps 1 and 3)*.
4	Information Collected	Describes the studies that the Committee had undertaken during the water use planning process *(Step 5)*.
5	Issues, Objectives and Performance Measures	Describes the issues, objectives and performance measures *(Steps 2 and 4)*
6	Operating Alternatives	Describes operating alternatives considered by The Committee and the modeling process *(Step 6)*.
7	Trade-off Analysis	Describes the trade-off analysis process and the package of recommendations developed by the Committee *(Step 7)*.
8	Monitoring Program	Describes the Alouette Water Use Plan Review monitoring program, and the criteria used to evaluate the proposed studies for eligibility under the Water Use Plan Program.
9	Review Period	Describes the timing and process for future review of the Alouette Water Use Plan.
10	Implementation of Recommendations	Describes the timing and process for future review of the Alouette Water Use Plan
11	Summary of Recommendations and Outcomes	Describes the Committee's recommendations and expected outcomes of the Alouette Water Use Plan Review.

[1] http://www.env.gov.bc.ca/wsd/plan_protect_sustain/water_use_planning/

2 DESCRIPTION OF THE ALOUETTE PROJECT

2.1 Background

The Alouette Dam and associated facilities form part of the Alouette-Stave-Ruskin hydroelectric development, as illustrated in Figure 2-1. Alouette Lake Reservoir and Stave Reservoir provide the main storage for this system.

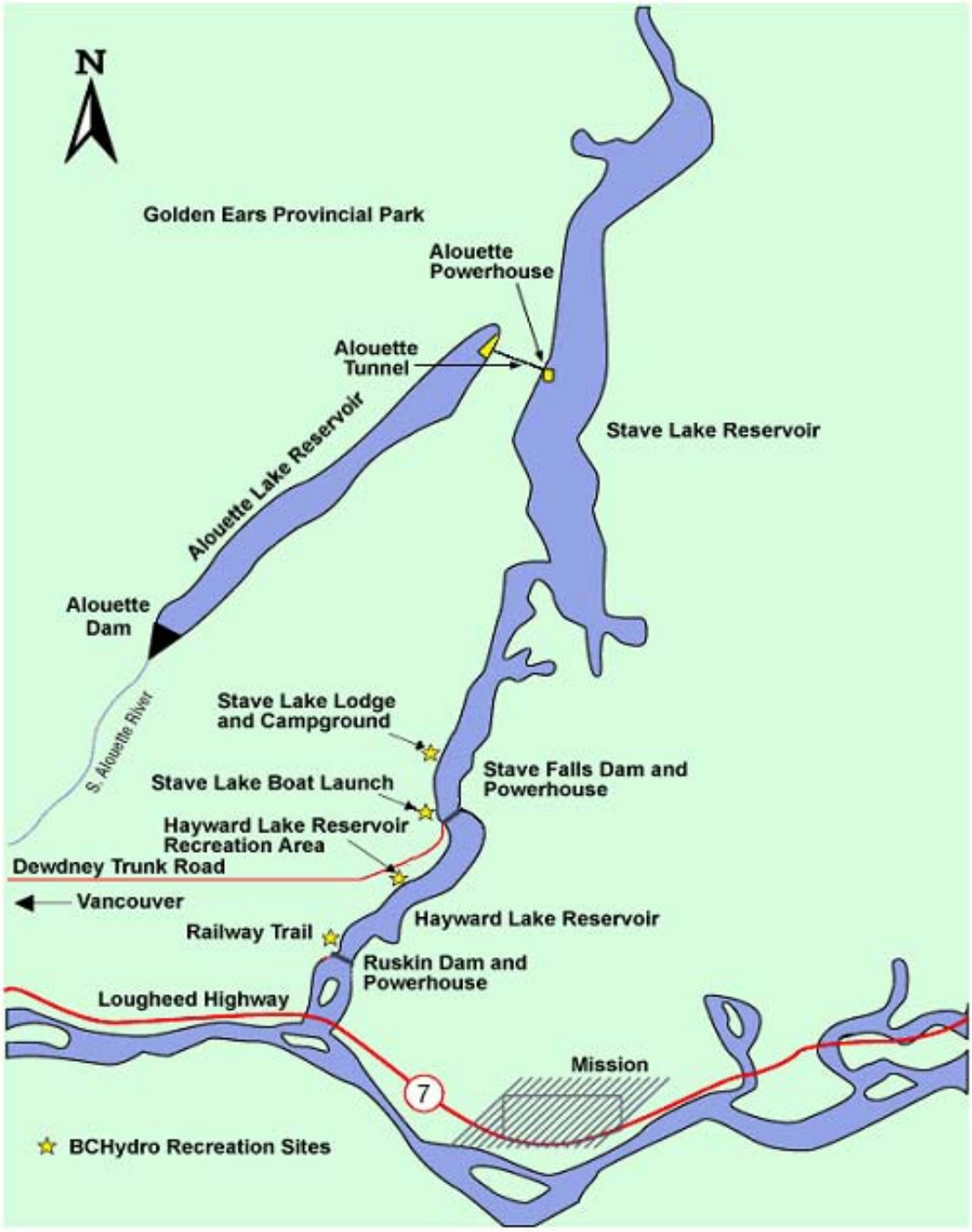


Figure 2-1: Diagram of Alouette and Stave Lake Reservoir

The Alouette Lake Reservoir lies in a narrow valley and extends in a northeast direction for 17 km from the dam. When the reservoir is at the normal maximum level of El. 125.5 m, the surface area is approximately 16 km^2. The total usable live storage is about 155 000 000 m^3. Below El. 110.7 m, the reservoir separates into two.

The tunnel intake to the Alouette Powerhouse is located on the east shore near the north end of the reservoir where the Alouette basin is separated from Stave Reservoir by a narrow granite ridge.

The Alouette Dam is located at the south end of the reservoir and, downstream of the dam, the South Alouette River flows through the municipalities of Maple Ridge and Pitt Meadows before discharging into the Pitt River. The Maple Ridge area has been intensively developed with many residences built along the river; the Pitt Meadows area is predominantly agricultural (BC Hydro, 2006a).

The Alouette generating facility is part of the Alouette-Stave Falls-Ruskin generating complex that includes four dams, a 1090 m long diversion tunnel and three powerhouses. Water can be used from the Alouette Lake Reservoir three times as it passes through each powerhouse. The generating complex as a whole can produce up to 204 MW and forms part of BC Hydro's integrated generation system as described in BC Hydro's publication, *Making the Connection* (2000).

The Alouette-Stave Falls-Ruskin generating complex is located close to the major load centre in the Lower Mainland. Its location is important in the provision of consistent voltage in the transmission network, and for system security in the event of transmission or generation problems elsewhere in the system. The Alouette-Stave Falls-Ruskin generating complex contributes about two percent of BC Hydro's hydroelectric generation. (UMA, 1996a)

2.2 Existing works

2.2.1 Earthfill Dam, Spillway and Low Level Outlet

The earthfill dam, rebuilt in 1983, is located at the natural outlet of the original Alouette Lake and is immediately downstream from a dam previously constructed at this site in the mid 1920s. Parts of the old embankment were incorporated into the present dam.

The crest of the dam was constructed to El. 130.5 m at the abutments, with a camber to El. 130.9 m in the centre. The Probable Maximum Flood level for the reservoir is El. 128.9 m.

The east end of the embankment abuts the left bank of the valley. At the west end, the embankment abuts the concrete gravity structure, which forms a part of the left training wall of the spillway.

Figure 2-2: Photo of Alouette Dam Spillway

The spillway, rebuilt in 1992, is located at the west end of the earth fill dam and cuts through a terrace on the right bank of the valley (Figure 2-2.). The main features are an approach channel, a single gate sluiceway, a free crest weir, a transition structure, a discharge channel and a stilling basin. The spillway is equipped with a single 6.25 m wide by 4.15 m high vertical lift gate, which has a maximum discharge capacity of 78 m^3/s (2765 cfs). The sill elevation of this gate is El. 121.35 m. The overflow weir, which is at El. 125.5 m, consists of a headworks key, an overflow crest and a downstream block. The spillway is capable of discharging approximately 1190 m^3/s (42 000 cfs) at a reservoir level of El. 128.9 m.

A Low Level Outlet (LLO) was constructed through the original dam in 1926 to permit releases for non-power uses. The outlet consists of an intake structure, a pipe conduit and an outfall structure. A 0.8 m diameter steel pipe insert was installed in the pipe conduit during the 1983 repair work. The flow is regulated by a vertical slide operating gate in the intake structure, which is manually operated from a platform on top of a steel tower. A guard gate was installed in 1993 upstream of the operating gate. The operating gate regulates the flow through the low level outlet. The LLO can discharge a maximum of 105 cfs. The sill elevation of the low level outlet is El. 113.1 m; however the minimum

reservoir level to avoid turbid discharge is El. 116 m (BC Hydro, 2002). Please see Figure 2-3: Schematic of Alouette System Works for details.

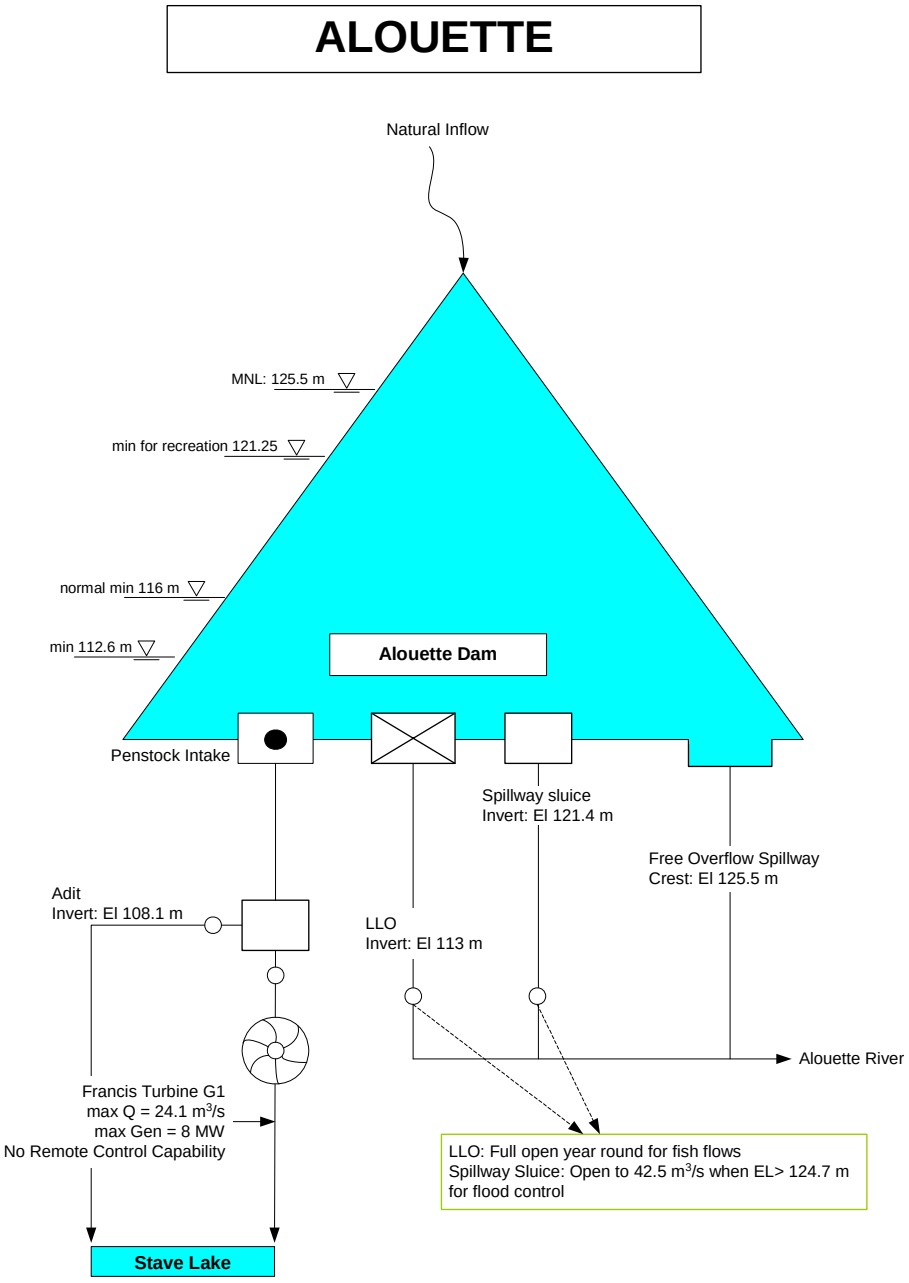


Figure 2-3: Schematic of Alouette System Works

2.2.2 Headworks, Tunnel, Adit and Powerhouse

The headworks are located at the north end of Alouette Lake Reservoir. The main structural features of the headworks are a portal structure, an entrance tunnel, a vertical shaft and a tower, which houses the gate hoisting mechanism. The entrance tunnel has a sill elevation of El. 105.8 m; however, the reservoir must be maintained above El. 112.6 m to avoid vortices. The tunnel is 1067 m long and

conveys water from Alouette Lake Reservoir to the Alouette powerhouse on Stave Reservoir. The tunnel is D-shaped and approximately 4.6 m in diameter. A 26 m high surge chamber is located at the downstream end of the tunnel and immediately upstream from the 72 m long, 3.7 m diameter penstock that conducts the water into a surface powerhouse with a single 8 MW unit. An adit gate, also located at the surge chamber, can be used to augment turbine discharge from Alouette Lake Reservoir into Stave Reservoir.

Water from the tunnel is discharged into Stave Reservoir through the turbine and/or the adit. The unit discharges approximately 23.8 m^3/s (840 cfs) at full load. With the adit gate fully open and the unit at full load the total discharge is about 56.6 m^3/s (2000 cfs) depending upon reservoir elevation (BC Hydro, 2002).

2.3 Natural Inflows

The Alouette Lake Reservoir is classified as a "coastal reservoir" where the majority of inflow results from seasonal storms and spring snowmelt. The runoff regime of the Alouette watershed is characterized by moderate flows in the spring (April to June) resulting from snow melt, a recession period during the drier summer months, followed by periods of very high flow from late October through February as a result of fall/winter storm events (BC Hydro, 2006).

Figure 2-4 illustrates the historical daily inflows of the Alouette Lake Reservoir, based on BC Hydro data from 1960 to 2004.

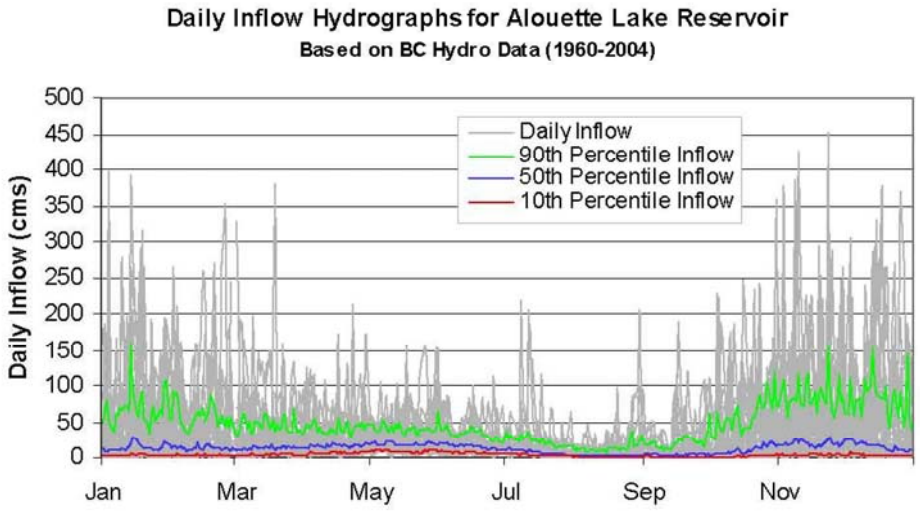


Figure 2-4: Daily Historical Hydrographs for Alouette Lake Reservoir 1960–2004

For further details on the hydrology of the Alouette system, please see Appendix B: BC Hydro Inter-office Memo re: Alouette Water Use Plan Review Hydrology of Alouette Lake Basin.

2.4 Current Operations

Under the September 1996 Alouette Water Use Plan, BC Hydro is required to fully open the Low Level Outlet allowing up to a 3 m^3/s (105 cfs) water release into the South Alouette River at maximum reservoir elevation. Inflows in excess of the Low Level Outlet release is stored in Alouette Lake reservoir, but is diverted to a powerhouse on the northwest shore of Stave Lake Reservoir for power generation. The Alouette generating station is normally operated as a base load facility running at relatively constant output for days or weeks at a time. The unit generates approximately 5 MW with the adit gate open and 8 MW with the adit gate closed. The unit discharges 23.8 m^3/s (840 ft^3/s) at full load and with the adit gate closed. With the adit gate fully open and the unit at full load, the total discharge is approximately 56.6 m^3/s (2000 ft^3/s), depending on reservoir elevation.

Alouette Lake reservoir is subject to high inflows, particularly from October through February. During this period, inflows that cannot be used by the Alouette powerhouse are stored in Alouette Lake reservoir until reservoir elevation reaches 122.6 m, where the adit gate is opened to increase total diversion into Stave Lake Reservoir to 56.6 m^3/s. Although this results in reduced power generation at the Alouette powerhouse, the discharge to the Stave Falls and Ruskin facilities increases the potential for generation at these facilities rather than spilling at Alouette dam.

Inflows that exceed the full capacity of the diversion tunnel are stored until reservoir elevation reaches 124.7 m, after which the excess water is released downstream of the Alouette Dam into South Alouette River using a prescribed spilling protocol (BC Hydro, 2002).

2.4.1 Spillway Gate Operation for Flood Control

Spill through the spillway gate into the South Alouette River will be initiated whenever (any time during the year) the reservoir level reaches elevation El. 124.7 m. The spill through the gate will be set at 42.5 m^3/s (1500 ft^3/s) until the reservoir level falls below elevation El. 124.7 m or until the water level reaches the level of the free crest weir (125.5 m).

As the reservoir level increases above 125.5 m, the spillway gate flow will be ramped down to maintain a total discharge of 42.5 m^3/s (1500 ft^3/s) from the spillway until the spillway gate is closed. After the spillway gate is closed, inflows will be passed over the free crest weir. Closing the spillway gate with increasing free crest weir flows reduces the peak flood flow from the dam.

As the reservoir level falls, the spillway gate will be re-opened to maintain a total discharge of 42.5 m^3/s (1500 ft^3/s) from the spillway until the reservoir level falls below El. 124.7 m (BC Hydro, 2002).

For a list of operating constraints, please see Section 4 Information Gathering/ Data Review.

3 CONSULTATIVE PROCESS

3.1 Introduction

The Alouette Water Use Plan Review consultative process followed Steps 3 to 8 of the provincial government's *Water Use Plan Guidelines* (British Columbia, 1998). These steps provide the framework for a structured approach to decision-making.

This section describes the Alouette Water Use Plan Review consultative process including process initiation, Consultative Committee participants, and Committee structure.

Table summarizes the steps in the provincial government's *Water Use Plan Guidelines.*

Table 3-1: Steps in the Water Use Plan Guidelines

Step	Description
1	Initiate water use planning process
2	Scope water use issues and interests
3	Determine consultative process
4	Confirm issues and interests of specific water use objectives
5	Gather additional information
6	Create operating alternatives for regulating water use to meet different interests
7	Assess trade-offs between operating alternatives
8	Determine and document areas of consensus and disagreement
9	Prepare a draft Water Use Plan and submit for regulatory review
10	Review the draft Water Use Plan and issue a provincial decision
11	Authorize Water Use Plan and issue federal decision
12	Monitor compliance with the authorized Water Use Plan
13	Review the plan on a periodic and ongoing basis

3.2 Initiation and Issues Scoping

As part of initiating the Alouette water use planning review process, BC Hydro held a preliminary key stakeholder information meeting on 11 October 2005 and followed this session with an information advertisement in the *Maple Ridge Pitt Meadows Times* and the *Maple Ridge News* to provide details about the review process to the public. Please see Appendix C for details.

The intent of the review process was to review the existing operating regime established and implemented according to the original 1996 water use planning process and monitoring program to determine if changes to the operating regime were necessary and if there were any new or outstanding issues that needed to be addressed.

Key interests identified included:

- Flood Management
- Cultural Resources and Heritage

- Fish
- Power Generation
- Recreation (in the Reservoir and the River)
- Wildlife

3.3 Consultative Committee Structure and Process

The Consultative Committee for this Alouette Water Use Plan Review process was formed from members of the Alouette Management Committee with additional representatives to ensure all key interests were represented. The Alouette Management Committee was formed in 1996 to oversee the monitoring program for the Alouette water use plan.

Observers at Consultative Committee meetings were also permitted. Observers attended on a drop-in basis and provided input, but could not participate in decision-making.

The Committee initially was comprised of 15 members. Over the course of the Alouette water use planning review process, some members opted to change their status to observer status or others were reassigned other duties. Those who moved to observer status were comfortable that other Committee members represented their interests. There were 12 Committee members who actively completed the water use planning review process (refer to Appendix A: Consultative Committee, Observers, Project Team and Subcommittees).

In November 2005, the Consultative Committee developed and adopted a Terms of Reference (refer to Appendix D: Consultative Committee Terms of Reference).

In addition to the Consultative Committee, participants formed several technical subcommittees to focus on specific issues and to provide technical advice to the Committee. These subcommittees included:

- *Fish Technical Subcommittee* addressed fish/fish habitat and wildlife issues in the Alouette Lake Reservoir and the South Alouette River.
- *Heritage Technical Subcommittee* addressed traditional use and archaeological issues at the Alouette Lake Reservoir and the South Alouette River.
- *Recreation Technical Subcommittee* addressed recreation concerns, including swimming, sport fishing and boating, in the Alouette Lake Reservoir and the South Alouette River.

These technical subcommittees reviewed identified issues and objectives in order to make recommendations for how they should best be dealt with during the Water Use Plan Review process. The subcommittees were also active in developing performance measures for use by the Consultative Committee. In some cases, the committees had time to highlight key data gaps associated with some of the issues and discuss what type of research would need to be carried out during the review period of the Water Use Plan.

The Consultative Committee and the technical subcommittees met between October 2005 and April 2006 to complete the Alouette Water Use Plan Review process. In January 2006, Consultative Committee members indicated their level of support for four operating alternatives modelled by BC Hydro. At the final Consultative Committee meeting in March 2006, members indicated their level of support for a new alternative created subsequent to the January 2006 Consultative Committee meeting.

The Alouette Water Use Plan Review consultative process included one public meeting, four Consultative Committee meetings, four *Fish Technical Subcommittee* meetings, one *Recreation Technical Subcommittee* meeting, and three *Heritage Technical Subcommittee* meetings (refer to Appendix E: Consultative Committee Schedule of Meetings and Activities). The subcommittees also held numerous conference calls and communicated by email or royal mail.

Meeting notes were taken during every public meeting and recorded the main discussions and key decisions made (refer to Appendix F: Documents Generated by the Alouette Water Use Planning Review Process for a list of documents).

4 INFORMATION GATHERING / DATA REVIEW

Step 5 in the Water Use Plan Guidelines is data gathering, as outlined above in Table 3-1. Since this process was a review of an existing Water Use Plan, rather than a new plan, no funding was allocated for additional studies to gather data. The focus therefore was to review the information and studies collected since the 1996 Water Use Plan. This information informed the Consultative Committee in the early stages of the review on prevailing water issues and provided the foundation for scoping out interests (Step 2 in the Water Use Plan Guidelines).

The following are the areas of monitoring reported out to the Consultative Committee at the first Consultative Committee meeting on 20 October 2005.

Hydrology (since 1996 Implementation of Water Use Plan)

The inflows in the last 10 years have not changed substantively from the previous years of record.

A mix of wet and average inflow has occurred in the years since the 1996 Water Use Plan implementation.

There has yet to be an extremely low inflow year since the 1996 Water Use Plan implementation.

There was a challenge with providing the prescribed 3-day flushing flows while maintaining the operation that opens the adit gate when reservoir levels exceed 122.6 m (for flood control). The reservoir elevation required to provide flushing flows greater 32 m^3/s exceed the 122.6 m threshold for adit gate operation. This forces the flushing flow operation to be opportunistic as it requires reservoir inflows to be high enough to overcome the adit gate operation.

Substrate Study

The number and magnitudes for the desired flushing flows were achieved over the review period of the past operating agreement, but not sequenced as originally conceived. The flushing flows appeared to meet the desired physical objectives for the substrate. The flushing flows in combination with the increased minimum flows provided significant ecological improvements, with more changes noticed in the upper reaches. As a result, the amount of fine sediments (sand) in the river approximates that of an undisturbed river (Higgins 2005).

There are additional impacts and uncertainties associated with urban development and how it is adversely affecting the mid and lower reaches. There are benefits to validate and quantify the results from the substrate monitoring *(future monitoring)*. There is some monitoring for Total Suspended Solids (Silver Valley) but in general there is little or no monitoring for how much sediment is being deposited in the system, as a result of new developments. There was a lot of support for continued operation and effectiveness of the Mud Creek settling pond at reducing the amount of fines getting into the river.

Smolt Enumeration Study (1998–2005)

Background

The goal of the study was to determine annual out-migration numbers of salmon and trout fry and smolts to determine the effect of increased flow releases from the Alouette Dam (Cope 2005).

Methodology

The study summarized eight consecutive years of data (1998–2005) from two incline plane traps and two rotary screw traps. A mark-recapture method was used to estimate: the daily out-migration of fry and the total out-migration of smolts.

Chum Fry Results

The study found that excellent incubation conditions resulted in high egg-to-fry survival. Estimated spawning escapements were typically well in excess of 100 000 fish. On average fry production has doubled.

Pink Fry Results

Pink Salmon were previously considered extinct. The study found that in 2003, spawning escapement was estimated to be 20 146 fish.

Chinook Fry Results

Chinook were previously considered extinct. Following the 1996 flow increase, chinook strays were observed in the system for the first time. Efforts to re-colonize Chinook salmon to the South Alouette River given the new flow regime appear to be successful as numbers increased steadily since 1999. A low 2005 catch was considered to be an artefact of the early backwatering and project termination, and hence not indicative of the years' smolt output.

Coho Smolts

The study found that the 2005 catch and estimate were low due to the earlier than normal backwatering of the trap location and trap efficiencies of close to zero when Coho smolts were still emigrating. The 2005 estimates were therefore considered compromised.

The study found that the eight-year average (1998–2005) for Coho smolts is 15 199 smolts and has been relatively consistent through time. Coho smolts do not appear to have responded to increased flow release, and the study therefore concluded that the South Alouette River is at or near capacity given the present nutrient and habitat conditions.

Steelhead Smolts

The study found that Steelhead smolts do not appear to have responded to flow releases with increased production and have averaged 2780 smolts per year over the eight year monitoring period. Because population numbers have been relatively steady through time, the study concluded that the South Alouette River is at or near capacity given the present nutrient and habitat conditions.

Discussion

A strong case can be made that the existing flow release has resulted in the restoration of the Chum and Pink salmon populations. Chum and Pink escapements are the largest on record (since 1947), with Chum salmon escapement at greater than 100 000 fish, and Pink salmon escapement at greater than 20 000 fish. Chinook salmon have also re-colonized the South Alouette and are successfully spawning.

The South Alouette River appears to provide excellent spawning and incubation habitat, with above average egg-to-fry survival rates. Large escapements are reworking and maintaining spawning gravel quality. An overall positive ecosystem response seems apparent. Large escapements of salmon are restoring nutrients to the riverine food web. The study found increased observations of higher-level predators and riparian dependent wildlife. Coho and Steelhead salmon smolts are maintaining annual production in the 16 000 and 3000 smolts range respectively. The consistency of results suggests the system is at capacity at current conditions in the 2 to 8 m^3/s range.

Enhancement Initiatives

There was a report and presentation on the main enhancement initiatives that have occurred over the past ten years, excluding ALCO Hatchery operations, which may have had an influence on the objectives of the past Water Use Plan (Davies 2006). The key outcomes are outlined in Table 4.1.

Table 4-1: Overview of Alouette Habitat Restoration Projects, 1996–2005

Project	Year	Type	Proponent/Agent[1]	Habitat created
Beaver Pond Project	1994-1996, 1999	Access off-channel pond; LWD added in 1999	DFO-HEB / ARMS	2700 m^2 pond; access to 5600 m^2 existing pond
Latimer Channel	1996	Intake and side channel	DFO-HEB	3000 m^2
Alouette LWD	1997 - 1998	Instream LWD installation	ARMS / NFSAP	3440 m^2
Clayton Channel	1999	Flow diversion to side channel	DFO-HEB	500 m^2
Spawning Gravel Placement	1999	Gravel replacement in mainstem	ARMS	460 tons of spawning gravel added
Oxbow Project	1999	Culvert installation	ARMS	600 m^2 pond made accessible
T10-T11	2000	Fishway access to tributary	DFO-HEB	2000 m^2 made accessible

Table 4-1: Overview of Alouette Habitat Restoration Projects, 1996–2005 cont'd

Project	Year	Type	Proponent/Agent[1]	Habitat created
Riparian Restoration	2001	Riparian planting	NFSAP	34 000 m^2 of streambank planted
Oxbow Project	2003	Off-channel pond	NFSAP / DFO-HEB	1500 m^2 off channel pond
Hennipen Fishway	2003	Fishway access to tributary	NFSAP / DFO-HEB	Improved access to 3.0 km of stream habitat
Shallow Rock Weirs	2003	Habitat complexing	NFSAP	18 rock weirs installed or 250 m^2

[1] DFO-HEB: Department of Fisheries and Oceans - Habitat Enhancement Branch
ARMS: Alouette River Management Society
NFSAP: North Fraser Salmon Assistance Project

5 ISSUES, OBJECTIVES AND PERFORMANCE MEASURES

5.1 Introduction

In Step 4 of the provincial government's *Water Use Plan Guidelines*, the Consultative Committee stated specific objectives for the desired outcomes in dealing with Alouette water use planning review-identified issues. In defining the objectives, the participants articulated what they sought to achieve through incremental changes in BC Hydro operations (e.g., maximize fish abundance and diversity). For each objective, the Committee attempted to define one or more performance measures to quantify how the objective would be measured (e.g., square metres of fish habitat). However, some objectives did not have any performance measures associated with them if an operational change would not result in a significant (i.e., measurable) difference. The Committee used the performance measures to compare the benefits and trade-offs between different operating alternatives for the Alouette facility.

This section provides a summary of the issues, objectives, and performance measures developed by the Consultative Committee. The presentation order of issues does not imply any priority or relative importance among the issues.

5.2 Issues

In the Alouette water use planning review process, the term "issue" was used to express any problem, need or desire expressed by the Consultative Committee with respect to the way their interests are affected by Alouette facility operations. The preliminary scoped issues may or may not be within the scope of the Alouette Water Use Planning Review process.

As per the provincial government's *Water Use Plan Guidelines*, issues are considered within the scope of the Alouette Water Use Plan if:

- A causal relationship can be drawn between ongoing operational water management decisions and a specific impact(s) on stated values.
- Impacts have the potential to differ under operating alternative scenarios.

Not all the issues raised by the Consultative Committee were within the scope of the Alouette Water Use Plan Review. However, in some cases, provisions were made outside the water use planning review process to address these issues through other programs or initiatives.

5.3 Objectives

In the Alouette water use planning review process, issues were probed to reveal implicit Consultative Committee member objectives. For example, by expressing an interest for increased lower South Alouette River fish spawning habitat, a Committee member's implicit objective is to increase fish populations in the lower South Alouette River.

An "ends" or "fundamental" objective is a statement of what is ultimately important to Consultative Committee members. It is devoid of consideration of how it might be attained, or whether it is measurable. Because an ends objective is not prescriptive, it creates opportunities for creativity and compromise. For example, the ends objective for fish is to "maximize fish abundance and diversity." A wide range of activities could further this objective.

A "means" or "sub" objective is a statement that summarizes the considerations that need to be addressed to attain an ends objective. Means objectives are associated with a performance measure for determining the impact of an operating alternative on a sub-objective.

Example sub-objectives for Alouette Lake Reservoir fish include:

- Maximize littoral productivity.
- Maximize pelagic productivity.
- Minimize fish stranding risk.

The extent to which these sub-objectives are satisfied is indicative of the extent to which the ends objective, "maximize fish abundance and diversity" is satisfied.

During the Water Use Plan Review, the Consultative Committee developed and agreed to a set of objectives according to the following categories:

- Financial (Power Generation)
- Recreation
- Fish
- Wildlife
- Aquatic Ecosystem
- Cultural Resources
- Flood control
- Operational Flexibility

5.4 Performance Measures

Performance measures are used to indicate impacts of different operating alternatives on objectives. The following technical subcommittees developed performance measures:

- *Fish Technical Subcommittee*
- *Heritage Technical Subcommittee*
- *Recreation Technical Subcommittee*

When developing a performance measure, the following considerations were taken into account:

- Reliability of the measure (are the results understandable?).
- Sensitivity of the measure (is there a difference between alternatives?).
- Assumptions of the measure (is there adequate information to develop the measure?).

The Consultative Committee developed a total of seven performance measures and these are summarized below in Table 5-1. Refer to Appendix G: Performance Measure Information Sheets for specific details on how the performance measures were calculated.

Table 5-1: Performance Measures Used to Assess Operating Alternatives for the Alouette System

Performance Measure	Unit	Goal	Description
Free crest spill event	#	Decrease	This Performance Measure characterizes how each alternative achieves flood control. It calculates how many times over the 45-year data set (the model) that high inflow events cause unregulated flows over the free crest spillway (i.e., above the capacity of the sluice gate = 42.5 m^3/s). The greater the number, the greater the flood potential for a particular alternative.
Flood risk days	Average # of days / year	Decrease	Similar to the Free Crest Spill Event Performance Measure, the Flood Risk Days Performance Measure provides an indication about how well an alternative is at minimizing flooding risk. It calculates the average number of days each year (between September and March) that reservoir levels are at or above El. 122.6 m (which is when the Adit Gate gets opened to pre-spill). The higher the number, the greater the flood risk for a particular alternative.
Effective littoral zone productivity	# of hectares (shoreline habitat)	Increase	Effective Littoral Zone provides an indication of algae and plant growth (productivity) in the reservoir. It is calculated as a single value that captures the cumulative effects of operations on the productive potential of the littoral zone across all the years of simulation. It is reported in units of hectares (ha) of shoreline habitat that have at least 20% of maximum growth potential defined by the combined effects of desiccation, PAR and UV light (known to inhibit growth in algae). The more stable the reservoir level is through the spring/summer growing season (i.e., higher the Effective Littoral Zone Performance Measure area), the greater the benefits for fish and wildlife for a particular alternative.
Value of electricity	$ - Average Annual power loss (relative to Alternative A)	Decrease	VOE provides an indication of the annual average generating losses (on the Alouette/Stave systems) for each alternative relative to the base case (Alternative A – current operations). It is calculated through a standardized methodology developed by Water Use Plans; it takes into account seasonal and daily variability according to the demand for electricity. The higher the number, the greater the financial impacts for a given alternative.

Table 5-1: Performance Measures Used to Assess Operating Alternatives for the Alouette System cont'd

Performance Measure	Unit	Goal	Description
Weighted recreation days	Average # of weighted days / year	Increase	This Performance Measure provides an indication for how well an alternative may be benefiting waterborne recreation users in the reservoir. It is calculated by applying a weighted factor for each day depending on the reservoir level and then summing up all the days during the recreation season. The resulting value is then averaged over the 45-year data set. The higher the value, the more recreation benefits there will be for a particular alternative.
Weighted site access days	Average # of weighted days / year	Increase	This Performance Measure provides an indication for how long the reservoir will have lower levels to carryout archaeological fieldwork. It is calculated by applying a weighted factor for each day that the reservoir is below El. 122.6 m (through most of the fall and winter), the values are then summed up for each year and averaged over the dataset. The higher the value, the greater access there should be for doing inventory work to assess the cultural resources for a particular alternative.
Kokanee Out-migration Release	0 = No 1 = Yes	Increase	This Performance Measure is an indicator to show whether an operating alternative has a surficial dam release to facilitate the out-migration of Kokanee. Each operating alternative will therefore be marked with either having the operation built in (a 3 – 6 m^3/s crest gate flow from 1 April to 30 May) or not.

5.5 Financial (Power Generation)

5.5.1 Background

The Alouette system consists of a dam at the south end of Alouette Lake, and a tunnel from the lake to an 8 MW powerhouse which discharges into Stave Lake. The Stave Falls facility consists of a concrete dam and a 52.5 MW powerhouse at the outlet of Stave Lake (UMA, 1996a).

5.5.2 Issues

The Water Use Plan implemented in 1996 sets the minimum reservoir elevation at El. 114 m. In practice, BC Hydro effectively operates the Alouette Lake Reservoir at a minimum target elevation of El. 116 m. One Consultative Committee member requested that the minimum operating level of the reservoir be permanently changed from El. 114 m to El. 116 m.

BC Hydro stated that they would be unwilling to give up this licensed right, and noted that the 2 m in the minimum elevation would effectively be like lost fuel, if it was needed. Therefore the Consultative Committee decided to maintain the minimum level of El. 116 m, rather than alter the licensed level.

The Consultative Committee identified no other issues with respect to power generation.

5.5.3 Objectives and Sub-objectives

The Consultative Committee's objective for power generation was to minimize impacts to power generation.

Table 5-2 summarizes the Power Generation Objective set by the Consultative Committee.

Table 5-2: Power Generation Objectives set by the Consultative Committee

	Objective
Fundamental Objective	**Minimize economic impacts to Alouette, Stave and Ruskin generation.**
Sub-Objectives	• Avoid cost increases for provincial electrical supply • Avoid other financial costs • Avoid other environmental impacts of replacement generation

5.5.4 Performance Measures

The performance measure used was the Value of Electricity (VOE). The VOE is calculated in dollars attributed to average annual power loss relative to current operations (Operating Alternative A).

The Value of Electricity provides an indication of the annual average generating losses on the Alouette/Stave systems for each alternative relative to the base case represented by Alternative A. It is calculated through a standardized methodology developed by Water Use Plans; it takes into account seasonal and daily variability according to the demand for electricity. The higher the number, the greater the financial impacts for a given alternative.

Table 5-3 summarizes the Alouette Power Generation performance measure used by the Consultative Committee to evaluate operating alternatives for the Alouette system.

Table 5-3: Alouette Power Generation Performance Measure

Performance Measure	**Unit of Measure**	**Description**
Value of Electricity	Dollars ($)	Value of Electricity represents the average annual power loss relative to current operations (Operating Alternative A).

For more information, please see Appendix G for the Performance Measures Information Sheets.

5.6 Recreation

The *Recreation Technical Sub-Committee* was tasked with reviewing recreation concerns, recommending objectives and developing a performance measure for the Consultative Committee's consideration. Initial scoping discussions were held with Committee members via telephone surveys conducted in October and

November 2005.[1] The Committee met as a whole on 1 December 2005. The Committee screened and summarized key issues to be the focus of any recommended operating changes.

5.6.1 Recreation – Alouette Lake Reservoir

5.6.1.1 Background

Alouette Lake Reservoir and Golden Ears Provincial Park is a significant resource providing residents of British Columbia with an opportunity to enjoy many recreational activities within the natural beauty of a park setting. As one of the most visited parks in the province, Golden Ears Park provides the opportunity for boating, fishing, swimming, wind surfing, camping, picnicking, hiking, horseback riding and wilderness camping.

The popularity of the park and its proximity to population centres of the Lower Mainland, coupled with increasing lower mainland population and growth in attendance illustrate the significance of the park and the potential for future demand. BC Hydro works in partnership with others to improve the recreational qualities of the park. BC Hydro works with BC Parks to promote boater safety by removing stumps and deploying navigational aids, and employs Alouette River Correctional Centre inmates to assist in debris removal. The Alouette River Corrections Office, the Ministry of Environment and the Fraser Valley Trout Hatchery have an ongoing stocking program of the lake (UMA, 1996b).

5.6.1.2 Issues

Current reservoir levels provide good opportunities for water-borne recreation interests in and around Alouette Lake Reservoir on most years. The reservoir is typically operated at a minimum of El. 121.25 m during the prime summer recreation season, and over the past 9 years the reservoir level has averaged approximately El. 122 m during this period. However, higher and more consistent reservoir levels during the shoulder seasons as well as the peak summertime season would provide considerable benefits for waterborne recreation interests around the park. This issue became a principal interest for the Consultative Committee during their deliberations.

Table 5-4 summarizes the main Alouette Lake Reservoir Recreation issues identified by the Recreation Technical Sub-Committee and how each issue was addressed through the Alouette Water Use Plan review process.

[1] Consultative Committee members Tom Blackbird, Jim Sheehan, and Gerry Miller were all interviewed. Ralph Kivi (Superintendent of Sewerworks, District of Maple Ridge).

Table 5-4: Alouette Lake Reservoir Recreation Issues

Issue	Description and Action
Aesthetics	Aesthetic impacts along the foreshore impact enjoyment of campers, hikers, boater and swimmers when level is below 119.5 m. It was noted that higher reservoir levels would improve aesthetic issues
Safety	Snags/stumps are exposed when the reservoir level is below 119.5 m, creating navigational hazards for boaters.
Access and Use of Facilities	Low reservoir levels (below 121.25 m) allow ATVs and motorcycles more opportunities for access up the eastside of the reservoir and around the forebay area of the dam (behind the security fence). Low levels also adversely impacts facility users (boat launch, boat /canoe rentals, and floating swimming platforms).
Area of Usable Beach	Low levels reduce the "wetted beach", significantly impacting enjoyment of campers, hikers, boaters and swimmers.
Area of Reservoir	Low levels (below 121.25 m) diminish waterborne recreational opportunities, as Gold Creek fan narrows the reservoir and pushes users to the eastside. This also limits the opportunities to use and access summertime camping sites around the reservoir.
Erosion	There were concerns about beach erosion when reservoir levels were near or at full pool (approximately 125.5 m). It was also observed that wake board boats are associated with larger waves and erosion.
Trespassing, Vandalism and Theft	ATV and motorcycle traffic impacts were a concern for wildlife and riparian vegetation in the drawdown zone when levels were below 119.5 m. This activity has the potential to negatively impact cultural resources that may be found below 125.5 m. The potential exists for vandalism of BC Parks' infrastructure, as a 6" outflow pipe becomes exposed at levels less than 122 m. Concerns arise about boat theft at low levels. Fires and garbage associated with unregulated camping activities become an issue when low reservoir levels create the opportunity for large beach/camping areas.

5.6.2 Recreation – South Alouette River

5.6.2.1 Background

The South Alouette River is located immediately downstream of Alouette Lake Reservoir. It provides recreational opportunities for the community and regional users. The system consists of a series of municipal parks, non-municipal sites of interest, and instream activities along the river as it meanders through the rural and urban areas of Maple Ridge and Pitt Meadows. The South Alouette River provides many recreational opportunities, including kayaking, canoeing, tubing, angling, swimming, wading, bird watching and equestrian trails (UMA, 1996b).

5.6.2.2 Issues

While there were a few recreation issues identified by the Consultative Committee for the South Alouette River and recognizing that the current flows from the dam were at the capacity of the low-level outlet, none of the issues were considered significant as long as the current minimum flows were maintained. The Consultative Committee determined early in the process that there was no justification to reduce these minimum flows, given the environmental benefits that were associated with them.

Table 5-5 summarizes the South Alouette River Recreation issues identified by the *Recreation Technical Sub-Committee.*

Table 5-5: South Alouette River Recreation Issues

Issue	Description and Action
Aesthetics	No known aesthetic issues were known since the operational flow changes were made in 1996.
Safety	Since the operational changes in 1996, there were no known safety issues reported on the river. High flows can present a potential safety hazard for municipal park users along the river, as the system is dynamic. Daily changes in flows from low to high (up to 100–200 cfs) were thought to impact equestrian users until trail crossing signs were installed. Reduced flows below (70–105 cfs) were associated with a greater exposure to rocks and debris, which may adversely affect recreationalists floating down the river. In addition, historic low flows (pre-1996) were thought to be associated with higher coliform counts that may be a health concern to river users.
Peak Flows for Activities	Active recreational activities along the river (e.g., kayaking) are linked to periods of high flows. Optimal flows for tubing and floating activities at various locations are considered to be in the range of flows from the low-level outlet (70–105 cfs) or slightly above. Increased flows also provide the greatest opportunities for angling. Flows of 80–105 cfs provide maximum "fishability", and angling opportunities are optimized at 105 cfs optimized and above. However, a key limitation for angling opportunities was restricted access to the river as a result of private property owners.
Wildlife Viewing	Since the 1996 operational changes, it was observed that there has been a dramatic increase in the opportunities to view wildlife resulting in an overall increase in the quality of the recreational experiences on the river.

5.6.3 Recreation – Objectives and Performance Measures

Table 5-6 below defines the identified recreation objectives agreed to by the Consultative Committee. The Committee concluded that the best way to deal with often conflicting recreational interests around the reservoir was to focus on waterborne recreation. Moreover, they chose not to focus on terrestrial recreation other than those that may adversely impact cultural heritage, wildlife, and other resources.

Table 5-6: Recreation Objectives and Sub-objectives

	Objectives
River: Fundamental Objective	Minimize adverse impacts to waterborne recreation in the South Alouette River
Reservoir: Fundamental Objectives	Improve waterborne recreation quality and opportunities in the Alouette Lake Reservoir Minimize adverse impacts associated with terrestrial recreation on environmental and cultural interests
Reservoir: Sub-objective	Maximize boater safety

5.6.4 Recreation – Performance Measures

One performance measure was developed to assess operating alternatives at meeting recreation objectives in the reservoir. Table 5-7 summarizes this performance measure used by the Consultative Committee.

Table 5-7: Alouette Recreation Performance Measure

Performance Measure	Unit of Measure	Description
Waterborne Recreation Quality and Opportunities	Number of weighted user days the reservoir is at preferred elevations	Weighted usable recreation days based on reservoir levels and season

See Appendix G for more details for how the performance measure is calculated.

5.7 Fish

5.7.1 Background

The *Fish Technical Sub-Committee* discussed fish issues and the results from the monitoring studies undertaken from 1996 to the present, reflecting on the post 1996 Water Use Plan experience. They identified a number of issues that informed discussions during the Water Use Plan review. It was noted by members that the 1996 Water Use Plan monitoring program was considered inadequately funded to undertake the monitoring activities set out by the Alouette Management Committee and that additional costs were borne by stakeholder support which is no longer available. Nevertheless, the Fish Technical Sub-Committee assessed both fish and fish habitat issues based on the monitoring that was done and their collective experiences and knowledge of the system.

Fish species returns were considered excellent for Chum, good for Pinks, uncertain for Coho due to a change in numbers, and uncertain for Steelhead due to smolt capacity linked to declining adult returns. Chinook were considered to be re-establishing, and might require assistance. No barriers to migration were identified up to the dam.

In terms of habitat, the ecosystem response was determined to be positive, with noticeable wildlife benefits. The lower river (downstream of 216th Street Bridge) was not a focus of the 1996 Water Use Plan, because of the limited ability to significantly influence conditions (given the degree of tributary flows that far downstream of the dam). Issues in the lower river were identified as dykes that concentrate flow, invasive species such as Carp, Small Mouth Bass, Yellow Perch, Canary Grass and Blackberry. Replanting was flagged as an issue, as were riparian landowner impacts. Silt was identified as a problem. Although in general silt flows have been mitigated through the reservoir being operated above El. 116 m and through the operation of the Mud Creek settling pond, high silt loads are still a concern.

Given the environmental benefits that resulted from the 1996 operational changes and given the limiting capacity to provide any additional flows through the low-level outlet, both the Fisheries Technical Committee and Consultative Committee did not consider any reduction in minimum flows from the dam. This focused the

discussion of providing additional fisheries benefits through operating changes in the Alouette Lake Reservoir.

5.7.2 Issues

5.7.2.1 Fish – South Alouette River

Table 5-8 summarizes the fish issues identified during the Alouette Water Use Plan review for the South Alouette River.

Table 5-8: Fish Issues in the South Alouette River

Issue	Description and Action
Restoring Sockeye Salmon to the Alouette System	First Nations, federal and provincial agencies, and community groups wanted to consider potential to create favourable conditions for possible restoration an anadromous sockeye salmon to the Alouette Lake Reservoir. This would entail facilitating Kokanee out-migration to the ocean and their return migration to the base of the dam. In order to facilitate the out-migration of Kokanee smolts, reservoir levels needed to be kept higher in the spring to use the crest gate and provide a desired surficial release from the dam. Another aspect of the Kokanee out-migration option, if recommended, was to mimic more of a spring freshet release or pulse flow. This operation would also provide ecosystem benefits, rearing benefits, would potentially minimize predation (as higher flows will minimize their time in the system).
Predation	The issue of predation and whether there would be any measurable differences in survival from operational changes was discussed. If flows were increased (e.g., spring flush), it was felt that there would be less predation for out-migrating salmonids (and in particular Kokanee smolts) as there would be less residence time in the lower river. However, there are many other factors that would need to be assessed to confirm this: numbers of fry, time of day, and amount of sediment/cover in the river. There was also concern expressed about how predators (sturgeon, saw bills, Dolly Varden, etc.) may be adversely impacting the enhancement efforts carried out since the 1996 flow changes.
Habitat Quality	Substrate quality was an important issue and how it may be maintained through the sequencing/magnitude of flushing flows. There was a high degree of uncertainty surrounding the need for prescribed flushing flows: their magnitude and duration, sequencing, and their consequent adverse effects if they were not delivered. See Substrate Flushing Flow below for more details. The degree of suitable boulder habitat for steelhead rearing was also considered. Given the uncertainty of this, it was recommended that it be addressed through a monitoring study.
Fish Species Impacts	<u>Pink Salmon</u> The Consultative Committee expressed a desire to improve pink salmon escapement. They recognized, however, that little could be done for Pink Salmon habitat because the primary limiting factor is the overwhelming number of Chum Salmon in the system. Chum out-compete Pinks for habitat because of their size, large number, and run timing. <u>Coho Salmon</u> Coho habitat curves suggest that a benefit from a reduction in river flows is possible. However, the *Fish Technical Sub-Committee* did not feel that populations were sensitive to habitat changes as a result of lower summertime flows. This is due to the uncertainty of fall smolt numbers and the fact that the river is already fully wetted bank to bank for much of its distance and the belief that higher winter flows are not having an adverse effect on smolt out-migration. It was also felt that flows from tributaries during the wintertime might be having a more significant and limiting effect on rearing. There was consensus among the *Fish Technical Sub-Committee* that Coho juveniles, because of their behavioral biology, would benefit far more by adding structures (root wads, LWD, etc.) to increase habitat complexity than by any type of flow change.

Table 5-8: Fish Issues in the South Alouette River cont'd

Issue	Description and Action
Fish Species Impacts (cont'd)	Sockeye Salmon The *Fish Technical Sub-Committee* would like to enhance opportunities for anadromous salmon smolt out-migration, including Sockeye, from the period April to June. They also flagged low flows during Sockeye returns as a potential issue. It is unclear when Sockeye typically return to the system. There may be a concern if sockeye return during low flows in August, but this is considered a low likelihood. The *Fish Technical Sub-Committee* suggested that the next 10 years focus on collecting the needed information in order to make better decisions about whether there is a better flow regime that would facilitate passage. Kokanee Salmon The *Fish Technical Sub-Committee* would like to enhance opportunities for anadromous salmon smolt out-migration, including Kokanee, from the period April to June. Chinook Salmon The *Fish Technical Sub-Committee* questioned whether or not Chinook are entering the system. If they are in the system, cobble/boulder habitat will support Chinook rearing. Steelhead Trout There is concern about low adult returns. The *Fish Technical Sub-Committee* suggested that maximizing smolt output would partially mitigate ocean survival problems. Increased winter flows and good cobble/boulder habitat would also support Steelhead rearing.
Impacts on SARA Listed Species	SARA listed species to be reviewed to assess the potential adverse effects of any flow changes that may be proposed.
Stranding	Stranding is not considered to be an issue. Current ramping rates appear to be working. Subsequent stranding after flooding events is considered to be having a minimal impact on the population.
Fish Health and Survival–	Temperature There was a suggestion that warm river temperatures could lead to a fish kill (die-off) in the river during peak summertime periods. Upon discussion, however, the Fish Technical Committee was not aware of any such fish kills. A review of the temperature data also suggested that this would be a very low probability event (see below). Sediment and Pollution Although suspended sediments are not currently known to be an issue (ever since the 1996 operational changes were made), it was an important issue that was identified. Generally, when the reservoir drops below 116 m and in combination with NE winds, there was a concern with sediments being released through the low-level outlet. This could impact both the hatchery and incubating eggs in the river. Fish Pollutants There was also concern expressed about potential pollutants (disease and pathogens) being transferred to the system from returning salmonids. Septic Fields There was concern expressed that septic leaching may be having an adverse effect, especially during summertime periods when tributary flows are at their lowest. Drought Proving/Insurance There was a suggestion early in the process that given the uncertainty of potential risks to some fish species associated with low flows and/or changing conditions like climate change, that additional summertime flows should be considered. Upon review of the operating conditions to achieve this, it was recognized that the facilities were somewhat limited to increase flows through the low-level outlet

Table 5-8: Fish Issues in the South Alouette River cont'd

Issue	Description and Action
Species Shifting and Temperature Effects	There was concern that low reservoir levels may result in warmer temperatures being released through the low-level outlet during critical summertime periods. An analysis of the available information was completed and reviewed by the *Fish Technical Sub-Committee*. It was observed that the system acclimatizes very quickly below the dam (< 2 km). It is not known whether there have been any problems, but if there were they would occur from 1 August to 15 September. It is believed, though not confirmed, that it takes about 20 consecutive days to affect the dominant species residing in an area. The *Fish Technical Sub-Committee* questioned whether a deeper water (i.e., cooler) intake could be built, but this was considered to be outside the scope of Water Use Plan. The *Fish Technical Sub-Committee* is also concerned about species shifting associated with warm summer Low Level Outlet releases from July to August, and flagged it as a monitoring program issue.
Substrate Maintenance Flushing Flow	<u>Substrate Quality</u> The impact of flushing flows on the lower river is unknown. Gravel additions may have impacted boulder habitat, although the influence of enhancement compared to flow increases is unclear. The *Fish Technical Sub-Committee* recommends maximum flexibility for opportunistic flushing flows. <u>Spill Frequency</u> Projected frequency of pre-spill activity (1 every 2 years) above 32 m^3/s for three days is considered adequate for substrate flushing purposes. The goal is to provide a minimum of 32 m^3/s every 3 years (i.e., interval of 3 years between spills). The concept of a prescribed flush was abandoned. However this was an identified issue to be monitored during the review period. <u>Mud Creek Pond</u> Currently, up to 100 m^3 of silt, sand, and gravel fills the Mud Creek settling pond each year and is trucked away. Although desirable gravel from this material is not used in the river system, the impact of this is mostly mitigated through the replenishment/erosion of clean gravel material placed around the Mud Creek confluence.
Nooksack Dace	It is unknown whether Nooksack Dace are present in the system, but if they are found, their health is an important recovery objective. If they are present, there are a number of uncertainties that would first need to be addressed: current health, critical habitats, how to improve conditions, etc. The *Fish Technical Sub-Committee* reviewed this issue (based on the curves and their collective knowledge) and agreed that from what is known at this point about Nooksack Dace habitat needs, the potential for harm at the current flow levels is considered low. Also should an issue arise in the future, it can be dealt with through an alternative regulatory process (e.g., Species at Risk Act).
Influence of Hatchery	Silt drawn from the Low Level Outlet when the reservoir is at an elevation of 118 m or less, is a hatchery impact not a river impact. Pink and Chum compete for space, but Pinks are better able to tolerate variable flow conditions, and therefore stable flows are hypothesized to favour the success of Chum over Pink. Pinks are nevertheless considered to be doing very well in terms of healthy adult returns, but could possibly be better. Hatchery brood stock is now caught on site, which is a benefit that the *Fish Technical Sub-Committee* would like to see maintained. Chinook salmon will likely need hatchery intervention to ensure sustainable population, as the Alouette is not considered to be a Chinook river.
Pesticides / Herbicides in the Lower River	Committee members expressed concern about the use of pesticides and herbicides by berry farmers along the South Alouette River. The concern was that these chemicals were leaching and making their way into the river and adversely affecting the aquatic environment.
Comprehensive Planning	There was concern raised about the focus of the Water Use Plan on the upper reaches of the river. While it was commented that dam releases had the most effect on the top end of the river (since the lower end of the river was largely influenced by the magnitude of the tributary flows), it was recognized that the entire river system was important to consider.

For more information on monitoring studies that were recommended to address some of the above issues and uncertainties please see Appendix H: Alouette River Water Use Plan Review Project – Uncertainties Identified by the *Fish Technical Sub-Committee*.

5.7.2.2 Fish - Alouette Lake Reservoir

Table 5-9 summarizes the fish issues identified during the Alouette Water Use Plan review for the South Alouette River.

Table 5-9: Fish Issues in the Alouette Lake Reservoir

Issue	Description and Action
Operational Changes	The principal fisheries issues that were considered in order to make potential operational changes in the reservoir were as follows: optimizing Kokanee shoal spawning success • maintaining tributary access during critical in/out migration periods • improving spawning success of other anadromous salmonids and lampreys During the course of the Water Use Plan, there was a realization that these issues were associated with a lot of uncertainty, as there was limited information to base decisions from. As such, baseline information was needed to determine the health, limiting factors, and preferred operating levels before any suitable recommendations could be made.
Kokanee Out-migration	A key interest of the Consultative Committee was facilitating the out-migration of Kokanee smolts as a component of sockeye restoration efforts in the watershed. This operation required high reservoir levels in order to provide surficial releases from the crest gate in the springtime.
Littoral Productivity	Littoral productivity is a concern with varying reservoir levels as vegetation dies off as it becomes dry. Fluctuating water levels, depending on their frequency, duration, and magnitude, can reduce the overall productivity of littoral areas. If water levels change gradually, new vegetation will grow in the wetted area of the bank. If water levels vary frequently, the productivity of the littoral zone is reduced, affecting spawning success and water quality. It was observed during the Water Use Plan review that pelagic productivity was a far more important driver in overall productivity of the reservoir (than littoral productivity), especially since there was already an existing fertilization program established. Moreover, it was recognized that any operational changes to benefit littoral productivity would largely be dwarfed by the production in the pelagic zone (Stockner and Beer 2004).
Temperature Effects	There were initially concerns that lower summertime reservoir levels may be having an adverse effect on fish species in the lower South Alouette River through the release of warmer water temperatures. This was review by the *Fish Technical Sub-Committee* and discussed above (under fish issues in the river).
Improve Coordination between BC Hydro Initiatives	*Fish Technical Sub-Committee* commented on the lack of synergy between BC Hydro initiatives (e.g., Bridge Coastal Restoration and Water Use Plan process) and the need for improved coordination with the Alouette Management Committee. They suggested that BC Hydro do what it could through manipulating water flows first through WUP, and then follow with BCRP funded enhancement works afterwards (e.g., habitat complexing to promote Coho in the system).

For more information on the issues and uncertainties investigated by the *Fish Technical Sub-Committee* that aided in the decision-making process, please see Appendix H: Alouette River Water Use Plan Review Project – Uncertainties Identified by the *Fish Technical Sub-Committee*.

5.7.3 Fish – Issues Summary

During the course of the Water Use Plan Review, the only fish issues that were recommended as potential components of operational changes were Kokanee out-migration, littoral productivity, and substrate maintenance flushing flows. Other key fish issues were typically associated with too much uncertainty to recommend operational changes and consequently these formed the data gaps to be addressed through the recommended monitoring program.

5.7.4 Fish Objectives and Sub-objectives

Table 5-10 summarizes the fish objectives agreed to by the Consultative Committee for the Alouette system.

Table 5-10: Fish Objectives

	Objectives
Fundamental Objective	**Optimize Salmon abundance**
River: Sub-Objectives	• Maximize habitat suitability • Minimize adverse temperature effects • Maximize migration opportunities/triggers (Chinook/sockeye) • Maximize opportunities for anadramous fish out-migration from Alouette Lake Reservoir and tributaries • Minimize opportunities for invasive species • Minimize fish stranding events • Satisfy SARA requirements • Minimize adverse health effects
Reservoir: Sub-Objectives	• Maximize littoral productivity • Maximize salmonid shoal spawning success • Minimize tributary access barriers.

5.7.5 Performance Measures

Table 5-11 summarizes the fish performance measure developed during the Water Use Plan Review and used by the Consultative Committee to evaluate operating alternatives.

Table 5-11: Alouette Fish and Fish Habitat Performance Measure

Performance Measure	Unit of Measure	Description
Effective Littoral Zone	Calculated as a single value that captures the cumulative effects of operations on the productive potential of the littoral zone across all the years of simulation. Reported in units of hectares (ha) of shoreline habitat that has at least 20% of maximum growth potential defined by the combined effects of desiccation, PAR and UV light (all known to inhibit growth in algae). In addition to the hectare measure, upper and lower elevation boundaries of the Effective Littoral Zone are also reported.	Performance Measure that tracks the potential for algae and aquatic plant growth based on the intensity of Photosynthetically Active Radiation at depth, mortality resulting from desiccation, and mortality resulting from "light starvation". The integration of these factors through time defines the Performance Measure, which is referred to as the effective littoral zone, or Effective Littoral Zone.
Kokanee Out-migration Release	The release is measured either as having the operation built in (Yes=1) or not (No=0)	Performance Measure that is an indicator to show whether an operating alternative has a surficial dam release to facilitate the out-migration of Kokanee. Each operating alternative will therefore be marked with either having the operation built in (a 3 – 6 m^3/s crest gate flow from 1 April to 30 May) or not.

For more information, please see Appendix G for the Performance Measures Information Sheets.

5.8 Wildlife

5.8.1 Background

It was generally accepted by the Consultative Committee that wildlife use downstream of Alouette Dam has increased in response to the river's general increase in fish productivity, though much of the evidence was anecdotal in nature.

Since implementation of the Water Use Plan process, the regulatory environment concerning aquatic wildlife use has changed considerably. The most notable has been the introduction of the Species at Risk Act, which came into force in June 2004.

Unlike prior Water Use Plan projects, the Alouette Water Use Plan review process has explicitly integrated the assessment requirements of the Species at Risk Act within the restricted scope of the Water Use Plan. A total of fourteen fish and wildlife species that are listed or are about to be listed in the near future on Schedule 1 of the Species at Risk Act were identified as potentially occurring in the general vicinity of the Alouette Dam and its zone of influence (i.e., have some geographical overlap). These include four fish species, four amphibian species, two plant species and one each of a mammalian, avian, reptilian and insect species Appendix I).

5.8.2 Issues

The *Fish Technical Sub-Committee* reviewed wildlife issues based on general knowledge of riparian habitat use and anecdotal observations. In the river system, no specific concerns were raised. For the reservoir, potential access and riparian issues were considered not significant, partly because of the steep reservoir bank gradient. In addition, the Ministry of Environment did not express any concerns related to wildlife impacts associated with reservoir operations. For more information on the issues and uncertainties investigated by the *Fish Technical Sub-Committee* that aided in the decision-making process, please see Appendix H: Alouette River Water Use Plan Review Project – Uncertainties Identified by the *Fish Technical Sub-Committee*.

Decision-making around wildlife issues were informed by a review of Schedule 1 listed SARA species believed to be present in the Alouette system, and an assessment of the potential impact of operational changes on those species. Given the narrow range of operational changes under consideration, the assessment concluded that no wildlife impacts were anticipated in relation to available habitat area, community structure and complexity. Table 5-12 summarizes the wildlife issues raised during the Alouette Water Use Plan Review.

Table 5-12: Alouette Wildlife Issues

Issue	Description and Action
Riverine Habitat	Downstream of the dam, no changes are proposed from the 1996 decision to fully open the Low Level Outlet year-round. As a result, riverine habitat conditions are expected to remain unchanged from their present state, which is considered to be good to excellent given the smolt enumeration study results and anecdotal observations of increased wildlife use (Cope, 2005). Though some changes in target reservoir elevations are expected, the normal operating range is not likely to change. As a result, the extent and nature of the drawdown zone is not expected to change either.
Riparian Habitat	As flood control continues to be a priority, no operational change will significantly increase the risk of flooding. Consequently, riparian habitat on the shores of the South Alouette River will likely continue along its normal path of successional growth because the frequency and magnitude of inundation, a key driver of species community structure, will remain the same.
Wildlife Impacts	For the purposes of this Water Use Plan, the *Fish Technical Sub-Committee* assumed that any operational change that benefited fish would also benefit aquatic wildlife. Because the drawdown zone is of limited area and contains no wetland habitat, direct operational impacts are not believed to be significant. There is considerable anecdotal evidence downstream of the dam that suggests wildlife use has increased dramatically since the 1996 Low Level Outlet release. As a result, no monitoring was recommended, as operational changes strictly for wildlife values are unlikely in the future.

Table 5-12: Alouette Wildlife Issues cont'd

Issue	Description and Action
SARA Listed Species	Geographic and habitat overlap between the species and the zone of operational influence was considered to determine the impact of changes in operations on SARA listed species. This assessment only considered the incremental change in operations relative to the water license revision implemented in 1996, as impacts arising from historical operations, as well as those associated with the facility's footprint, are outside the Water Use Plan process. For the purposes of this assessment, geographic overlap, habitat overlap, and habitat risk are defined as follows: Geographic Overlap: Likelihood of occurrence within the general vicinity of the facility and zone of potential operational influence based on general species distribution information. Determines list of species that require assessment. Habitat Overlap: Likelihood that usable habitats are partially or completely found within the general vicinity of the facility and/or zone of potential operational influence. Habitat Risk: Likelihood that the facility and/or operations adversely impact usable habitats within the zone of influence. Because little or no change in habitat structure and complexity is expected following implementation of a new operating strategy for the Alouette system, the potential for adverse impacts to the usable habitats of Species at Risk Act-listed species is considered to be non-existent to very low. The primary reason that there is some low level risk is due to uncertainty that usable habitats are either available within the zone of operational influence, or if available, whether they are potentially impacted by the range of operational change being considered.

For more information on the assessment of impacts on Schedule 1 listed SARA species, please see Appendix I: Water Use Plan Technical Memo –Species at Risk Act species considerations in the Alouette Water Use Plan review process.

5.8.3 Wildlife – Objectives and Performance Measures

Table 5-13 summarizes the wildlife objectives agreed to by the Consultative Committee for the Alouette system.

Table 5-13: Wildlife Objectives

	Objectives
Fundamental Objective	**Optimize the quality and quantity of available habitat for wildlife**
River: Sub-Objectives	• Used fish as a proxy for wildlife (i.e., refer to fish sub-objectives for the river)
Reservoir: Sub-Objectives	• Optimize riparian habitat (e.g., access issues by recreationalists, erosion impacts) • Optimize access for wildlife

5.8.4 Performance Measures

No wildlife performance measures were developed.

5.9 Aquatic Ecosystem

5.9.1 Background and Issues

Aquatic ecosystem was another environmental category considered important by the Consultative Committee. While directly related to fisheries issues, it was considered separate and distinct from it – in recognition that fish abundance and diversity may be at odds with the overall aquatic ecosystem diversity under certain flow operations. No specific issues associated with aquatic ecosystem diversity were expressed or known during the Alouette process. Diversity seems to have increased in the river, however, with the re-introduction of pink salmon since the 1996 flow changes.

The *Fish Technical Sub-Committee* reviewed aquatic ecosystem issues and concluded that it would be too difficult to be able to develop any meaningful performance measure and particularly challenging to try and measure and quantify aquatic ecosystem benefits through some form of a biodiversity index. It was also felt that pursuing assessment tools to characterize aquatic ecosystem benefits was more aligned to providing an accountability mechanism for BC Hydro shareholders rather than serving as a baseline to inform future management decisions. As such, this was considered an item for BC Hydro to undertake outside of the Water Use Plan process.

5.9.2 Aquatic Ecosystem – Objectives and Performance Measures

The Consultative Committee agreed to the following aquatic ecosystem fundamental objective: ***optimize aquatic community diversity***.

No performance measure was developed for aquatic ecosystem.

5.10 Cultural Resources

5.10.1 Background

A *Heritage Technical Sub-Committee* was formed to provide information and recommendations to the Consultative Committee about heritage and cultural issues and how they are related with potential changes in operations. The Committee met 28 September 2005, 8 December 2005, and 20 February 2006.

The *Heritage Technical Sub-Committee* extended the area for review above the dam to include the Alouette Lake Reservoir, and focused on operational issues of BC Hydro's water management practices in the Alouette watershed. Issues of the environmental footprint of the existing facilities were not considered, as they lie outside the bounds of the water use planning process, and extend into legal questions of aboriginal title and rights. BC Hydro has no mandate to address these issues, although it was noted by the Katzie Nation that the New Relationship proposed by the provincial government has the potential to affect this.

The *Heritage Technical Sub-Committee* visited the Alouette Lake Reservoir in December 2005 to revisit known sites, map their elevations, check for other high potential sites, and look for pictographs on rock bluffs.

5.10.2 Issues

Table 5-14 summarizes the heritage issues identified in the South Alouette River and Alouette Lake Reservoir.

Table 5-14: South Alouette River and Reservoir Cultural Resources Issues

Issue	Description and Action
Downstream Impacts to Archaeological Sites	Impacts to the Pitt River were not considered significant, as determined by previous fisheries investigations that determined BC Hydro flow contributions from the Alouette Lake Reservoir are noticeable only as far as the 216th bridge. Although, the impact of BC Hydro operations on archaeological resources between the dam and 216th is not well understood. A monitoring program to identify impacts in this area of the river is recommended to gather the data necessary to develop a performance measure in time for the next Water Use Plan review period.
Discussion of Upstream Impacts to Archaeological Sites	A preliminary investigation of site potential is to be carried out in the field, however the intensity of data collection will not be sufficient to develop a useful performance measure. The primary intent of this field study is to develop context by which to qualitatively assess the merits of various operating alternatives and more importantly, identify the scope of future monitoring programs.
Heritage Monitoring	The *Heritage Technical Sub-Committee* recommends maximizing site inundation to prevent "pot hunting". A cursory qualitative assessment however, will be carried out to assess the relative merits of each alternative. The *Heritage Technical Sub-Committee* recommends that BC Hydro minimize reservoir fluctuations that may cause damage to sites by erosion. The Heritage Technical Subcommittee recommends that BC Hydro provide opportunities to study archaeological resources in the drawdown zone in order to better understand the nature and extent of the resource as well as the impacts of reservoir operations on archaeological sites.
Deep Drawdown	The deeper and longer reservoir levels are kept low, the more opportunities there will be to carryout archaeological inventory work and learn about the cultural resources there are in the reservoir area. Ideal conditions would be to keep the reservoir at its lowest point (114 m according to BC Hydro's water license) continuously for 2 weeks over three consecutive years. The *Heritage Technical Sub-Committee* looked at the pros and cons associated with a planned archaeological inventory deep drawdown and concluded that it was not warranted due to its potential for adverse impacts to downstream fisheries resources.
Potential Impacts of Monitoring Program	The *Heritage Technical Sub-Committee* recommends that all monitoring programs or physical works projects brought forward by this Water Use Plan review should be screened for their potential impact to archaeological sites. Should the possibility of an impact exist, the monitoring activity of physical works project should include a site investigation procedure, as well as mitigation plan for potential archaeological impacts. It was recommended that a Heritage Committee be established during the Water Use Plan review period.
Discussion of Traditional Ecological Knowledge and Water Use Plan Implementation	Traditional Ecological Knowledge (TEK) was identified as providing a potential source of information to supplement scientific information in this process. However, TEK was not included in the review process due to the short timeline and the opinion that science and TEK are very different ways of understanding and communicating information. The *Heritage Technical Sub-Committee* will instead seek opportunities for elders and Water Use Plan scientists to share information as the monitoring projects unfold, by providing meeting environments and structures that are conducive to elder participation, and by improving the cultural awareness in the Monitoring Committee membership.

5.10.3 Objectives and Sub-objectives

Table 5-15 summarizes the cultural resources objectives agreed to during the Alouette Water Use Planning process.

Table 5-15: Cultural Resources Objectives

Fundamental Objective	Maximize the protection of cultural resources within the Alouette System
Sub-Objectives	• Maximize the number of days at high reservoir elevation to cover sites that may be located within the drawdown zone and prevent pot hunting. • Maximize the number of days at high reservoir elevation to facilitate access to potential upland sites. • Maximize the number of days in early winter where reservoir elevation is at or less than 116 m for site investigation within the drawdown zone (required only for the first three years of Water Use Plan implementation. • Minimize the extent of reservoir fluctuation to prevent possible erosion and hence degradation of existing archaeological sites. • Minimize number of flood events to prevent exposure of new archaeological sites through bank erosion

5.10.4 Performance Measures

No downstream heritage performance measure was prepared at this time as little is known of downstream archaeological resources, including the nature and potential for impacts due to reservoir operations. The flood control objective is coincident with the general heritage site protection objective in that minimizing the risk of floods also minimizes the potential for site exposure due to flood related bank erosion.

A performance measure was developed to characterize the ability to access and carry out archaeological inventory fieldwork in the reservoir drawdown area.

Table 5-16 summarizes the Alouette Cultural Resources Performance Measure used by the Consultative Committee to evaluate operating alternatives for the Alouette system.

Table 5-16: Alouette Recreation Performance Measure

Performance Measure	Unit of Measure	Description
Site Access Days	Average number of weighted days / year	This Performance Measure provides an indication for how long the reservoir will have lower levels to carry out archaeological fieldwork. It is calculated by applying a weighted factor for each day that the reservoir is below El. 122.6 m (through most of the fall and winter), the values are then summed up for each year and averaged over the dataset. The higher the value, the greater access there should be for doing inventory work to assess the cultural resources for a particular alternative.

For more information on this Performance Measure, please see Appendix G for the Performance Measures Information Sheet.

5.11 Flood control

5.11.1 Background

Flood control events have and will continue to occur down the lower South Alouette River and flood plain. The degree and frequency of these events has been partially mitigated through the construction and operation of the Alouette facilities (dam, diversion, and turbines). However, continued urban development in and around the floodplain poses additional challenges to protect people and property. In general, the South Alouette River is characterized by natural riverbanks as it runs through Maple Ridge and flows through largely dyked channels as it passes through Pitt Meadows into the Fraser River.

BC Hydro faces a number of constraints when attempting to mitigate potential downstream flood events: limited ability to route flood waters into the Stave system, limited reservoir storage, rapid increases in the level of the reservoir, limited ability to forecast and predict the likelihood, magnitude and timing of flood control events, limited capabilities of the infrastructure (e.g., adit and crest gates), and no control and influence over downstream tributary inflows which may independently cause flooding. Because of these constraints, the risk of flooding can never be eliminated from the system. Moreover, these constraints often severely limit the flexibility in time with which flood management actions can take place.

High flow events and flood control issues were critical to the deliberations and decisions made by the Alouette Stakeholder Committee during the 1996 Water Use Plan. Since that time, no new flood control issues or concerns have been raised specific to the recommended flow changes.

During the Alouette Water Use Plan Review process, Consultative Committee members discussed high flow and flood control events and were asked if they had, or knew of, any concerns with BC Hydro's current operations related to flood control. The only specific comment that was raised related to BC Hydro's communication protocol with the public during high flow events and this was seen as very positive initiative (and one that should be continued). In addition, discussions took place with representatives from both the cities of Maple Ridge and Pitt Meadows to see if they had any specific concerns or recommendations with BC Hydro's operations. No specific flood related operational issues emerged from these discussions. However, Pitt Meadows did describe problems with their pumping system when Fraser River levels were high (as a result of backwatering effects and tidal issues) and asked BC Hydro to adjust some of their pre-spill procedures to better facilitate their pumping requirements (this is described in greater detail in Appendix J: Water Use Plan Technical Memo).

Although the District of Pitt Meadows recognizes that BC Hydro has limited ability to control potential flood events, they have requested that BC Hydro consider the possibility of adjusting the pre-spill procedure to help minimize the time during which floodwaters potentially impact the District's ability to carry out its own flood management activities in the area.

5.11.2 Issues

The Consultative Committee was generally satisfied with how high flow events have been handled since the 1996 Water Use Plan was implemented. Some outstanding issues were identified, which are summarized in Table 5-17.

Table 5-17: Alouette Flood Control Issues

Issue	Description and Action
Development	Concerned about the continued urban development in the flood plain. Neither the Consultative Committee nor BC Hydro has jurisdiction over urban development.
Pitt Meadows Pump Houses and Gate System	The District of Pitt Meadows has infrastructure on the lower sections of the South Alouette River that are used to help control damage on lands adjacent to the river's dyking network during flood events that threaten the area's crops, residential homes and out buildings, including commercial greenhouses. During periods of high inflow the District attempts to control flooding by allowing the accumulating waters to drain into the South Alouette River through the adjacent dykes. When the South Alouette River experiences high flow, combined with high tide events and a backwatered Fraser River confluence, the elevation of the river can rise to a point where the water directed into the Alouette system does not drain away as intended, and often flows into the already impacted lands (i.e., opposite the intended direction). The concern is that BC Hydro operations, particularly with respect to flood control, may at times exacerbate the problem. For more information, see Appendix J: Water Use Plan Technical Memo – Pitt Meadows Flood Control Issues.
Minimizing Impacts when Flooding Occurs	After a flood has occurred, it is important to gradually ramp down to 1750 cfs. Main concern with high flow events is seepage and bank erosion/loss of land (when flows approach 1750 cfs at 232nd bridge). A new gauge was later installed on the 232nd bridge abutment.

5.11.3 Objectives and Sub-objectives

The Consultative Committee developed and agreed to a fundamental flood control objective for the Alouette Water Use Plan Review. Refer to Table 5-18.

Table 5-18: Flood control Objective

Fundamental Objective	Minimize flood damage to people and property.

5.11.4 Performance Measures

Two performance measures were developed and used by the Consultative Committee in order to assess the performance of potential operating alternatives – number of free crest spill events, and number of flood risk (or flood management) days.

Free Crest Spill Performance Measure

The impacts of modelled Alouette Lake Reservoir operations on the risk of flooding are captured in a Performance Measure that tracks the number of free-crest spill events from Alouette Dam. The Performance Measure is reported as the number of free-crest spill events over a 45-year simulation model run.

Current operating practice identifies 56.5 m^3/s as the critical flood discharge at which damaging flood conditions start to occur. Given that the spillway gate is only capable of releasing a maximum discharge 42.5 m^3/s, the critical flood discharge can occur only at times of free crest spill. As a result, only free crest spills are tracked for Performance Measure calculation.

The duration of free crest spill typically ranges from three to five days. Because spill events tend to be similar in duration, only the event itself is counted through time and not the total number of spill days.

Flood Risk Performance Measure

Similar to the Free Crest Spill measure, the Flood Risk Days performance measure provides an indication about how well an alternative is at minimizing flooding risk. It calculates the average number of days each year (between September and March) that reservoir levels are at or above El 122.6 m (which is when the adit gate gets opened for pre-spilling procedures). The higher the number, the greater the flood risk for a particular alternative.

For more information on this Performance Measure, please see Appendix G for the Performance Measures Information Sheets.

5.12 Operational Flexibility

5.12.1 Summary

This objective area was identified because it was felt that there could be proposed operational changes that would not be adequately characterized (and measured) through the financial and flood control objectives and performance measures. It was therefore expected to represent the flexibility that BC Hydro has with its operations in order to respond to unforeseen events (e.g., climate change, or irregular hydrological events). The Consultative Committee therefore agreed to the following fundamental objective: ***minimize the constraints that limit operational flexibility.***

During the modelling process however, it was observed that all the identified constraints in the operating alternatives were being measured through the other performance measures (financial and flood control). As a result, no performance measure was developed for this objective area.

6 OPERATING ALTERNATIVES

6.1 Introduction

In Step 6 of the provincial government's *Water Use Plan Guidelines*, the Consultative Committee created and evaluated various operating alternatives for satisfying the Alouette Water Use Plan review objectives described in Section 5. The BC Hydro project team simulated these alternatives using computer models of the Alouette system. The Committee used the modelling results and performance measures to compare how well each alternative performed in satisfying the water use planning objectives.

6.2 Operating Alternatives

Five operating alternatives were developed and discussed by the Consultative Committee during the Alouette Water Use Plan Review.

6.2.1 Operating Alternative A

Alternative A reflects current BC Hydro operations. This alternative serves as the reference base case, which reflects the operating constraints as they currently exist, and is consistent with the Water Use Plan implemented in 1996. The principal operating constraints for Alternative A are:

- The Low-Level Outlet is fully open (70–105 cfs).
- A minimum reservoir elevation of El. 121.25 m is maintained to maximize recreational opportunities from Victoria Day to Labour Day.
- The minimum normal reservoir elevation is El. 116 m.
- The adit gate is opened when the Alouette Lake Reservoir level reaches El. 122.6 m or greater, to mitigate flood risk.

6.2.2 Operating Alternative B

Alternative B is the same as Alternative A ***plus*** an additional constraint designed to improve waterborne recreation opportunities in the reservoir, as follows:

- The Low-Level Outlet is fully open (70–105 cfs).
- A minimum reservoir target elevation of El. 123 m from 15 May to 30 September.
- The minimum normal reservoir elevation is El. 116 m.
- The adit gate is opened when the Alouette Lake Reservoir level reaches El. 122.6 m or greater, to mitigate flood risk.

6.2.3 Operating Alternative C

Alternative C is the same as Alternative A ***plus*** a reservoir operation that facilitates the out-migration of Kokanee each year, as follows:

- The Low-Level Outlet is fully open (70–105 cfs).
- A minimum reservoir target elevation of El. 121.25 m is maintained from Victoria Day to Labour Day.
- Keep reservoir level high in order to maintain a flow release using the spillway sluice of 3 m^3/s for 8 weeks (1 April to 30 May). Low-level outlet is closed during this operation.
- The minimum normal reservoir elevation is El. 116 m.
- The adit gate is opened when the Alouette Lake Reservoir level reaches El. 122.6 m or greater, to mitigate flood risk.

6.2.4 Operating Alternative D

Alternative D is the same as Alternative A, with additional constraints to balance recreational and fisheries interests identified in Alternatives B and C as follows:

- The Low-Level Outlet is fully open (70–105 cfs).
- A minimum reservoir target elevation of El. 121.8 m is maintained from 15 April to 14 June for recreational interests and in order to provide a 3 m^3/s surface release from spillway gate.
- A minimum reservoir target elevation of El. 122.5 m is maintained from 15 June to 5 September.
- A minimum reservoir target elevation of El. 121.25 m is maintained from 6 September to 30 September.
- Remainder of year minimum normal elevation is El. 116 m.
- The adit gate is opened when the Alouette Lake Reservoir level reaches El. 122.6 m or greater, to mitigate flood risk.

6.2.5 Operating Alternative E

Alternative E is identical to Alternative D except it reduces the minimum reservoir constraint of El. 121.25 m in the last two weeks of September to minimize flood risk. The constraints for Alternative E are as follows:

- The Low-Level Outlet is fully open (70–105 cfs).
- A minimum reservoir elevation of El. 121.8 m is maintained from 15 April to 14 June for recreational interests and in order to provide a 3 m^3/s surface release from spillway gate.
- A minimum reservoir elevation of El. 122.5 m is maintained from 15 June to 5 September.

- A minimum reservoir elevation of El. 121.25 m is maintained from 6 September to 15 September.
- Remainder of year minimum normal elevation is El. 116 m.
- The adit gate is opened when the Alouette Lake Reservoir level reaches El. 122.6 m or greater, to mitigate flood risk.

7 TRADE-OFF ANALYSIS

7.1 Introduction

In Step 7 of the provincial government's *Water Use Plan Guidelines*, the Consultative Committee evaluated the trade-offs associated with the operating alternatives described in Section 6. The alternatives varied in the benefits they provided to satisfy recreational, cultural resources, fish, financial, and flood control interests.

The trade-off analysis process involved discussions of the relative value among the Alouette Water Use Plan objectives: gaining more of some values in exchange for less of others. The Consultative Committee sought the operating alternative that best balanced the range of water use planning objectives specified in Section 4.

This section describes the trade-off analysis process and values that Consultative Committee members placed on different Alouette water use planning review objectives. The structure of this section is organized according to the sequential rounds of the trade-off analysis process.

7.2 Overview of the Trade-off Analysis Process

The Consultative Committee conducted the trade-off analysis process in two Committee meetings during the Alouette water use planning review process. Value-based trade-off techniques and preference analysis were used by the Consultative Committee to select a preferred operating alternative. The technical and value trade-offs were performed using interactive consequence tables and direct ranking exercises. Alternatives were evaluated and those that were clearly "dominated," or performed worse across performance measures either by direct comparison or agreement by the Committee, were removed from further analysis.

The process for selecting a preferred operating alternative involved the following steps:

1. Assess trade-offs among alternatives with reference to the performance measures.
2. Eliminate performance measures that were not significant or considered important across the alternatives.
3. Eliminate alternatives that the Consultative Committee agrees are "dominated" by other alternatives.
4. If possible, combine elements of alternatives to design better alternatives and repeat, or
5. Assess the degree of Consultative Committee support for the remaining alternatives, and
6. Ideally, reach agreement and recommend a preferred alternative.

7.3 Modelling Operating Alternatives

Modelling the operating alternatives involved a number of steps and computer programs. Once the Consultative Committee developed an alternative, the modellers used an Operations Model developed for BC Hydro's water use planning process to simulate operations of the Alouette Dam facility according to the specified constraints of each alternative.

Conceptually, the Operations Model takes the quality assured 45-year dataset (1960 to 2004) of inflow records and applies the operating constraints that the Consultative Committee has developed for each alternative. Within these constraints, the model optimizes for power generation. To better mimic reality, the model only assumes that it has three days of foresight (weather prediction) in order to plan around and meet the operating constraints. The end result is a number of outputs and graphs showing water levels, river flows, and diversion flows that approximate what each alternative would look like had it been implemented. From these records the performance measures are calculated. And these results were summarized for each operating alternative in a Consequence Table. The graphs and Consequence Tables were the main reference tools used by the Consultative Committee in their deliberations to select a preferred operating alternative.

7.4 Round 1 Trade-Off Analysis – 19 January 2006 Consultative Meeting

At the first trade-off session, the Consultative Committee discussed and attempted to reach agreement on a preferred alternative and the need of a mandatory substrate flushing flow. They reviewed Alternatives A, B, C and D and assessed how well they were at meeting their objectives.

7.4.1 Reservoir Elevation Graphs

Figure 7-1 compares the median reservoir levels over the 45-year dataset throughout the year for each operating alternative.

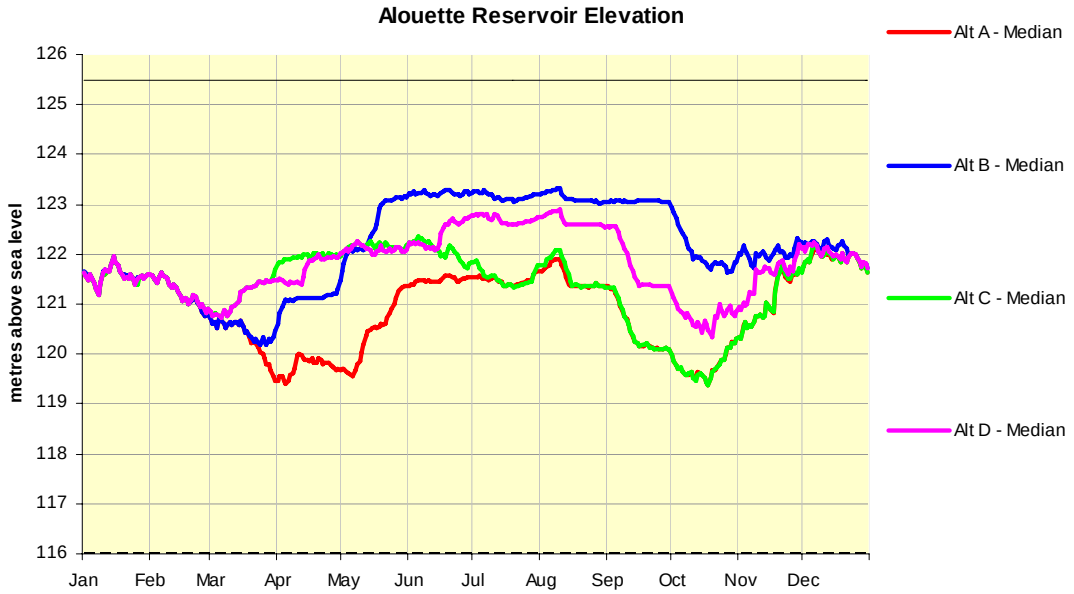


Figure 7-1: Alouette Lake Reservoir Elevation Levels

7.4.2 Round 1 - Consequence Table

From the modelled results, the performance measures were calculated and summarized for each data year (1960–2004). While there is year-to-year variation for every performance measure, the following table (known as a *Consequence Table)* shows the median PM values (50th percentile) over the 45-year dataset.

Table 7-1 summarizes the performance of each operating alternative used during the first round of the trade-off analysis.

Table 7-1: Consequence Table

Performance Measures	Unit	What's better	Alternatives			
			A	B	C	D
Free Crest Spill Events	#	Less	3	6	3	3
Flood Risk Days	# of days/yr	Less	15	55	16	20
Littoral Productivity (ELZ)	# of ha	More	85	11	82	77
Value of Electricity	$/yr (000s) *(relative to A)*	Less	0	229	30	105
Weighted Recreation Days	# / yr	More	49	108	58	91
Weighted Site-Access Days	# / yr	More	49	29	44	35

7.4.3 Round 1 – Selecting an Operating Alternative

The Consultative Committee did two ranking exercises (direct ranking and swing weighting) to gain insight into which alternatives were best at meeting their interests. The results from these exercises facilitated discussions, which led to the following conclusions:

- Alternative A dominated the performance of Alternative C across the performance measures, except for the fact that there were no criteria to show the benefit of facilitating the out-migration of Kokanee/Sockeye from the reservoir (this led to the creation of a new measure for Round 2).
- Alternative D clearly dominated the performance of Alternative B.
- Consultative Committee members ranked Alternatives C and D as either their most or second most preferred options with the exception of one member (who preferred Alternative A because they felt that the difference between flood risk days was significant).
- From these discussions, one new hybrid alternative was recommended (subsequently to become Alternative E). This new alternative would attempt to provide similar benefits to Alternative D, but with less risk of flooding than Alternative D according to the number of flood risk days.

7.4.4 Round 1 – Mandatory Substrate Maintenance Flushing Flow

Another operating decision discussed at the 19 January 2006 Consultative Committee was the need and desire for a mandatory substrate flushing flow. The flushing flow emanated from a recommendation from the Alouette Management Committee, which was reviewed and supported by the Fisheries Technical Committee.

A substrate (or channel) maintenance flushing flow is designed to maintain the gravel bed in a more optimum condition and better meet fisheries interests (i.e., minimizing the embeddedness and the percentage of fines in the substrate – below 20 per cent for example). The flushing flow calls for a 3-day dam release of 32 m^3/s every third year in the fall/winter time (anytime between 15 September and 28 February). BC Hydro engineers performed an analysis to assess the impacts of a prescribed flushing flow (Appendix K). On average, a mandatory flushing event is estimated by BC Hydro to cost about $170,000 and result in approximately 17 more flood risk days (i.e., the number of days that the reservoir is at or above El. 122.6 m).

The principal trade-off with this decision came down to risk: the risk of potential increases to flood exposure versus the risk of poorer substrate quality and its corresponding potential risk to fish and ecological interests.

The Consultative Committee had mixed opinions about which was the most important risk factor and deferred this issue to the Fisheries Technical Committee for more information.

7.5 Round 2 Trade-Off Analysis – 2 March 2006 Consultative Meeting

Round 2 was the final round of trade-off discussions and consisted of the Consultative Committee agreeing to a preferred operating alternative, discussing an additional Kokanee pulse flow, and expressing their level of support for the monitoring program and a series of recommendations. This section documents the areas of agreement and disagreement on these items.

Compared with Round 1, there was only one new alternative (Alternative E) and one new performance measure (Kokanee Out-migration Release) that were reviewed and used by the Committee.

In addition, the Committee reviewed and accepted the Fisheries Technical Committee's recommendation to abandon a mandatory substrate flushing flow for the time being. The Fisheries Technical Committee felt that the current opportunistic flushing flows in combination with tributary inflows was working to maintain the quality of the substrate. The Consultative Committee also agreed with the Fisheries Technical Committee identifying this issue as a critical data gap to be addressed during the course of the review period.

7.6 Reservoir Graph for Alternative E

The Consultative Committee reviewed the new alternative (Alternative E). Figure 7-2 summarizes the modelled results of the reservoir levels for Alternative E. Each trace line on the graph shows the reservoir level throughout the year for each year of record. The coloured lines represent the 90^{th}, 50^{th} or 10^{th} percentile averages for the 45-year dataset. In other words, 80 per cent of the time you should expect the reservoir level to be between the blue and green lines, and 50 per cent of the time below/above the red line.

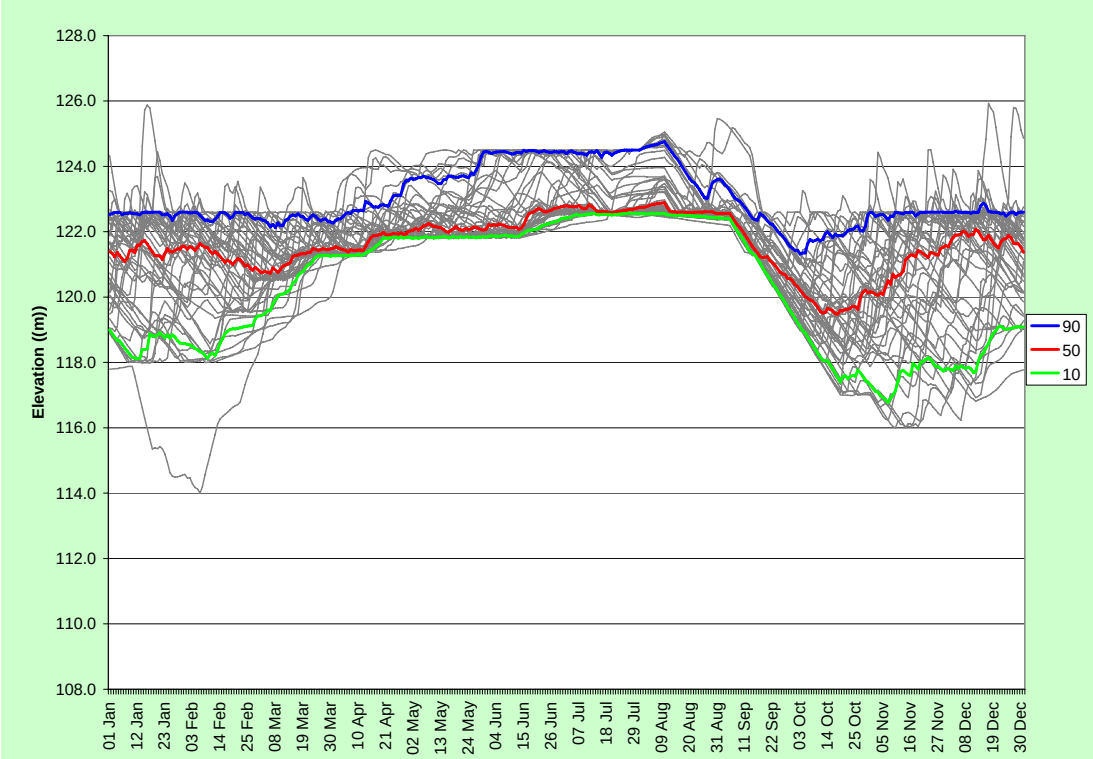


Figure 7-2: Modelled Results of the Reservoir Levels for Alternative E

7.7 Round 2 – Consequence Table

Table 7-2 summarizes the performance of Alternative E against the previously defined Alternatives used during Round 1.

Table 7-2: Consequence Table

Performance Measures	Unit	What's better	Alternatives				
			A	B	C	D	E
Free Crest Spill Events	#	Less	3	6	3	3	3
Flood Risk Days	# of days	Less	15	55	16	20	16
Littoral Productivity (ELZ)	# of ha	More	85	11	82	77	23
Value of Electricity	$ (000s) *(relative to A)*	Less	0	229	30	105	35
Weighted Recreation Days	#	More	49	108	58	91	88
Weighted Site-Access Days	#	More	49	29	44	35	48
Kokanee Outmigration Release	-	-	No	No	Yes	Yes	Yes

7.7.1 Round 2 – Selecting an Operating Alternative

The final round of the trade-off discussions focused on whether or not Alternative E was better meeting the overall objectives and performance measures and acceptable to Consultative Committee members, as it was developed as a consensus builder to address flood risk concerns associated with Alternative D.

Consultative Committee members were asked to express their level of support for Alternative E according to the following terminology:

Endorse: I fully support alternative

Accept: This alternative is okay

Accept: With the following reservations

Block: I cannot live with this alternative

Consultative Committee member support and comments are summarized in Table 7-3:

Table 7-3: Consultative Committee Member Support for Operating Alternative E

Name	Ranking	Comments
Jim Sheehan	Endorse	
Matt Foy	Endorse	Terminology is not typical from a regulatory perspective. But if this has been used previously in other Water Use Plans, do not want to start setting a different precedent and will therefore accept wording of "endorse".
Susanne Thorpe	Endorse	Terminology is not typical from a regulatory perspective. But if this has been used previously in other Water Use Plans, do not want to start setting a different precedent and will therefore accept wording of "endorse".
Ken Stewart	Endorse	
Gerry Miller	Endorse	
Ron MacLean	Endorse	
Jenny Ljunggren	Endorse	
Geoff Clayton	Endorse	
Greg Wilson	Endorse	
Ken Wilson	Accept with Reservations	Reservation of the probability of a 1 in 10 year heritage drawdown (116 m) as under current operating conditions. Katzie requested BC Hydro to address this reservation somehow. Katzie will send letter to the comptroller with this reservation.
Tanya Hoffman	Accept with Reservations	Reservation of the probability of a 1 in 10 year heritage drawdown (116 m) as under current operating conditions. Katzie requested BC Hydro to address this reservation somehow. Katzie will send letter to the comptroller with this reservation.

Table 7-3: Consultative Committee Member Support for Operating Alternative E cont'd

Name	Ranking	Comments
Debbie Miller	Accept with Reservations	Reservation of the probability of a 1 in 10 year heritage drawdown (116 m) as under current operating conditions. Katzie requested BC Hydro to address this reservation somehow. Katzie will send letter to the comptroller with this reservation.
Chris Weyell	Endorse	
Hugh Smith	Endorse	
Tom Blackbird	Accepts	Sent via email – Tom accepted Alternative E even though it was not the best for recreation. This was in recognition of the benefits provided by Alternative E across the other aspects.
Leslie Elchuk (observer)	Endorse	

The Consultative Committee therefore selected Alternative E as their preferred operating alternative, with the representatives from the Katzie Nation conditionally[1] supporting it.

7.7.2 Round 2 – Kokanee Out-migration Pulse Flow

Another operational decision discussed by the Consultative Committee at their final 2 March 2006 meeting was based on a Fisheries Technical Committee's recommendation to provide an additional pulse flow during the Kokanee out-migration operation. It was felt that there would be additional benefits to both the ecosystem and in the success of facilitating more Kokanee smolts through the crest gate and down the river, if there was a short increase (or pulse) in dam releases. The Fisheries Technical Committee therefore proposed an increase in flows from 3 m^3/s to 6 m^3/s for a one-week period during the assumed 8-week out-migration zone from 15 April to 14 June. Costs to provide this pulse flow were estimated at approximately $20,000 per event.

BC Hydro commented that this pulse flow would be very dependent and sensitive to any inflows; accordingly it may be very difficult to operationalize in some years. A dry spring would be the best opportunity to be able to regulate a 6 m^3/s flow pulse (through adjustments to generation). Otherwise it was felt to be too difficult to deliver, given the existing facilities and therefore the need to have crews on hand adjusting the gates (throughout inflow events).

After review and discussion by the Consultative Committee the following decision was agreed to:

[1] Katzie representatives sought a firmer commitment that BC Hydro was willing to undertake reservoir operations that would better allow archaeological inventory work to be carried out during the review period; as favourable conditions occurred.

- To opportunistically provide a pulse flow– targeting four out of the eight years of the review period (note that three or five events is less ideal; and two or six events is worse still out of the eight year period).
- The pulse should be between 3 to 6 m^3/s extra (i.e., ranging from 6 m^3/s to 9 m^3/s total dam release).
- The pulse should be tied to monitoring to ensure that it is effective; if not, it should be stopped.
- And, the pulse should be ideally timed to the last week of the migration period, after the initial group of migrants (i.e., first peak) have left the reservoir.

7.7.3 Round 2 – Other Decisions

Other decisions and recommendations made at the final 2 March 2006 Consultative Committee meeting are summarized in the following sections and these included agreeing to a review period, a monitoring program and a series of recommendations.

8 MONITORING PROGRAMS

8.1 Background

A component of every Water Use Plan is the development of a monitoring program to address key uncertainties and inform better future management decisions. The Province has set criteria that all studies must be evaluated on. The criteria set the eligibility for funding under the Water Use Plan program. The criteria can be summarized according to the following questions:

1) Would the study result in operational changes?

2) Can it provide results (statistical power) within a timely manner?

3) Is it the most cost effective (can it be achieved through other Water Use Plan monitoring)

4) Do the benefits outweigh the costs of the study?

Consultative Committee members were asked to consider two aspects in their evaluations of the proposed studies:

1) The likelihood that a study result will lead to a change in a future water management decision; and

2) The relative importance of the study given the uncertainty, study cost, and value of information that it will provide.

Moreover, Consultative Committee members were asked to consider the specific studies according to the following rankings (Note: a number of studies had already been screened out during the technical committee reviews):

High	must be undertaken in order to make responsible future water management decisions
Medium	study is recommended as it will likely affect future water management decisions
Low	study is not likely to serve as a basis to make future water management decisions

The Consultative Committee was informed that the approval process for the monitoring program takes approximately one year and consists of the following steps:

1) Monitoring program drafted as a component of the draft Water Use Plan, sent to the Water Comptroller.

2) Following Order from the Water Comptroller, a draft Terms of Reference for the monitoring program is produced.

3) The draft Terms of Reference is circulated to stakeholders, agencies, First Nations.

4) The final Terms of Reference gets drafted.

5) Water Comptroller approval.

6) Implementation during the Water Use Plan review period.

The Technical Sub-Committees developed the studies with these questions in mind, but it was ultimately up to the Consultative Committee to weigh the benefits of information versus the individual study costs versus the importance of the data gap being filled relative to a change in future operations.

A summary table of monitoring activities and associated costs was prepared and distributed to the Consultative Committee for the purposes of discussion of the monitoring program components.

8.2 Monitoring Studies – Management Questions

Table 8-1 summarizes the water use management questions that each monitoring study was designed to answer:

Table 8-1: Water Use Management Questions of the Monitoring Studies

Issue Area	Management Questions
Study #1: Smolt Enumeration	Does the average base-flow release of 2.6 m^3/s from the Alouette Dam continue to be adequate to sustain current levels or improve salmonid smolt production downstream of the dam? Species of interest include pink, Chinook, and Coho salmon as well as steelhead and cutthroat trout.
	What is the migration pattern of Kokanee smolts once they leave Alouette Lake?
	Is there evidence of a persistent, declining trend in egg to smolt survival that would suggest a degrading condition in spawning substrate quality?
Study #2: Kokanee Out-migration	Is the surface release of at least 3 m^3/s from the Alouette Dam (obtained through the spillway gate) adequate to promote the downstream migration of Kokanee smolts out of the Alouette Lake Reservoir?
	Does a post-surface release flush of 6 m^3/s, lasting seven days, following the tail end of the out migration period, encourage more smolts to leave the system?
	How long should the surface release last to ensure out migration of all smolts prepared to leave the system?
Study #3: Substrate Quality	Do the results of the Toe-Pebble count procedure reflect the general composition of bed materials within the channel downstream of the Alouette Dam?
	Is the < 20% fines threshold adequate to distinguish a state in substrate quality that would require a prescribed flushing event?
	Is an alternative methodology required to qualify/calibrate the results of the Toe-Pebble count procedure?
	For each year of the monitor, is a prescribed flushing flow necessary given the current state of substrate quality?
Study #4: Sockeye Adult Enumeration	Are the Alouette Lake Kokanee smolts successfully adapting to an anadromous existence by returning from the ocean environment to spawn in Alouette Lake?
	What is the run timing of adult sockeye returns?
	Are the adult sockeye caught during the monitor members of the "Alouette stock" or are they strays from other coastal systems?
	Are the returning adult sockeye numbers sufficient to create a self sustaining population given the existence of the Alouette Lake Fertilization Program, and whatever strategy is used to get the retuning adults back into the reservoir?

Table 8-1: Water Use Management Questions of the Monitoring Studies cont'd

Issue Area	Management Questions
Study #5: Water Temperature	How often are water temperatures ≥ 25°C, the incipient lethal temperature of most stream rearing salmonid species, including the duration of each event and the frequency of occurrence?
	Is the duration of observed warm water events less than one day, thus limiting exposure to warm waters and therefore thermal stress impacts?
	Are warm temperature events restricted to certain sections of river, indicating the inflow of cooler waters into system (most likely ground water)?
	Is the duration and frequency of warm water events such that it would promote a shift in fish community structure and/or reduce summer survival and growth of rearing juvenile salmonids, as indicated by a change in salmonid smolt numbers?
	Given the extent of thermal stratification in the reservoir and the location of the Low Level Outlet, is there an operational change that can be implemented to mitigate the occurrence of warm water events.
Study #6: Kokanee Age Structure	Is the existing Kokanee population in the Alouette Lake reservoir recruitment limited?
	If there is evidence of a recruitment constraint to productivity, can it be linked to reservoir operations, in particular the extent of reservoir fluctuation during the spawning and incubation period (deemed to be mid-October to the end of February)?
	If found linked to reservoir operation, what is the nature of the relationship and can it guide the development of possible mitigative reservoir operations?
Study #7: Archaeological Impact Assessment – Reservoir	Where are the archaeological sites in the reservoir?
	What are the relative heritage values of identified sites?
	What is the nature and extent of the impacts to archaeological sites that are caused by reservoir operations?
Study #8: Archaeological Inventory and Evaluation	Are there archaeological resources that are impacted by river flows?
	Would an operational change potentially lessen those impacts?

8.3 Monitoring Program – Consultative Committee Support

The Consultative Committee supported the entire monitoring program: each monitoring study was ranked as a high priority in order to make responsible future water management decisions. Costs for the monitoring program were estimated at approximately $1,500,000 over the eight-year review period (or approximately $187,500/year on average).

Specific comments from Consultative Committee members are summarized in Table 8-2: Consultative Committee Issues on the Proposed Monitoring Program.

Table 8-2: Consultative Committee Issues on the Proposed Monitoring Program

Monitoring Study	Description and Comments
#1 Smolt Enumeration Study	This study has three components: 1. smolt enumeration 2. egg to fry survival rate (substrate indices), and 3. Kokanee leaving the system. Some Consultative Committee members expressed concern that the results from this study may not lead to a change in future operations, although they recognized the benefits from a consistency and research perspective. The other potential value of data is that information might be useful for flow changes, if not for operational levels, and hopefully value to BC Hydro for other systems. It was suggested that BC Hydro could use incline plane traps only (getting rid of the screw traps), and cut the budget by a third. A further suggestion was to transfer upstream monitoring to the lower site. The Consultative Committee recommends and considers this a HIGH ranked study. This study is to also address the management questions associated with the Kokanee Out-migration Study #2 (using the downstream screw trap site with an allowance for fencing, sandbagging, etc.) and the effects of warm water temperatures on fish productivity and community structure (Study #5).
#2 Kokanee Out-migration Study	The Consultative Committee felt that parts of this study could be better integrated into Study #1 above, and this may result in additional cost savings. It was also noted that there would be three years of data with the upper trap to assess the Kokanee out-migration operation (including two years of BCRP funding). There was an outstanding question as to whether the downstream trap could provide reasonable data, given the fact that the Fraser River may backwater and confound the results. In the end, the Consultative Committee ranked this study HIGH.
#3 Substrate Quality Study	No comments. Consultative Committee ranked this study as HIGH.
#4 Sockeye Adult Enumeration Study	No comments. Consultative Committee ranked this study as HIGH.
#5 Water Temperature Study	No comments. Consultative Committee ranked this study as HIGH.
#6 Kokanee Age-Structured Population Assessment	The Consultative Committee questioned whether or not this study would provide enough evidence to make it worthwhile. Data collected in the past will be analyzed, and new data collected will be analyzed in the same way going forward to provide ample evidence. Consultative Committee members commented that it is ideal to study this in September, and suggested that more trolling might help bump up the data. Consultative Committee gives this study a HIGH rank, so long as a detailed Terms of Reference is provided after more homework is done.
#7 Archaeological Impact Assessment	This study provides a survey of the drawdown area, an inventory of archaeological sites, and monitoring of impacts (erosion monitoring system) with recommendations for mitigation. The cost is estimated at $105,000, with an additional $10,000 for the river component. The funds will be kept in reserve to be used opportunistically. Consultative Committee gives this study a HIGH rank.

8.4 Monitoring Plan Terms of Reference

A draft Monitoring Plan Terms of Reference has been developed and was circulated to the Consultative Committee for comment. Please see Appendix M: Terms of Reference for the Alouette Monitoring Program for more information.

8.5 Monitoring Program Timeline

Table 8-3 summarizes the planned timeline and cost distribution of the proposed monitoring program. Costs for the monitoring program are estimated at approximately $1,612,000 over the eight-year review period and will range from $188,600 to $225,800 annually. Budget details can be found in the Monitoring Program terms of reference (Appendix M).

Table 8-3: Annual Cost Summary of the Alouette WUP Monitor.
All costs are in 2006 dollars unless otherwise indicated.

Monitor	Annual Cost (2005 dollars)								Program Total
	2007	2008	2009	2010	2011	2012	2013	2014	
Smolt Enumeration	$96,260	$96,260	$96,260	$96,260	$96,260	$96,260	$96,260	$101,360	$775,180
Kokanee Out-migration	$33,525	$33,525	$33,525	$33,525	$33,525	$33,525	$33,525	$37,625	$272,300
Substarte Quality	$10,453	$7,453	$7,453	$7,453	$7,453	$7,453	$7,453	$9,953	$65,124
Sockeye Adult Enumeration	$30,525	$29,025	$27,025	$11,475	$11,475	$11,475	$11,475	$13,375	$145,850
Water Temperature	$8,146	$3,446	$3,446	$3,446	$3,446	$3,446	$3,446	$5,346	$34,168
Kokanee Age Structure Analysis	$2,350	$2,350	$2,350	$2,350	$2,350	$2,350	$2,350	$5,450	$21,900
Archaeological Impact Assessment[1]	$14,375	$14,375	$14,375	$14,375	$14,375	$14,375	$14,375	$14,375	$115,000
5% contigency[2] **and 2% annual inflation adjustment**	$11,217	$14,435	$18,042	$19,708	$23,192	$26,746	$30,371	$38,316	$182,027
Annual Total[2]	$206,851	$200,869	$202,476	$188,592	$192,076	$195,630	$199,255	$225,800	$1,611,549

[1] Total to be held in reserve for opportunistic use

[2] Contigency on labour only

8.6 Annual Updates

The Consultative Committee recommended that a Monitoring Advisory Committee be created from a core group of its members. The primary mandate of the Monitoring Advisory Committee is to meet annually to review BC Hydro's compliance with the Alouette Water Use Plan and to discuss the content and implications of monitoring study results. A draft terms of reference for the Monitoring Advisory Committee was circulated among Consultative Committee members for comment. Details of the proposed Monitoring Advisory Committee terms of reference can be found in Appendix L.

9 SUMMARY OF RECOMMENDATIONS

9.1 Background

During the course of this Water Use Plan Review a number of recommendations were raised. Some of these were related to operations (i.e., related to Water Use Plans) and some of these were outside the mandate and scope of Water Use Plans and/or jurisdiction of BC Hydro or the Comptroller of Water Rights.

Consultative Committee members were asked to express their level of support for the various recommendations according to the following:

✓ I support this recommendation

X I cannot support this recommendation

– I am indifferent / don't care one way or another

9.2 Water Use Plan Related Recommendations

Table 9-1 summarizes the Consultative Committee recommendations that were considered within the scope of the Water Use Plan Review process.

Table 9-1: Consultative Committee Comment for the Water Use Plan Recommendations

#	Recommendation	Support (support, can't support, indifferent) *	Specific Consultative Committee Member Comments
1	The Consultative Committee recommends a review period of approximately eight years (2014) for this Water Use Plan Review (tying into a system wide Water Use Plan with the Stave system).	12 support	1) Makes sense (Geoff Clayton)
2	The Consultative Committee endorses the current crest gate ramping rates developed and supported by the AMC.	12 support	1) Slow but workable (Hugh Smith) 2) Safe – AMC (Geoff Clayton) *3)* Work in progress for the past years (Lesley Elchuk)
3	The Consultative Committee recommends that BC Hydro continue to implement opportunistic flushing flows (i.e., shaping pre-spill events) as defined and recommended by both the AMC and the *Fish Technical Sub-Committee*. This entails a 3-day flow of a minimum of 32 m^3/s (and ideally up to 42 m^3/s) on an annual basis, as inflows permit.	12 support	1) Would prefer a guaranteed frequency, but understand flood control concerns and that opportunistic frequency should be 1 in 3 or better (Greg Wilson) 2) Triggers - % of fines, egg: fry survival rate (Suzanne Thorpe) 3) See 8, trigger point (Ken Stewart) 4) 3 day 32+ m^3/s on ± 3 year. Return – opportunistic (Hugh Smith) 5) If opportunistic flushing flows are infrequent or inadequate, operational changes will be required (Ken Wilson) 6) Effective so far, should be in the future (Geoff Clayton) 7) Must be trigger in place if monitoring found fines needed flushing (Jenny Ljunggren)

Table 9-1: Consultative Committee Comment for the Water Use Plan Recommendations cont'd

#	Recommendation	Support (support, can't support, indifferent) *	Specific Consultative Committee Member Comments
4	The Consultative Committee recommends that the current monitoring program continue to be funded until the Water Comptroller orders the revised monitoring program.	12 support	1) Provided it includes all current programs (Ken Stewart) 2) Required for continued information (Geoff Clayton) 3) At historic level of funding (Jenny Ljunggren)
5	The Consultative Committee supports the inclusion of Traditional Ecological Knowledge during the development and implementation of the monitoring program.	8 support 4 indifferent (Ken Stewart, Jenny Ljunggren, Ron MacLean, Gerry Miller)	1) Information was not presented (Ken Stewart) 2) Not sure of level of involvement. No information provided. (Jenny Ljunggren) 3) Not enough information (Ron MacLean)
6	The Consultative Committee recommends continued support from BC Hydro in maintaining and improving their ongoing communications strategy related to high flows and flooding events.	10 support 1 indifferent	1) Continue to improve through work on emergency planning (Hugh Smith) 2) Safe rationale (Geoff Clayton) 3) More involvement with outside organizations. (Jenny Ljunggren)
7	The Consultative Committee recommends that a communication protocol (or mechanism) be developed in the event that the Alouette Water Use Plan cannot be met (because of unusual circumstances) and there are allocation decisions (inter-system trade-offs) with the Stave system.	12 support	1) Communications protocol to allow input from stakeholders 2) Required (Geoff Clayton)

* Please note that totals vary as not all Consultative Committee members responded to all recommendations.

9.3 Non-Water Use Plan Related Recommendations

As mentioned, non-water use planning recommendations are not directly tied to operations and as such are considered outside the scope of Water Use Planning and likely outside the jurisdiction of BC Hydro or the Comptroller of Water Rights' ability to authorize BC Hydro (under the Water Act). For example, a suggestion that there is a need for a more comprehensive watershed management plan for the entire system. Endorsement by the Consultative Committee for any Non-Water Use Plan Recommendation does not involve any commitments on the part of any Committee member or organization, unless it is done voluntarily.

Table 9-2 summarizes the Consultative Committee's level of support for the recommendations that did not fall within the scope of the Water Use Plan Review process.

Table 9-2: Consultative Committee Support for the Non-Water Use Plan Recommendations

#	Recommendation	Support (support, can't support, indifferent) *	Specific Consultative Committee Member Comments
A	The Consultative Committee supports a review of the Alouette fertilization program; one that is not reliant on (material cost) donations from Alouette River Management Society and Corrections BC.	12 support	1) Review program – 10 year review (Hugh Smith) 2) Soon! (Jenny Ljunggren) 3) Required to hold program together (Geoff Clayton)
B	The Consultative Committee recommends the continued operation of the Mudd Creek settling pond at its current level including gravel supplementation.	12 support	1) Not a BC Hydro project. Collaborate but not BC Hydro responsibility (Hugh Smith) 2) Great silt control. BCH support for this valuable project is recognized as very beneficial for silt control (Geoff Clayton)
C	The Consultative Committee supports an endorsement letter for a Kokanee spawning behaviour study to be carried out through the BCRP.	10 support	
D	The Consultative Committee would like to see a methodology developed that is more explicit for considering and including potential Species at Risk Act issues into water use planning. *Already Completed*	9 support 2 indifferent (Jenny L. and Ron MacLean)	1) Not to do with operational changes (Jenny Ljunggren)
E	The Consultative Committee would like to see more accurate water monitoring of flows (e.g., new staff gauge) on the lower Alouette and improved safeguards in the event that minimum flows are not released from the low-level outlet (e.g., web cam, electronic monitoring, automated alarm).	10 support	1) Review needs (Chris Weyell) 2) Staff gauge? Needs an action item, i.e. review options and needs (Hugh Smith) 3) Alarm to hatchery potential? (Suzanne Thorpe) 4) Not there yet. Required for safe operation (Geoff Clayton) 5) Hatchery alarm (Lesley Elchuk)
F	The Consultative Committee recommends improved BC Hydro coordination within their operations and initiatives (e.g., corporate policies, Bridge Coastal Restoration Program and Water Use Plans). For example a more integrated monitoring program.	11 support	1) Ongoing internal reviews (Hugh Smith) 2) Too much overlap and uncertainty as to who funds what (Jenny Ljunggren) 3) Badly required (Geoff Clayton) 4) Has been recognized by BC Hydro. Doing work internally. More integrated monitoring program.
G	The Consultative Committee supports habitat enhancement initiatives on the South Alouette River.	11 support	

Table 9-2: Consultative Committee Support for the Non-Water Use Plan Recommendations cont'd

#	Recommendation	Support (support, can't support, indifferent) *	Specific Consultative Committee Member Comments
H	The Consultative Committee is concerned about impacts from the continued expansion of urban development (non-point sources of pollution) and through riparian removal by owners adversely impacting the river ecology and recommends that the responsible agencies review and address this issue.	9 support 1 indifferent (Hugh Smith)	
I	The Consultative Committee is concerned about ecosystem impacts associated with leaching and drainage of herbicides and pesticides into the river and recommends that the responsible agencies measure and address this issue.	9 support 2 indifferent (Hugh Smith, Gerry Miller)	1) BC Hydro not involved (Chris Weyell) 2) Very important to get baseline (Jenny Ljunggren) 3) Water quality tests required (Geoff Clayton)
J	The Consultative Committee recommends that BC Parks and BC Hydro establish a heritage committee to review recreation impacts on archaeological resources?	8 support 2 indifferent (Hugh Smith, Gerry Miller)	1) Seems more like a Parks action, not BC Hydro (Hugh Smith) 2) Perhaps address through Parks plan review process – if happening soon, i.e., Golden Ears Park (Jim Sheehan) 3) Check with Parks (Suzanne Thorpe) 4) Not put forward by the BC Parks representative, not well explained (Ken Stewart) 5) At no cost to BC Hydro (Jenny Ljunggren)

* Please note that totals vary as not all Consultative Committee members responded to all recommendations.

10 IMPLEMENTATION OF RECOMMENDATIONS

The operational changes recommended by the Alouette Water Use Plan Review Consultative Committee will be implemented once the Comptroller of Water Rights and government approve the Alouette Water Use Plan Review. The Comptroller of Water Rights will review the recommended Water Use Plan under provisions of the *Water Act* and will involve Fisheries and Oceans Canada, other provincial agencies, First Nations and holders of water licences who might be affected by the change. In the interim, BC Hydro will continue planning and operating based on the constraints specified under current permitted operations.

Figure 10-1 illustrates the next steps in the Alouette Water Use Planning Review process.

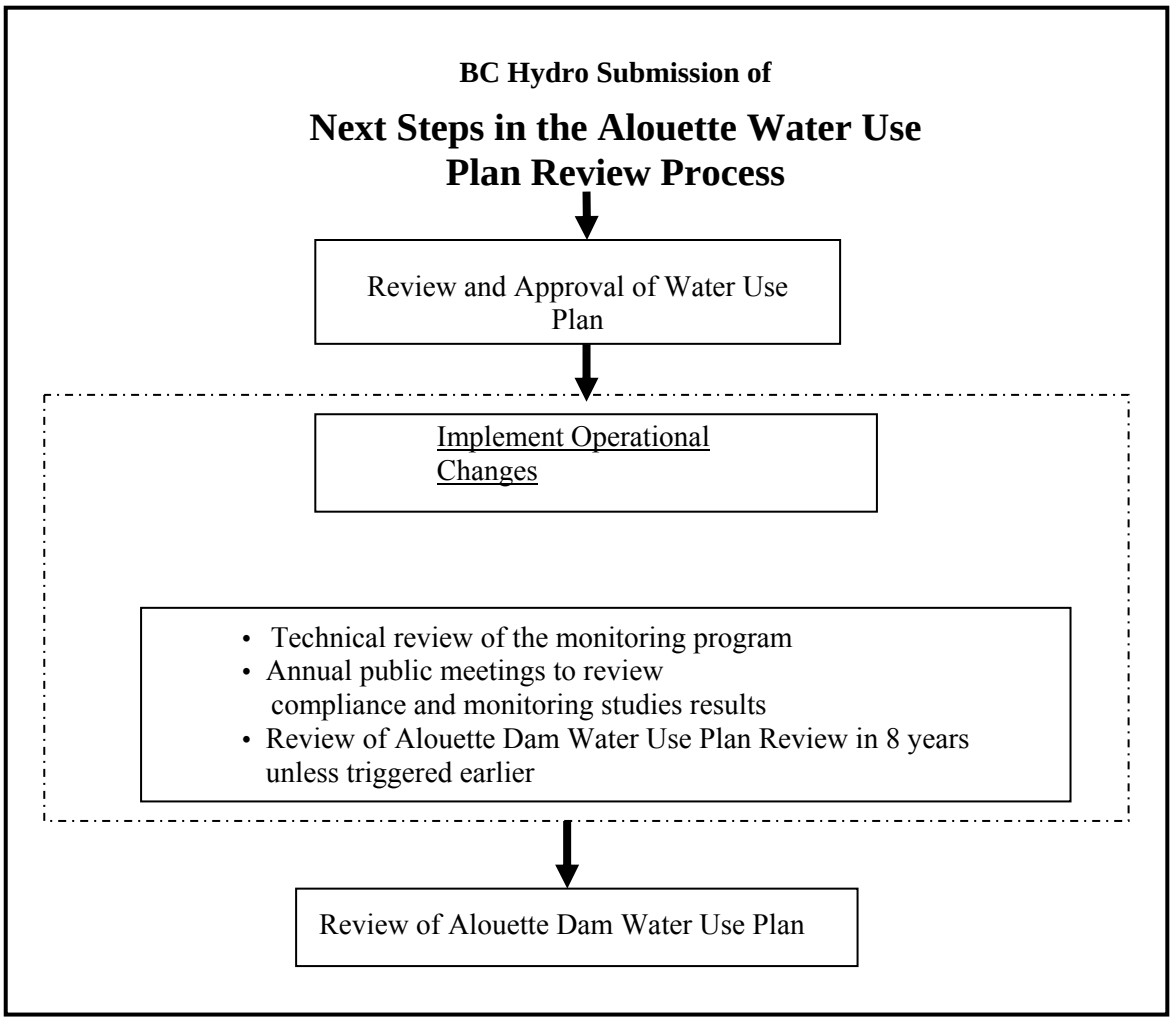


Figure 10-1: Next Steps in the Alouette Water Use Plan Review Process

The following is a summary of the review, approval and implementation process for the Alouette Water Use Plan Review:

BC Hydro will submit two documents to the provincial Comptroller of Water Rights for review and approval:

1. The Alouette Water Use Plan Review Consultative Committee Report.
2. Alouette Draft Water Use Plan.

Review and Approval of the Water Use Plan Review: As described for Step 10 of the provincial government's ***Water Use Plan Guidelines***, the government will review and issue a decision on the Alouette Draft Water Use Plan Review under provisions of the ***Water Act***. This process involves referring the draft Plan for review and comment to Fisheries and Oceans Canada, other provincial agencies, First Nations, and holders of water licences who might be affected by the changes. This review and approval process is anticipated to take approximately 6 to 12 months once the draft Plan is submitted to government. As part of the review, the government may require modifications to the draft Plan. The outcome of the review process will be a final plan authorized by the Comptroller of Water Rights.

Implement Operational Changes: Once the government has approved the Alouette Water Use Plan and the Comptroller of Water Rights has provided BC Hydro with direction, BC Hydro will implement the approved operational changes.

Implement Non-Operational (Monitoring and Physical Works) Projects: Once the Comptroller of Water Rights has provided BC Hydro with direction on the Alouette Water Use Plan, BC Hydro will:

- Review of the Alouette Water Use Plan Review will be reviewed in conjunction with the Stave River water use plan review date currently to be scheduled estimated as 2014 but may be later depending on monitoring and operational programs.

11 REVIEW PERIOD

The Consultative Committee agreed to an eight-year review period for the revised Alouette Water Use Plan after its implementation to coincide with the review of the Stave Water Use Plan. It is expected that the next Water Use Plan will be undertaken on a system wide basis in combination with the review of the Stave Water Use Plan, currently scheduled for 2014, but may be later depending on monitoring and operational programs considerations.

12 REFERENCES

BC Hydro. (1996). Alouette Generating Station: Water Use Plan. 23 pp.

BC Hydro. (2002). System Operating Order 4P-45: Alouette Project. January 2002.

BC Hydro. (2006). *Alouette Water Use Plan Review: Hydro Operations Studies*. Prepared for BC Hydro Alouette Water Use Plan Review Project. Burnaby, B.C.

Cope, Scott. (2005). *Alouette River Salmonid Smolt Migration Enumeration: 8-year Summary (1998-2005)*. Prepared for BC Hydro Alouette Water Use Plan Review Project. Burnaby, B.C. 15 pp.

Davies, Ross (2006). South Alouette River Projects Summary Report: 1995-2005. Prepared for BC Hydro Alouette Water Use Plan Review Project. Burnaby, B.C. 15 pp.

Higgins, P. (2005). An assessment of the effectiveness of flushing flows for managing fine sediment in fish habitat of South Alouette River. Draft Report. Prepared for BC Hydro Alouette Water Use Plan Review Project. Burnaby, B.C. 20 pp + App.

McDaniels Research Ltd. (1996). *The Alouette Stakeholder Committee: Process, Analysis and Recommendations*. Prepared for BC Hydro. 50 pp.

Province of British Columbia. (1998). *Water Use Plan Guidelines*. ISBN 0-7726-3731-8

Province of British Columbia. (2000). *First Nations and Water Use Planning*.

Stockner, J and J. Beer. (2004). The Limnology of Stave/Hayward reservoirs with a perspective on carbon production. Prepared for BC Hydro Environmental Services by Eco-Logic Ltd. West Vancouver. 30 pp. + App.

UMA (1996a). *Alouette Operating Plan Review Issues Identification: A Discussion Paper*. Prepared for BC Hydro. 13 pp.

UMA (1996b). *Alouette Operating Plan Review Recreation Analysis*. Prepared for BC Hydro. 23 pp.

APPENDIX A: CONSULTATIVE COMMITTEE, OBSERVERS, PROJECT TEAM AND SUBCOMMITTEES

Table A-1: Alouette Project Water Use Plan Consultative Committee

Member	Affiliation
Tom Blackbird	Ministry of Environment, Lands and Parks
Geoff Clayton	Alouette River Management Society and AMC
Ross Davies	Alouette River Management Committee
Matt Foy	Department of Fisheries and Oceans and AMC
Ron MacLean	Fraser Regional Correctional Center (ALLCO Hatchery)
Gerry Miller	Alouette Communications Task Team
Jim Sheehan	District of Maple Ridge
Craig Speirs (replaced by Ken Stewart at Meeting #3)	District of Maple Ridge
Ken Stewart	District of Maple Ridge
Greg Wilson	Ministry of Environment, Lands and Parks
Hugh Smith	BC Hydro
Chris Weyell	BC Hydro
Ken Wilson	Technical Support to Katzie First Nations
Jenny Ljunggren	Alouette River Management Society (ARMS)
Debbie Miller	Katzie First Nation and AMC

Table A-2: Alouette Project Water Use Plan Committee Member Alternates and Observers

Name	Affiliation
Suzanne Thorpe (alternate for Matt Foy)	Fisheries and Oceans and AMC
Leslie Elchuk (observer)	District of Pitt Meadows
Tumia Knott (observer)	Kwantlen First Nation
Ray Kenny (observer)	Ministry of Tourism, Sport and the Arts (Archaeology Branch)
Tony Matahlija (observer)	North Fraser Salmon Assistance Project (NFSAP)
Shannon Harris	Ministry of Environment

Table A-3: Alouette Project Water Use Plan Fisheries Technical Sub-committee Members

Member	Affiliation
Greg Wilson	Ministry of Environment, Lands and Parks
Jenny Ljunggren	Alouette River Management Society
Geoff Clayton	Alouette River Management Society and AMC
Matt Foy	Department of Fisheries and Oceans and AMC
Ron MacLean	Fraser Regional Correctional Center (ALLCO Hatchery)
Debbie Miller	Katzie First Nation and AMC
Gerry Miller	Alouette Communications Task Team
Suzanne Thorpe	Department of Fisheries and Oceans and AMC
Ken Wilson	Technical Support to Katzie First Nations
Hugh Smith	BC Hydro
Ross Davies	Alouette River Management Committee

Table A-4: Alouette Project Water Use Plan Heritage and Cultural Technical Sub-committee Members

Member	Affiliation
Tanja Hoffman	Katzie First Nation
Debbie Miller	Katzie First Nation & AMC
Mike Leon	Katzie First Nation & AMC

Table A-5: Alouette Project Water Use Plan Recreation Technical Sub-committee Members

Member	Affiliation
Susanne Thorpe	Department of Fisheries and Oceans & AMC
Gerry Miller	Alouette Communications Task Team
Tom Blackbird	Ministry of Environment, Parks
Jenny Ljunggren	Alouette River Management Society

Table A-6: Alouette Project Water Use Plan Project Team Members

Member	Affiliation
James Bruce	BC Hydro
Charlotte Bemister	BC Hydro
Chris Caryula	BC Hydro
Kathy Groves	BC Hydro
Justin Himmelright	BC Hydro
Paul Vassilev	BC Hydro
Michael Harstone	Compass Resource Management
Amy Robinson	Amy Robinson Consulting

APPENDIX B: BC HYDRO INTER-OFFICE MEMO RE: ALOUETTE WATER USE PLAN REVIEW HYDROLOGY OF ALOUETTE LAKE BASIN

BC hydro ENGINEERING

Inter-office memo

TO:	Paul Vassilev	3 November, 2005
FROM:	Chris Caryula	File: REGWUP ALC200
SUBJECT:	Alouette Water Use Plan Review Hydrology of Alouette Lake Basin	

1 INTRODUCTION

The Alouette project is most upstream in a 3 reservoir hydroelectric project with the following general characteristics:

- Alouette Dam impounds Alouette Lake Reservoir.
- Spill and other non-power releases from the Alouette Dam discharge into the Alouette River.
- Power releases from Alouette Reservoir (turbine discharge) are diverted through a 4.6 m diameter and 1067 m long tunnel to the Alouette Powerhouse (one unit, typical maximum output ~ 9 MW) located on Stave Lake Reservoir.
- Non-power releases from the diversion tunnel are discharged through an Adit Gate to Stave Lake Reservoir.
- Discharge from the Alouette Powerhouse enters Stave Lake Reservoir.

This report highlights the hydrology of the Alouette hydroelectric system. Physiography and climatology are reviewed for the Alouette Lake watershed.

Methods used to calculate reservoir inflows, such as BC Hydro's FLOCAL program, are discussed. Typical inflow hydrographs and summaries are provided. Flow records for the Alouette system referred to in this report were used in power studies conducted for the Alouette Water Use Plan Review.

Procedures used to provide daily and seasonal inflow forecasts are also described.

wr499

2 BASIN DESCRIPTION

2.1 Physiography[1]

The Alouette drainage basin is adjacent to the western boundary of the Stave watershed as shown in Figure 1.

Alouette has a drainage area of 202 km^2 that ranges in elevation from 120 m to 1800 m. The median basin elevation is 650 m as indicated in the hypsometric curve shown in Figure 2. The curve defines the percentage of the watershed above or below a given elevation.

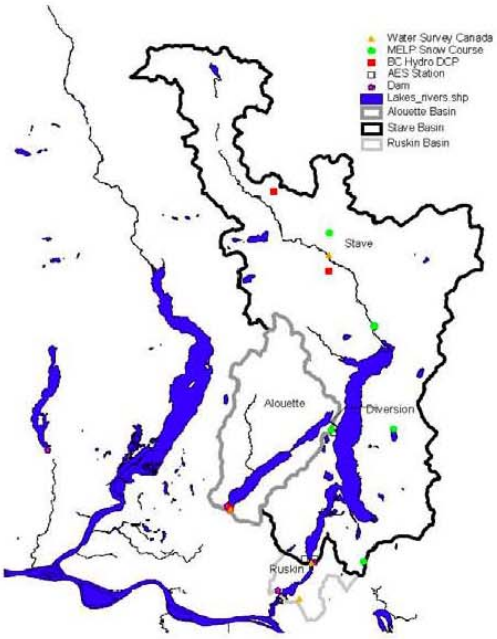


Figure 1 : Location Map and Hydrometeorological Stations

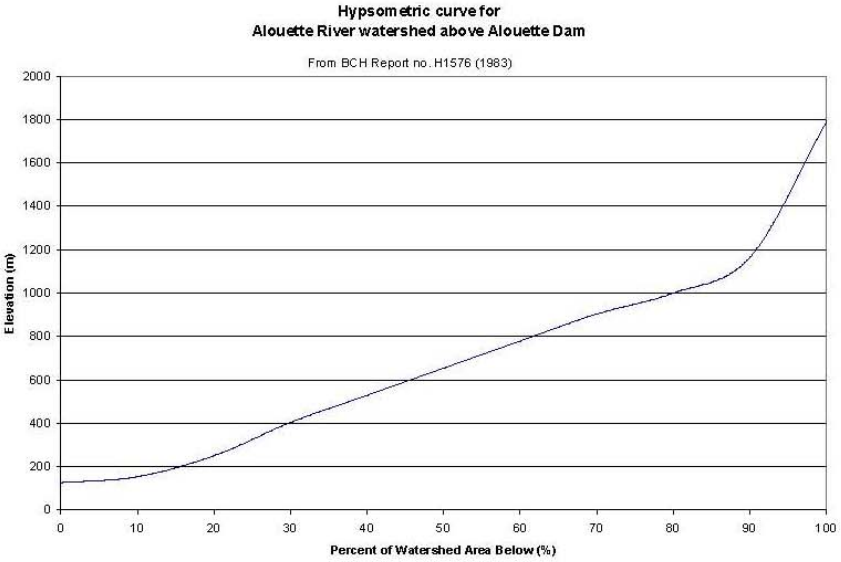


Figure 2: Hypsometric curve for the Alouette River Watershed

[1] Basin information obtained from BC Hydro "Stave Falls Project: Probable Maximum Flood", BC Hydro Hydroelectric Generation Projects Division, Report No. H1588, September 1983

wr499

Flows from Alouette Lake Reservoir are either diverted through a diversion tunnel to a power plant located on Stave Lake Reservoir, or are allowed to spill past Alouette Dam down the Alouette River. Approximately 94 % of annual inflow to Alouette Lake Reservoir is diverted through the diversion tunnel to Stave Lake Reservoir, based on 1984 to 2000 data.

Alouette Lake Reservoir, which is impounded by Alouette Dam, is approximately 16 km long. The stage-storage relationship shown in figure 3 indicates the storage capacity of the reservoir at different reservoir elevations. Storage of an estimated 198 million cubic metres is available between the minimum and maximum operating levels of 112.60 m and 125.50 m, respectively[2]. Storage available between the normal operating range[3] of 116.0 m and 125.5 m is estimated from the stage-storage curve at about 149 million cubic metres.

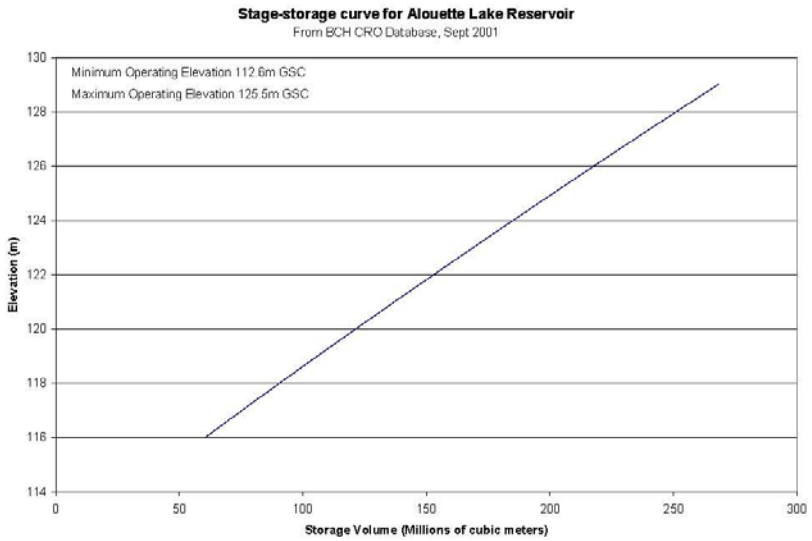


Figure 3: Stage-storage relationship for Alouette Lake Reservoir

[2] Water Licence #7148

[3] BC Hydro, "System Operating Order 4P-45 – Alouette project", October 1997

wr499

2.2 Climatology

The major source of precipitation in the Alouette Lake Reservoir drainage basin during the fall and winter months comes from frontal southwesterly flows of warm moist air aloft. The abrupt rise of the Coast Mountains above the flat or rolling topography of the Lower Fraser Valley has a significant influence on this moist air. Strong orographic lifting provides the primary mechanism whereby moisture aloft is converted to basin precipitation.

In contrast, sources of precipitation in the summer are generally from weak frontal or convective storms. About one third of the annual precipitation occurs from these weak weather systems during the six-month warm period from April through September. Summer frontal or convective storms strong enough to initiate heavy rainfall in the order of 100 mm in a 24-hour period occur relatively infrequently.

Figure 4 shows a bar chart of historic monthly precipitation at the Stave Upper data collection platform (DCP). The station elevation is 930 m. Minimum and maximum monthly precipitation is indicated to illustrate the variability in the data. As can be seen from the plot, about two-thirds of the annual precipitation normally falls between the six months from October to March.

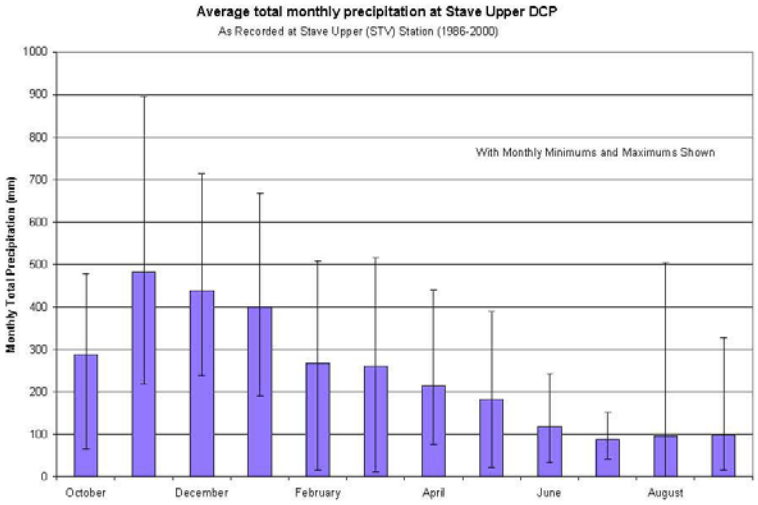


Figure 4: Maximum, mean and minimum monthly precipitation at Alouette watershed

wr499

- 5 -

Figure 5 shows maximum, mean, and minimum daily temperatures at Stave Upper DCP. Because temperature generally decreases with increasing elevation, much of the precipitation falls in the form of snow at higher elevations during the winter months.

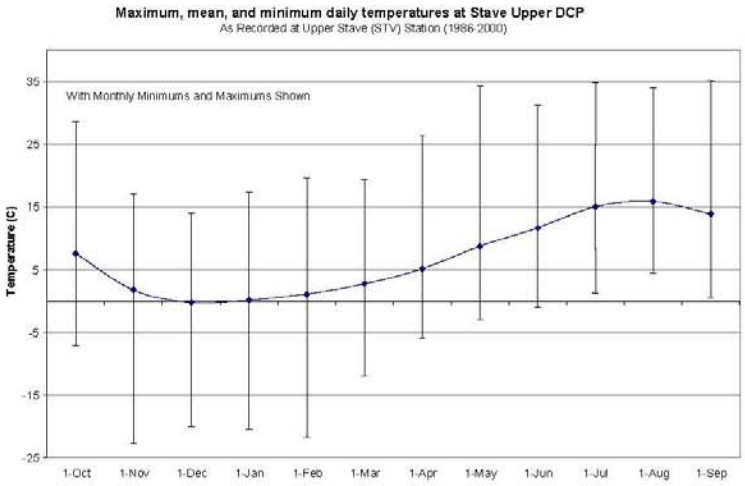


Figure 5: Maximum, mean and minimum daily temperature at Alouette watershed

Figure 6 shows the maximum, mean, and minimum snow water equivalent for Stave Lake snow course (1D08) located at 1210 m elevation.

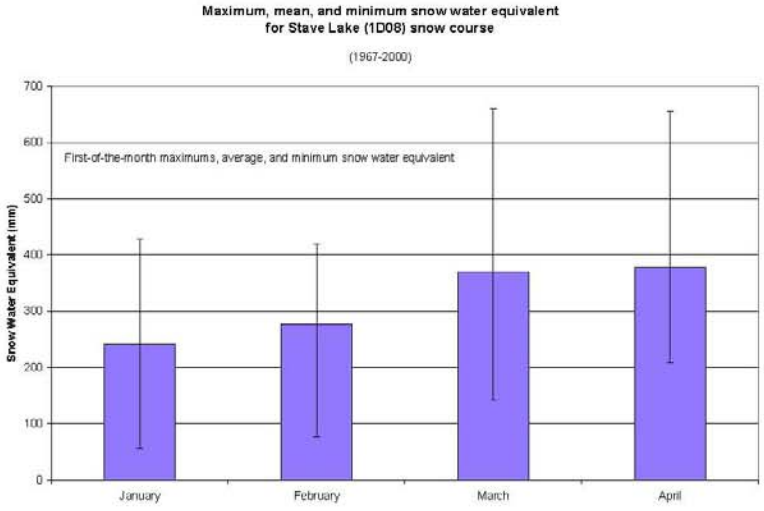


Figure 6: Maximum, mean, and minimum snow water equivalent for Stave Lake (1D08) snow course

wr499

3 RESERVOIR INFLOWS

3.1 Inflow calculations

Reservoir inflow calculations: Inflow is the volume of water entering a reservoir within a given period of time. Reservoir inflows are calculated rather than measured directly. Daily inflows may be derived from mean daily discharge from the reservoir and change in reservoir storage over a period of 24 hours. The generic formula is:

$$INFLOW = OUTFLOW + \Delta\ STORAGE \quad \ldots\ldots (1)$$

where INFLOW = average inflow over a one - day period
OUTFLOW = average outflow over a one - day period
Δ STORAGE = S2 - S1, where
S2 = reservoir storage at the end of the day
S1 = reservoir storage at the end of the previous day

Reservoir storage for a specific reservoir elevation is derived from a stage – storage curve unique to each reservoir.

The nature of the calculation of inflows can result in "noisier" hydrographs than observed at unregulated, natural river channels. Noisy inflows can arise due to various sources of error, such as wind set up on the reservoir, resolution of elevation measurements, errors in reservoir elevation readings, errors in outflow measurements through turbines, spillways or valves, errors in stage-storage curves and errors in the rating curves for various outlet facilities. The impact of noise tends to reduce as the time interval over which inflow is computed increases.

Storage relationships: The Storage relationships used to determine the volume of water in Alouette Lake Reservoir is shown in Figure 3.

Outflow relationships: Flow through turbines at the Alouette powerhouse is computed based on megawatt output and hydraulic head. "Hydraulic head" is a measure of the vertical distance between the water level in the reservoir and the water level immediately below the turbine outlet. Power output is proportional to head and turbine discharge. A generic relationship between these variables is shown in Figure 7.

wr499

- 7 -

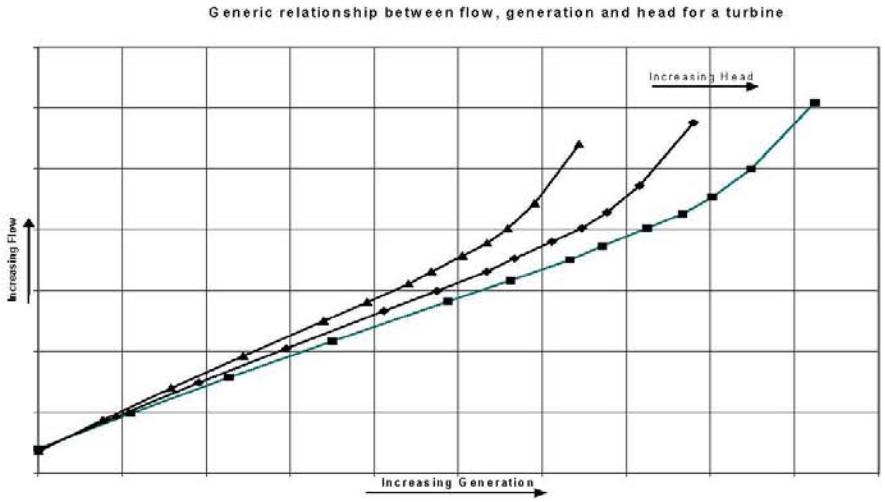


Figure 7: Generic relationship between flow, generation, and head for a turbine

"Rating curves" show the relationship between flow, opening, and elevation for a given release device. A rating curve for spill facilities at Alouette Dam is shown in Figure 8.

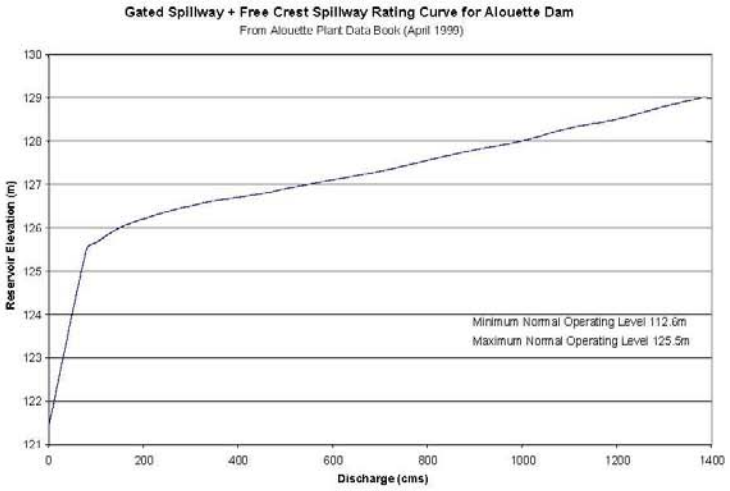


Figure 8: Rating curve for Alouette Dam

Data records: BC Hydro computes inflow using a computer program called FLOCAL. Specifically;

Inflows to Alouette Lake Reservoir are computed based on equation (1).

wr499

Various information, including gate openings, reservoir and tailwater elevations, energy, spill, turbine flows, and inflows are stored in FLOCAL. A FLOCAL configuration for the Stave River system is shown in Figure 9.

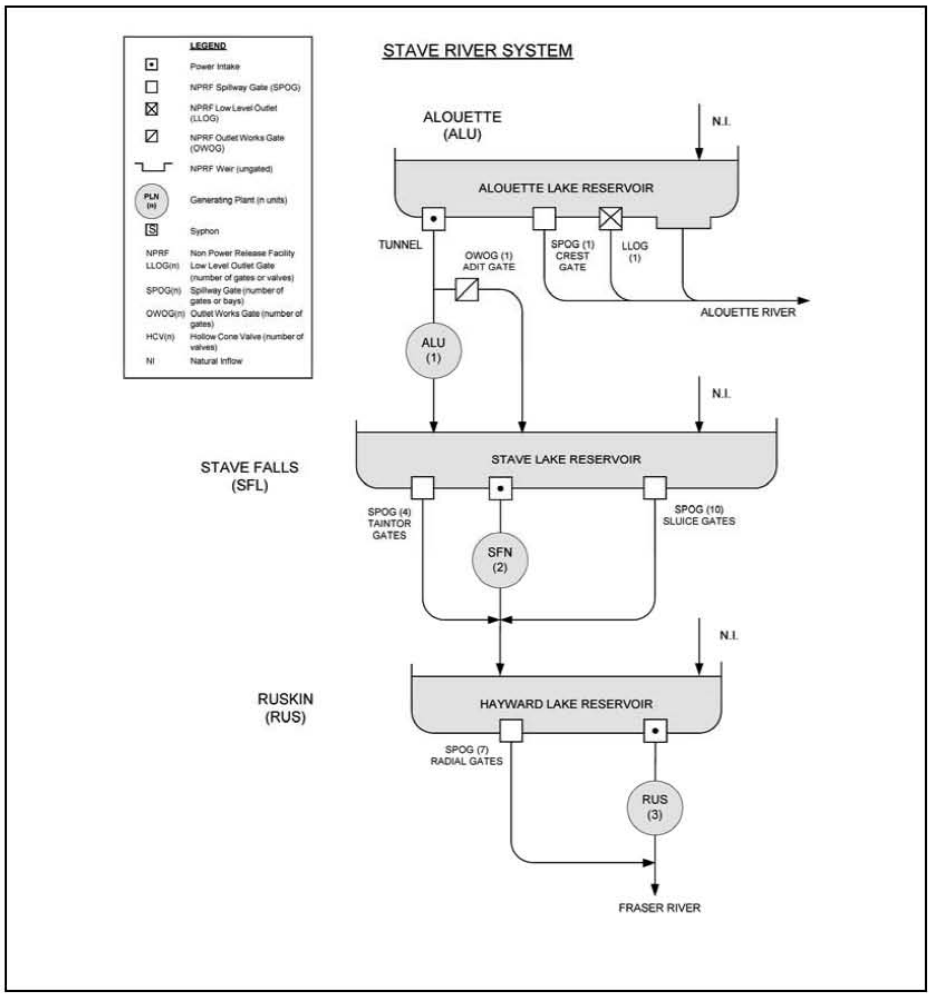


Figure 9: Schematic of the FLOCAL configuration for the Stave River system

wr499

3.2 Reservoir inflow characteristics

Figure 10 shows "spaghetti plots" of historical inflows to the Alouette project. The 10th, 50th and 90th percentile inflows are shown in bold.

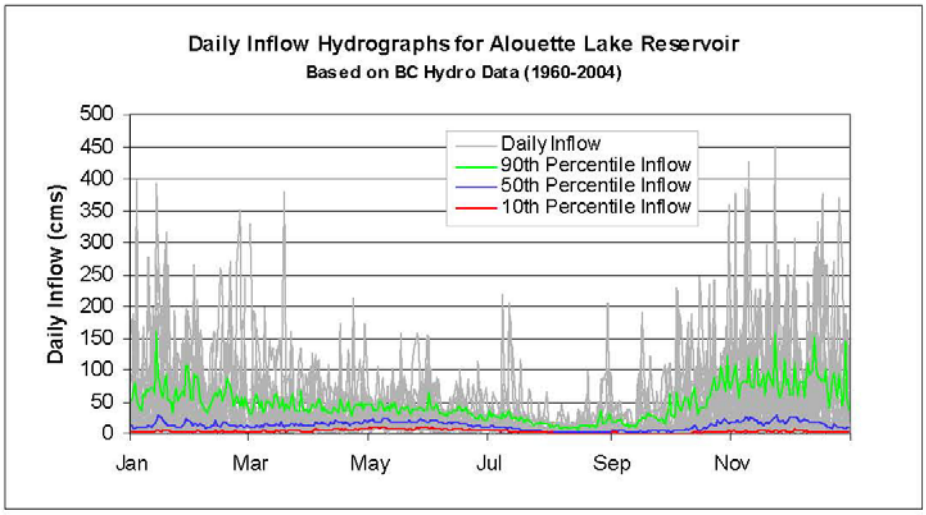


Figure 10: Historical Daily Inflows to Alouette Lake Reservoir

Figure 11 and Table 1 summarizes the daily inflows by month. Average monthly and maximum and minimum daily inflows are shown to highlight the variability of inflows to the project.

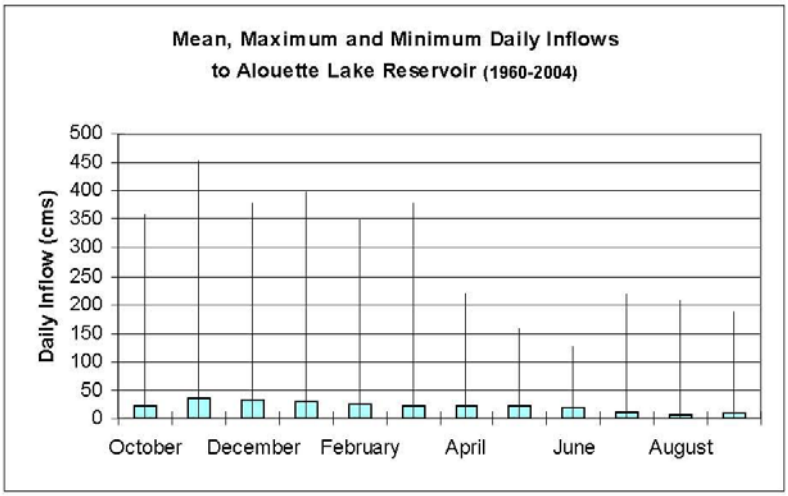


Figure 11: Variability in Alouette Project's daily inflows

wr499

Table 1: Alouette Project's daily inflows (1960-2004)

Month	Mean	Maximum	Minimum
October	11	218	0.40
November	6	206	0.01
December	9	189	0.06
January	23	360	0.06
February	35	452	0.08
March	32	378	0.06
April	30	397	0.15
May	24	351	0.12
June	22	379	0.17
July	22	221	0.17
August	23	156	0.17
September	19	126	0.96

wr499

A "flow duration curve" indicates the percent of time that a flow is greater than a given discharge. Figure 12 shows a flow duration curve of daily inflows for the years 1960-2004; it illustrates the large range and variability of inflows.

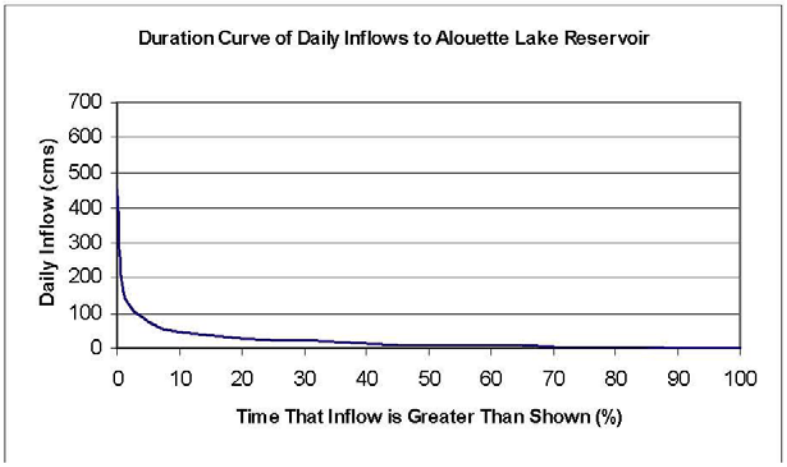


Figure 12: Duration curves of daily inflows to Alouette Lake Reservoir

Figure 13 shows a duration curve for annual inflow volume.

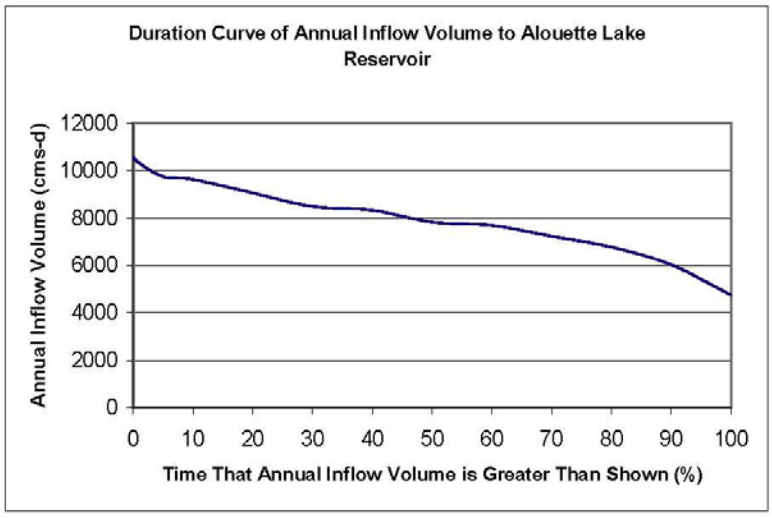


Figure 13: Duration curve of annual volume to Alouette Lake Reservoir

wr499

Figure 14 shows a comparison between the mean annual local inflow and total live storage available at a number of project reservoirs.

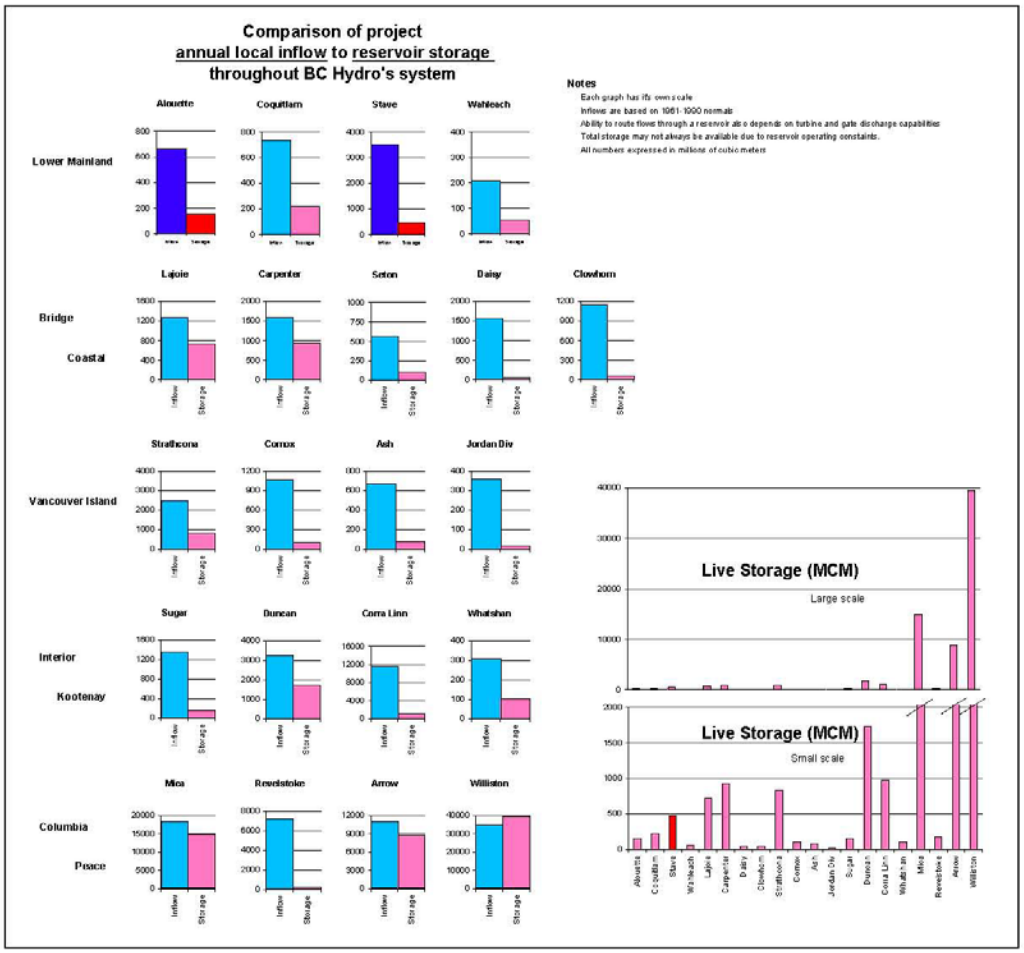


Figure 14: Comparison of project annual inflows to reservoir storage throughout BC Hydro's system

wr499

4 OPERATIONAL INFLOW FORECASTING

BC Hydro's Resource Management produces two main types of hydrologic forecasts: daily and seasonal inflow forecasts for the Alouette project.

Daily inflow forecasts: Inflow forecasts are short-term forecasts that indicate the inflow expected over the next few hours or days. These forecasts are used to plan hydroelectric power scheduling and flood control, for optimum use of available water resources.

Each morning of each working day, the forecast team forecasts the daily inflow for the next five days. The River Forecast System (RFS) software produces these forecasts using the UBC watershed model. For a given watershed, the model simulates basin state conditions, such as the snowpack, groundwater, and soil moisture. Then using forecasts of daily precipitation, and minimum and maximum temperatures over the next five days, the model simulates the various components of the runoff, which include rainfall and snowmelt runoff, glacier melt, and baseflow. Together, these components represent the expected inflow hydrograph for the reservoir.

Seasonal inflow forecasts: Seasonal inflow forecasts estimate the volume of water that is expected to flow into the Alouette system during a given period. BC Hydro typically produces forecasts for the period February through September. The forecasts are updated on the first of each month from January 1 to August 1.The ability to forecast seasonal runoff for this period lies in the fact that a significant portion of the runoff during the forecast period is the product of snowmelt runoff. By measuring snow water equivalent in the mountain snowpack, as well as other parameters such as precipitation and streamflow up to the forecast date, a more accurate estimate of future runoff can be made than one based on historical inflow data alone. To produce Alouette water supply forecasts, BC Hydro uses a regression-based statistical Volume Forecast model (VOLCAST), which is currently updated to the Volume Distribution and Calculation model (VoDCA). With the increased usage of computer-based watershed models, such as the UBC Watershed Model, a second method of forecasting runoff volume is available.

wr499

5 HYDROMETEOROLOGIC NETWORK

Hydrometeorological data is required to plan, monitor, and operate facilities in the Alouette system's watershed. Characteristics of the hydrometeorological data collection stations in the watershed are summarized in Tables 2-4. Locations of hydrometeorological stations are shown in Figure 1.

Table 2: Hydrometeorological stations used for RFS daily forecasting

Station	Type	ID	Elev (m)	Latitude	Longitude	Characteristics[4]
Alouette Lake Forebay	DCP	ALU	125	49°17'	122°29'	T, P
Abbotsford Airport	AES	YXX	61	49°02'	122°22'	P
Gold Creek	DCP	GOC	794	49°23'	122°58'	P
Stave Falls	DCP	STA	330	49°32'	122°19'	P

Table 3: Hydrometeorological stations used for VOLCAST seasonal forecasting

Station	Type	ID	Elev (m)	Latitude	Longitude	Characteristics[4]
Abbotsford Airport	AES	YXX	61	49°02'	122°22'	P
Alouette Lake Forebay	DCP	ALU	125	49°17'	122°29'	T, P
Stave Falls	DCP	STA	330	49°32'	122°19'	T, P
Coquitlam Lake	DCP	COQ	160	49°21'	122°46'	T, P
Stave Lake	S	1D08	1210	49°35'	122°19'	SWE
Nahatlatch River	S	1D10	1520	49°50'	122°03'	SWE
Grouse Mountain	S	3A01	1100	49°23'	123°05'	SWE
Palisade Lake	SP	3A09P	880	49°27'	123°02'	SWE
Dog Mountain	S	3A10	1080	49°23'	122°58'	SWE

Table 4: Other stations used for operations

Station	Type	ID	Elev (m)	Latitude	Longitude	Characteristics[4]
Alouette River near Haney	WSC	08MH005	N/A	49°14'	122°34'	Q

Prepared by: _____
C. Caryula, AScT, EIT

Reviewed by: _____
K. Groves, P. Eng.

[4] Characteristics: Temperature (T), Precipitation (P), Snow water equivalent (SWE), Flow (Q)

wr499

APPENDIX C: ADVERTISEMENT FOR THE WATER USE PLANNING PROCESS

BC hydro

Alouette Water Use Plan Review

BC Hydro is undertaking a review of its Alouette Water Use Plan (WUP), completed and implemented in 1996. The WUP considers the interests in the watershed that may be impacted by BC Hydro's Alouette Reservoir operations, such as fisheries habitat, recreation, power, flood control and cultural interests, and strives to achieve operations that meets the needs of these uses.

One of the recommendations of the plan was that it be reviewed in ten years to ensure that the new operating parameters that were put in place are successful and meeting their objectives.

To complete this review, BC Hydro has asked the Alouette Management Committee (AMC) to form the basis for the consultative committee. The AMC is a multi-stakeholder committee that was formed as part of the original WUP implementation to oversee studies and monitor the plan. To complement the AMC, a few key stakeholders have been invited to join the review.

This review is expected to take about five main table meetings – all-day sessions from 9:00 a.m. to 4:30 p.m.

Organizations involved in this review of the Alouette Water Use Plan include:

- Alouette River Management Society
- Alouette Communications Task Team
- BC Hydro
- Districts of Maple Ridge and Pitt Meadows
- Fraser Regional Corrections Center Allco Hatchery
- Fisheries and Oceans Canada
- Katzie First Nation
- Ministry of Environment (Fisheries and Parks)
- Public representatives

Observers are welcome to attend meetings, but must RSVP to Chris Joy at 604 528-2357 to confirm meeting dates, location and space availability.

If you have any questions, please contact Charlotte Bemister, BC Hydro Community Relations Coordinator, at 604 528-2354 or use the toll-free project information line at 1 800 663-1377.

At BC Hydro, our purpose is to keep B.C.'s electricity reliable and low cost for generations.

A05-543

www.bchydro.com

for generations

Publication: Maple Ridge - Pitt Meadows News
Size: 3 col (5.625") x 85 lines
Insertion date: Nov 26 and 30th

APPENDIX D: CONSULTATIVE COMMITTEE TERMS OF REFERENCE

1.0 INTRODUCTION

The purpose of the Terms of Reference is to ensure that participants of the Alouette WUP Review process have a clear understanding of their purpose and responsibilities, to provide assurance that public values will be integrated into resource management decisions, and enhance the smooth functioning of the Committee work.

2.0 CONSULTATIVE COMMITTEE PURPOSE

The broad consultative purpose is to integrate public values into water flow management decisions related to BC Hydro operations. The specific Committee purpose is to provide clearly documented value based recommendations for consideration by BC Hydro when preparing their Water Use Plan (WUP) for the Alouette facilities. The objective of the Committee will be to recommend:

- A preferred operating regime (or range of regimes) for the facilities, considering allocation of water to different water uses (e.g., flood control, fisheries, power generation, traditional use, aquatic ecosystem 'health', recreation, etc.),
- Criteria for a monitoring and assessment program, where required, and
- Timing for periodic review of the Alouette Water Use Plan.

Consensus is a goal, but not a requirement of the WUP process. Consensus is defined in the WUP Guidelines as a decision in which the participants can accept, without having to agree to all the details of the operating regime. Where the process identifies a preferred operating alternative (consensus), documentation will include areas of agreement, as well as areas of contention, and the underlying tradeoffs between alternative water uses. Where no preferred operating alternative is identified (non-consensus), documentation will record that agreement was not reached, and indicate differences of opinion and reasons for disagreement.

3.0 CODE OF CONDUCT

All participants of the Alouette Water Use Plan Review will endeavour to:

- Support an open and inclusive process
- Treat others with courtesy and respect
- Listen attentively with an aim to understand
- Be concise in making your point
- Speak in terms of interests instead of positions
- Be open to outcomes, not attached to outcomes

- Challenge ideas, not people
- Let opposing views co-exist
- Avoid disruption of meetings (e.g., cell phones, caucusing at the table, etc.)
- Use the "parking lot" for issues that fall outside the day's agenda
- Aim to achieve consensus on issues being addressed

The facilitator will ensure that the code of conduct is followed by Consultative Committee members.

4.0 PROCESS

4.1 Committee Tasks

The Committee will achieve its purpose by undertaking Steps 4 to 8 of the *Water Use Plan Guidelines*. In summary these include:

- Confirm issues and interests in terms of specific water use objectives along with quantitative and/or descriptive measures for assessing their achievement
- Identify existing information and information gaps related to the impacts of water flows, and their timing, on each objective
- Create alternative operating regimes to compare impacts on water use objectives
- Assess the tradeoffs between alternative operating regimes in terms of objectives
- Determine and document areas of agreement and disagreement

4.2 Procedure in the Event of Disagreement

The following interest-based negotiation steps will be used as a tool for resolving issues:

- Define the issue
- Identify interests
- Brainstorm options
- Evaluate options
- Choose an option

Interests are defined as the needs, wants, fears and concerns that are connected to an issue. Positions are defined as a predetermined solution to a problem without consideration for the interests of others.

5.0 DELIVERABLE

A *Consultation Report*, signed off by the participants, documenting the overall process; water use interests, objectives and performance measures; information collected, operating alternatives reviewed, trade-off assessment, and areas of final agreement and disagreement.

The target date for the delivery of this report is Winter 2006.

6.0 WATER USE PLAN PREPARATION, REVIEW, AND APPROVAL

Recommendations in the *Consultation Report* will be fully considered by BC Hydro as they prepare the Draft Water Use Plan for the Alouette facilities. A copy of the draft Water Use Plan, prepared by BC Hydro, will be distributed to the Consultative Committee.

The Draft Water Use Plan and the Consultative Report will be submitted to the BC Comptroller of Water Rights. The Comptroller will coordinate a final regulatory review and approval as outlined in the Water Use Plan Guidelines.

The target date for the delivery of this report is Winter/Spring 2006.

7.0 MEMBERSHIP

7.1 Committee Membership

The Alouette WUP Review Consultative Committee has been established in accordance with Steps 2 and 3 of the WUP Guidelines. Committee Members represent a broad range of interests affected by the operations of the Alouette facilities.

7.2 Alternates

Committee Members can designate Alternates (either a non-Committee Member or another Committee Member) to represent them when they are unable to attend a meeting or on issues where an Alternate has more relevant knowledge or experience.

Members should ensure that their Alternate is familiar with these Terms of Reference, the *Water Use Plan Guidelines* and is up-to-date on the issues and decisions that have been made. Alternates who attend meetings should ensure that the Committee Member is updated on all issues that were discussed.

7.3 New Members

Only under rare conditions will any individuals or organizations be considered to apply to become Consultative Committee Members by:

- Submitting a request for Committee Membership to the BC Hydro process coordinator. The process coordinator will inform and make a recommendation to the Committee at their next meeting on the merits of expanding the membership.

- Applicants must be present at the meeting where the application is considered and be prepared to describe the interests they represent and the reasons why they believe those interests are not adequately represented in the process.
- Committee Members will consider new applications based on the principle of a fair, open and inclusive process.

New Committee Members will be required to:

- Abide by the terms of reference
- Become familiar with past work completed by the Committee
- Accept agreements previously made by the Committee

7.4 Observers and Guests

WUP Observers are included in the Communications distribution list, receiving all communications including meeting notices, information packages, agendas and minutes. WUP Observers are not full Committee Members and thus do not participate fully in discussions, do not sit at the main table, and do not participate in the tradeoff and decision activities. Observers may, by decision of the Committee, be given opportunity to provide input into the discussions of the Committee.

Guests may be invited to attend meetings to provide a technical presentation or respond to questions on a subject that is relevant to the development of the Alouette Water Use Plan. Such presentations must be pre-arranged as an agenda item with the Facilitator and/or the BC Hydro Communications representative.

Observers and guests will not participate in making Committee decisions.

8.0 ROLES AND RESPONSIBILITIES

8.1 Committee Members

In addition to following the code of conduct, participants of the Alouette WUP Review are responsible for:

- Attending and openly participating in Consultative Committee meetings. Given the short timeline for the Alouette process and the fact that there will only be four or five meetings held, Committee members who miss more than one meeting, without providing an Alternate, may be moved into the Observer role;
- Articulating their interests with respect to water use;
- Reviewing relevant information and coming to meetings prepared;
- Making recommendations concerning study/research work;
- Exploring the implications of a range of operating alternatives;
- Seeking areas of agreement;

- Ensuring continuity in representation, through the use of a designated Alternate and / or provision of advance comments or information to the facilitator in the event of an expected absence;
- Being accountable to constituents, other Committee Members and the general public;
- Keeping constituents current on progress and decisions of the Committee; and
- Signing off on the final Consultation Report provided it is a true and accurate record of the Alouette WUP Review Committee process, documenting decisions and all areas of agreement and disagreement.

8.2 Facilitator

In addition to following the code of conduct, the Facilitator is responsible for:

- Aiding the Consultative Committee in achieving its purpose and associated tasks (i.e., undertaking Steps 4 to 8 of the Water Use Plan Guidelines);
- Making every endeavour to ensure that all parties are heard and that all differences are resolved fairly, without unnecessary delay or expense;
- Making every endeavour to be, and remain, completely impartial between the parties, according equal attention and courtesy to all persons involved; and
- Assisting with the *Consultation Report* for review and sign off by the Consultative Committee.

8.3 BC Hydro Project Team

A BC Hydro Project Team has been established to assist with the work of the Consultative Committee. In addition to following the code of conduct, the BC Hydro Project Team is responsible for assisting and taking the lead role in technical support for the Committee. This includes working with the entire Committee, internal BC Hydro resources and external resources including the regulatory agencies, local resources and experts in:

- Managing and resourcing the process to maintain an acceptable time schedule;
- Compiling and providing existing data and information;
- Establishing the scope, limits and boundaries for proposed studies; and
- Arranging and managing studies for collection of new data and information.

The BC Hydro Project Team is also responsible for assisting with administrative tasks, which include:

- Arranging meetings;
- Preparing and distributing the meeting minutes of Committee meetings or any sub-committee, working table or technical work group meetings. Meeting minutes shall focus on content, not people. All such notes will be distributed directly to each Committee Member, designated Alternates and observers and guests. Committee Members may distribute minutes and materials to their constituents only after they have been formally accepted and finalized by the Committee;
- Arranging for facilitation services (as necessary);
- Maintaining a database of interested parties who are to receive copies of meeting notes and other written materials;
- Distributing meeting notes and supporting materials;
- Developing and maintaining communication links with interested parties;
- Producing and issuing all communications materials;
- Supporting report and document preparation and copying;
- Assisting with preparation and presentation of the *Consultation Report*; and
- Presenting the Draft Water Use Plan to the Consultative Committee.

9.0 WORKING GROUPS

To expedite the completion of tasks identified by the Committee, Working Groups may be established to undertake work between Committee meetings.

Working groups will:

- Be open to all Members, who will be notified in advance of any meeting;
- Schedule meetings to optimize opportunities for attendance;
- Offer opportunity for input from Members who cannot make a scheduled meeting;
- Include non-Committee Members, such as technical or scientific experts, as appropriate;
- Include a facilitator as required; and
- Prepare options and/or recommendations for consideration by the Committee.

Working groups will not make decisions on behalf of the Committee.

10.0 PUBLIC COMMUNICATION

The following procedure will be followed with respect to public communication:

- Committee meetings will be open to the public *space permitting* and coordinated through the facilitator in advance;
- Media requests will be dealt with on a case-by-case basis at the preceding Committee meeting;
- Members will coordinate media materials through BC Hydro's Community Relations representative and—*in advance*—to the Committee. When this is not possible (e.g., on the spot interviews), Members will report back and update the Committee;
- Newsletters, press releases or media updates describing the process and its progress will be prepared on a periodic basis by BC Hydro;
- Committee Members will describe their points of view as interests rather than positions and will not criticize or discredit the process or the views of others when communicating with the broader public with respect to the process; and
- Where needed, the Committee will select an appropriate spokesperson, such as the facilitator or BC Hydro communications, to represent the Committee.

APPENDIX E: CONSULTATIVE COMMITTEE SCHEDULE OF MEETINGS AND ACTIVITIES

MEETINGS

Public Meetings

20 September 2005 – Alouette River Management Society Heritage Centre

Consultative Committee Meetings

11 October 2005 – Alouette River Management Society Heritage Centre

10 November 2005 – Katzie First Nations Band Office

19 January 2006 – BC Hydro Edmonds

2 March 2006 – Westwood Plateau Golf & Country Club

Fisheries Technical Subcommittee Meetings

9 November 2005 – Katzie First Nations Band Office

24 November 2005 – Katzie First Nations Band Office

1 December 2005 – Katzie First Nations Band Office

9 February 2006 – Alouette River Management Society Heritage Centre

Heritage Technical Subcommittee Meetings

28 September 2005 – Katzie First Nations Band Office

8 December 2005 – Katzie First Nations Band Office

20 February 2005 – Katzie First Nations Band Office

Recreation Technical Subcommittee Meetings

1 December 2005 – Alouette River Management Society Heritage Centre

Activities

The Heritage Technical Sub-Committee (HTC) visited the Alouette Reservoir December 12 and 13, 2005 to revisit known sites and map their elevations, check for high potential areas, and look for pictographs on rock bluffs.

APPENDIX F: DOCUMENTS GENERATED BY THE ALOUETTE WATER USE PLANNING PROCESS

Consultative Committee Meetings

Alouette Water Use Plan Review: Summary Notes – Public Meeting #1, 11 October 2005

Alouette Water Use Plan Review: Summary Notes – Consultative Committee Meeting #1, 20 October 2005

Alouette Water Use Plan Review: Summary Notes –Consultative Committee Meeting #2, 10 November 2005

Alouette Water Use Plan Review: Pre-Reading Package for Consultative Committee Meeting #3, 19 January 2006

Alouette Water Use Plan Review: Pre-Reading Package for Consultative Committee Meeting #4, 2 March 2006

Alouette Water Use Plan Review: Summary Notes – Consultative Committee Meeting #4, 2 March 2006

Technical Sub-Committee Meetings

Meeting Minutes, Alouette Water Use Plan Review Project, Fisheries Technical Sub-Committee Meeting #1, 9 November 2005

Meeting Minutes, Alouette Water Use Plan Review Project, Fisheries Technical Sub-Committee Meeting #2, 24 November 2005

Meeting Minutes, Alouette Water Use Plan Review Project, Fisheries Technical Sub-Committee Meeting #3, 5 December 2005

Meeting Minutes, Alouette Water Use Plan Review Project, Fisheries Technical Sub-Committee Meeting #4, 9 February 2006

Meeting Minutes, Alouette Water Use Plan Review Project, Heritage Technical Sub-Committee Meeting #1, 28 September 2005

Meeting Minutes, Alouette Water Use Plan Review Project, Heritage Technical Sub-Committee Meeting #2, 8 December 2005

Meeting Minutes, Alouette Water Use Plan Review Project, Heritage Technical Sub-Committee Meeting #3, 20 February 2006

Meeting Minutes, Alouette Water Use Plan Review Project, Recreation Technical Sub-Committee Meeting #1, 1 December 2005

Memos

BC Hydro Inter-office memo from Paul Vassilev to Chris Caryula, re: Substrate Flushing Flow Operations Scenario, 17 January 2006.

BC Hydro Inter-office memo from Paul Vassilev to Chris Caryula, re: Alouette Water Use Plan Review Hydrology of Alouette Lake Basin, 3 November 2005.

BC Hydro WUP Technical Memo from James A. Bruce to Alouette WUP Review Consultative Committee, subject: Pitt Meadows Flood Control Issues, 30 January 2006

BC Hydro WUP Technical Memo from James A. Bruce to Alouette WUP Review Consultative Committee, subject: SARA species considerations in the Alouette WUP review process. 10 February 2006.

BC Hydro WUP Technical Memo from James A. Bruce to Alouette WUP Review Consultative Committee, subject: Alouette Lake Reservoir summer temperature profiles. 21 November 2005

BC Hydro WUP Technical Memo from James A. Bruce to Alouette WUP Review Consultative Committee, subject: River temperature data. 22 November 2005.

BC Hydro WUP Technical Memo from James A. Bruce to Alouette WUP Review Consultative Committee, subject: Habitat curves. 23 November 2005

Reports

BC Hydro. (2005). *Framing Issues into Objectives*. Prepared for the Consultative Committee of the Alouette Water Use Plan Review.

BC Hydro. (2005). *Scoped Issues*. Prepared for the Consultative Committee of the Alouette Water Use Plan Review.

BC Hydro. (2006). *Alouette Water Use Plan Review: Hydro Operation Studies.* BC Hydro Report E460. Prepared for the Consultative Committee of the Alouette Water Use Plan Review. 60 pp. + App.

BC Hydro. (2005). Operations Summary Report. Prepared for the Consultative Committee of the Alouette Water Use Plan Review. 23 pp.

Cope, Scott. (2005). *Alouette River Salmonid Smolt Migration Enumeration: 8-year Summary (1998-2005)*. Prepared for BC Hydro Alouette Water Use Plan Review Project. Burnaby, B.C. 15 pp.

Davies, Ross (2006). *South Alouette River Projects Summary Report: 1995-2005.* Prepared for BC Hydro Alouette Water Use Plan Review Project. Burnaby, B.C. 15 pp.

Higgins, P. (2005). *An assessment of the effectiveness of flushing flows for managing fine sediment in fish habitat of South Alouette River.* Draft Report. Prepared for BC Hydro Alouette Water Use Plan Review Project. Burnaby, B.C. 20 pp + App.

Bruce, J. A. (2005). Alouette River Fish Habitat Monitor: A Test of the Dynamic Equilibrium Hypothesis. Draft Report. Prepared for BC Hydro Alouette Water Use Plan Review Project. Burnaby, B.C. 27 pp.

BC Hydro. (2005). Inclusion of Traditional Ecological Knowledge in the Alouette Water Use Planning Framework. Prepared for BC Hydro Alouette Water Use Plan Review Project. Burnaby, B.C. 7 pp.

Other

BC Hydro. (2005). *Alouette WUP Review: Consultative Committee Terms of Reference.* Prepared for the Consultative Committee of the Alouette Water Use Plan Review.

BC Hydro. (2006). *Alouette Monitoring Committee Terms of Reference.* Prepared for the Consultative Committee of the Alouette Water Use Plan Review.

BC Hydro. (2006). *Alouette WUP Review: Monitoring Program Terms of Reference.* Prepared for the Consultative Committee of the Alouette Water Use Plan Review.

French, C. (2005). Detailed Bathymetric map of Alouette Lake Reservoir. Prepared for the Consultative Committee of the Alouette Water Use Plan Review by Atek Hydrographic Surveys Ltd. Pender Harbor, BC.

APPENDIX G: PERFORMANCE MEASURE INFORMATION SHEETS

Reservoir Cultural Heritage

Description

The impacts of modeled Alouette Lake Reservoir operations on cultural heritage values is captured in a performance measure (PM) that tracks the number of days the reservoir is at or below 116 m to allow identification of archeological sites within the drawdown zone.

The PM statistic is calculated as a single value for each year of simulation and is reported in units of access-days. The annual PM statistics are summarized using the 10^{th}, 50^{th}, and 90^{th} percentile statistics[1] to reflect the degree to which these PM data can vary from year to year.

Although the PM will be calculated for the entire simulation period to given a sense of the likelihood of occurrence, in reality it will only be relevant for the first three years of WUP implementation.

Means Objective

The Cultural Heritage PM is associated with the primary objective of maximizing the protection of heritage sites both within the reservoir area and downstream of the dam. Here, the term protection implies access to sites for study or use, as well as the inundation (or some other protective barrier or procedure) to prevent "pot hunting". The means objectives by which the primary objective is met are as follows:

1. *Inundation:* Maximize the number of days at high reservoir elevation to cover sites that may be located within the drawdown zone and prevent pot hunting.
2. *Upland Access:* Maximize the number of days at high reservoir elevation to facilitate access to potential upland sites.
3. *Drawdown Access:* Maximize the number of days in early winter where reservoir elevation is at or less than 116m for site investigation within the drawdown zone (required only for the first three years of WUP implementation).
4. *Reservoir Fluctuation:* Minimize the extent of reservoir fluctuation to prevent possible erosion and hence degradation of existing archaeological sites.
5. *Bank Erosion:* Minimize number of flood events to prevent exposure of new archaeological sites through bank erosion.

Performance measures will only be calculated for the Drawdown Site Access objective. There is too little data on site location, extent and state of preservation to develop

[1] These summary statistics reflect the expected 1 in 10 year worst case, most likely case, and expected 1 in 10 year best case respectively.

meaningful performance measures for the other means objectives at this time. For the purposes of this review however, the upland access and inundation objectives are considered to be coincident with the recreation PM, thus positive changes in recreation value are likely to benefit these two cultural heritage objectives as well. Similarly, the food PM is considered to be coincident with the downstream bank erosion objective, where minimizing the occurrence of flood events would also promote downstream archaeological site protection. The only objective that cannot be tracked at this time is the reservoir fluctuation objective. It requires detailed knowledge of site location so that specific boundary elevations can be set – information that is not currently available.

Rationale

In order for Katzie First Nation to develop meaningful performance measures in future WUP reviews, an intensive study of the reservoir will be required to identify the location, extent and state of preservation of significant archaeological sites. To do so, Katzie First Nation will require periodic access to the full extent of the drawdown zone. Though BC Hydro is licensed to draft the reservoir down to 114 m, there are fisheries related constraints that limit drawdown to 116 m.

The primary constraint is the need to maintain sufficient head in the reservoir to ensure adequate downstream base flows through the Low Level Outlet (LLO) pipe. The inlet of the LLO pipe that supplies the base flow to South Alouette Lake is located at an elevation of 113.15 m. At 116 m, there is sufficient head above the LLO inlet to supply 1.9 m^3s^{-1} compared to the 3.0 m^3s^{-1} at full reservoir. This is considered to be the minimum required to preserve ecosystem function downstream of the dam. As the water level drops from 116 m to 114 m, the volume of water flowing through the LLO pipe decreases dramatically, and ceases completely at 113.2 m.

The other main constraint is to keep the reservoir sufficiently high so not to disturb bottom sediments during wind events. Past experience has shown that reservoir elevations less than 116 m has often been linked with the entrainment of fine sediments to the South Alouette River, causing potential harm to downstream fish resources.

Because of these environmental constraints, reservoir elevation is rarely allowed to drop below 116 m. As a result, potential sites below 116 m will be considered fully protected for the time being and for the present WUP, do not require study. However, if the opportunity should arise for study below 116 m, Katzie First Nation would like to be notified as soon as possible so that they may mobilize a crew to carry out the work for the duration of that opportunity.

In order to minimize the opportunity for "pot hunting," as well as impacts to recreation value, the ideal time for carrying out such archaeological work is considered to be near the end of the recreation season (considered to be 1 October for the purposes of this review) till the end of November. This period is also considered to be a good time because it is when the reservoir is typically at such low levels for flood control reasons. It is unlikely that study work would be carried out during December, even though similar hydrological and operational conditions may prevail. To increase the opportunity of studying the drawdown area during low water level conditions, study crews could be mobilized again between 5 January to 31 March, prior to the spring freshet period.

Because work can still proceed at reservoir levels higher than 116.0, a weighting scheme is used to value the preference of reservoir water levels. In this scheme, water levels above 122.6 m are assigned a weight of 0, recognizing that access to the drawdown area above 122.6 m (the elevation at which flood control measures at taken), is commonly unhindered and can be studied at almost any time. As water level drops from 122.6 m, the weight increases linearly from 0 to 1, reflecting an increasing preference for lower elevations until 116 m is met. Water levels below 116 m are all weighted as 1 and are considered to be of greatest interest.

The Site Access PM is calculated as the sum of weighted days over the period of 1 October to 30 November and 5 January to 31 March:

$$\text{Site Access PM} = \sum_{day=5,249}^{94,339} Wt\ (WL_{day})$$

Where,

$$Wt(WL_{day}) = \begin{cases} 0 & iff \quad WL_{day} \geq 122.6m \\ (122.6 - WL)/6.6 & iff \quad 116m < WL_{day} < 122.6m \\ 1 & iff \quad WL_{day} \leq 116m \end{cases}$$

The performance measure is calculated for each year of simulation and summarized across all years (n = 45 years) using 10th, 50th and 90th percentile statistics, where

1. the 10th percentile value represents a 1 in 10 year worst case,
2. the 50th percentile value represents the minimum PM value 5 out of every 10 years (the typical outcome), and
3. the 90th percentile value represents a 1 in 10 year best case.

Methodology

Calculation

The calculation of the PM is as follows:

FOR EACH YEAR 'Y' OF SIMULATION

FOR EACH DAY 'D' OF YEAR 'Y'

IF DURING THE STUDY PERIOD (1 OCTOBER TO 30 NOVEMBER, 5 JANUARY TO 31 MARCH)

CALCULATE WT GIVEN WATER LEVEL ON DAY 'D' OF YEAR 'Y'

PM(Y) = PM(Y) + $WT(WL_{D,Y})$

NEXT D

NEXT Y

CALCULATE SUMMARY PERCENTILE STATISTICS OF PM(Y) DATA

As noted earlier, the ELZ PM is calculated for each year of simulation and is reported as 10^{th}, 50^{th} and 90^{th} percentile summary statistics for the period of simulations (n = 45 years).

Data Needs

The only data needs required for this PM are the daily reservoir elevation data from the simulation model.

Critical Uncertainties

There is only one critical uncertainty associated with the use of this performance measure:

Critical Uncertainty	Implications to Decision Making Process
1. Alouette Lake Reservoir water surface elevation data generated from BC Hydro's operations simulation model may not necessarily reflect actual operating practice.	Inaccuracies in the operations simulation model are likely to be small relative to the volume of flow that must be managed. Model biases (error) are also likely to be similar between operating strategies. As a result, relative differences in the PM between strategies should be accurate, though absolute values may not be.

Effective Littoral Zone

Description

The impacts of modeled Alouette Lake Reservoir operations on its littoral productivity is captured in a performance measure (PM) that tracks the potential for algae and aquatic plant growth based on the intensity of Photosynthetically Active Radiation (PAR) at depth, mortality resulting from desiccation, and mortality resulting from "light starvation". The integration of these factors through time defines the PM, which is referred to as the effective littoral zone, or ELZ.

The PM statistic is calculated as a single value that captures the cumulative effects of operations on the productive potential of the littoral zone across the all years of simulation. It is reported in units of hectares (ha) of shoreline habitat that have at least 20 per cent of maximum growth potential defined by the combined effects of desiccation, PAR and UV light (all known to inhibit growth in algae). In addition to the hectare measure, upper and lower elevation boundaries of the ELZ are also reported.

Means Objective

The Effective Littoral Zone PM is associated primarily with the means objective of maximizing the productivity and area of littoral zone habitats. Meeting this primary objective can also lead to ancillary benefits to two other means objectives for which there are no PMs:

1. *Pelagic Zone:* To maximize littoral habitat, water level fluctuations must be lessened, which in turn results in fewer fluctuations, and hence impacts, to the volume of the pelagic zone.
2. *Pothole Stranding:* To maximize littoral habitat, water level fluctuations must be lessened, which in turn lowers the risk that pothole stranding of fish may occur.

The means objectives listed above are collectively components of a more generalized or "global" objective of maximizing the abundance of fish in the reservoir. In maximizing fish values, it is recognized that aquatic wildlife values are enhanced as well. This may occur through several mechanisms:

1. Increased forage for piscivorous aquatic animals, as well as potential forage for herbivorous animals through better development of littoral areas.
2. Reduced risk of predation by lessening the expanse between the water's edge and the cover provided by riparian vegetation when attempting to encourage littoral development by stabilizing the reservoir.

Rationale

A number of physical and biological factors govern the productivity of littoral areas. These may include such factors as:

- the depth to which light penetrates the waters surface to fuel photosynthesis,

- the amount of time that suitable substrate remains wetted, and therefore allows for benthic colonization,
- the gradient shoreline areas which governs the extent of soil accumulation,
- the levels of available nutrients, which govern the rate of growth,
- survival rates under conditions of desiccation, and
- inter-specific interactions such as predation and grazing.

Fluctuating water levels, depending on their frequency, duration, and magnitude, can reduce the overall productivity of littoral areas by affecting the degree to which each of these factors govern the growth and survival of algae and other macrophytes (Figure 1). As water level recedes, aquatic vegetation that was once wetted now becomes dry and is subject to mortality through desiccation. At the same time, higher light intensities are brought into deeper areas that were once too dark to support photosynthesis and therefore plant growth. Conversely, when water level rises, new areas previously dry become wetted and therefore become capable of supporting aquatic vegetation. At depth, areas that once supported vegetation growth now become too dark for photosynthesis and a situation is created where these plants now "starve" to death.

If the fluctuations in water level occur slowly, there is time for new plant growth to occur and compensate the losses. However, if the frequency of water level fluctuations is too rapid, then the opportunity for such compensatory growth is lost. The primary factor that determines the likelihood of compensatory growth is the rate of colonization and growth of plants (including algae), which is a function of a number of physical variables (e.g., availability of nutrients, water temperature, and light intensity and duration) and tends to be much slower than the rate of mortality.

Unfortunately, the numerical nature of these relationships is not well understood, and therefore the development of reliable models of littoral habitat productivity is not possible. Nevertheless, the theoretical concepts underlying these relationships can be used to develop *relative* performance measures that allow for comparisons between alternatives (i.e., assess whether one operating alternative is be better than another, and *relatively* by how much).

Not all factors can be incorporated into such performance measures. Factors that involve complex dynamics such as the rate of colonization, the effects of nutrients on growth, and the role of inter-specific interactions, are all too poorly understood to be incorporated into a measure of littoral performance, particularly by means of numerical relationships. Factors that can be used include the effects of light penetration, dewatering (hence the effects of desiccation), and the importance of shoreline gradient. Even for these factors, numerical relationships are uncertain, and must be constructed based on a paucity of information. For the PM used here, the following relationships and assumptions were made:

1. Algae and plant growth is proportional to the intensity of photosynthetically active radiation (PAR) available at depth and follows an exponential relationship with an extinction coefficient of 0.187 (Based on the Secchi Disk data collected in Alouette Lake Reservoir since 1998[2]):

$$G_z = I_z = I_0 e^{-0.187z} \quad \text{Eq. 1}$$

Where,

G_z = Growth potential at depth 'z'

I_z = PAR intensity at depth 'z'

I_0 = PAR intensity at the waters surface = 1

z = depth (m)

2. UV radiation inhibits photosynthesis, and therefore growth, near the water's surface. Like PAR, the relationship with depth is exponential. From Wetzel 2001, an extinction coefficient of 10 was deemed a reasonable value given that the reservoir is oligotrophic:

$$G_{d,UV} = - I_d = - I_0 e^{-10z} \quad \text{Eq. 2}$$

3. Growth potential during periods of desiccation is assumed to have a half-life of 0.5 day (derived from discussions with John Stockner) or approximated by:

$$G_z = G_z \times 0.75 \quad \text{Eq. 3}$$

4. Growth potential during periods of desiccation is assumed to have a half-life of roughly 2½ days (derived from discussions with John Stockner) or approximated by:

$$G_z = G_z \times 0.25 \quad \text{Eq. 4}$$

5. Because the potential macrophyte plant growth is low (based on snorkel observations collected to date by MOE personnel, G Wilson pers. comm.) the focus of the ELZ PM will be on periphyton growth only. As a result all shoreline areas regardless of slope will be considered suitable for the littoral development calculation.

Based on the equations above the Performance Measure of potential algae and macrophyte growth 'G' at depth 'd' in littoral areas is defined as follows:

$$G_z = \begin{cases} G_z \cdot 0.75 & \textit{iff dry at depth } z \\ G_z + e^{-0.187z} - e^{-10z} & \textit{iff wetted and PAR} > 1\% \textit{ of surface level} \\ G_z \cdot 0.25 & \textit{iff PAR} < 1\% \textit{ of surface level} \end{cases} \quad \text{Eq. 5}$$

2 A total of 133 observations in North and South basins collected between 1 March and 30 October since 1998 to 2003 (mean = 9.1m ± 2.9 m (SD)). Extinction coefficients were estimated using the standard relationship 1.7/z where z is Secchi disk depth (Wetzel 2001). The average for the entire data set was 0.187 with a 95% confidence interval of 0.178 - 0.198.

This equation is calculated at all depths for each day during the active growing period of the year (assumed to be 1 March to 30 October) and for all years of simulation. To simplify the calculation, daily growth is converted to a number on a scale of 0 (no growth) to 1 (maximum growth), allowing maximum growth to be defined as the number of growing days (245 in this case) times the number of years of model simulation.

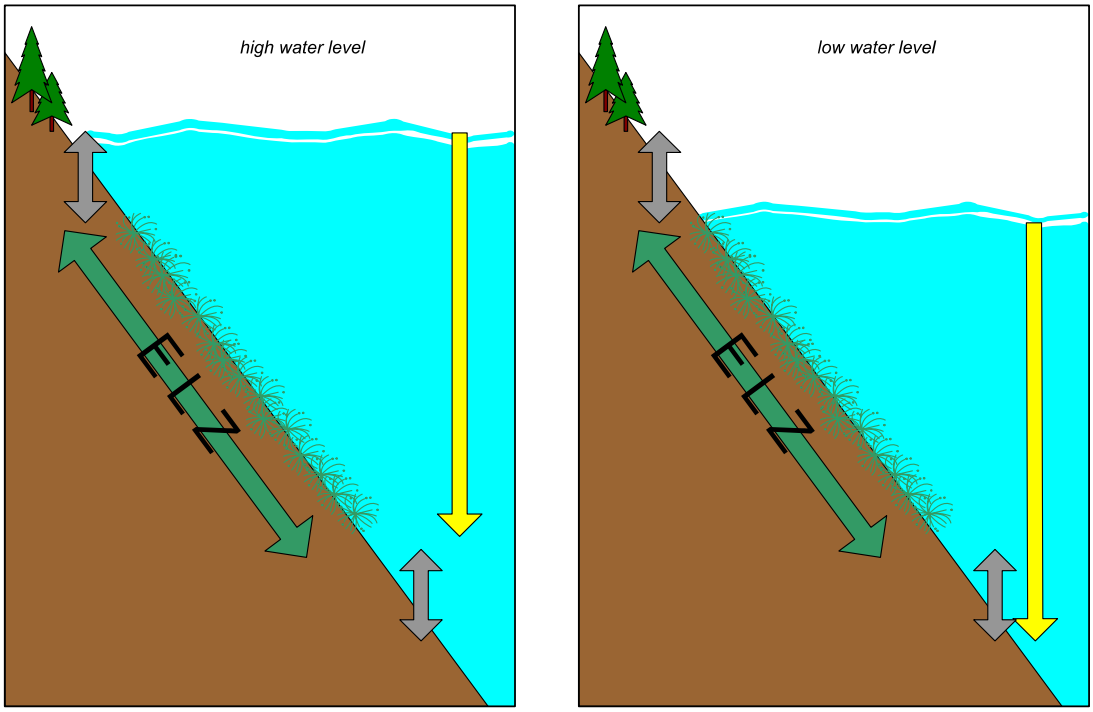


Figure 1: Conceptual diagram of effective littoral zone (ELZ) in reservoirs. Productivity in high shoreline areas is influenced by exposure during drawdown periods, whereas low shoreline areas may receive adequate light for insufficient time to be biologically productive.

Methodology

Calculation

The Effective Littoral Zone PM (ELZ) is a summary value of daily growth potential for algae and macrophytes calculated at 10 cm intervals of depth, for each day of the growing season (1 March to 30 October), and each year of simulation. The daily growth statistic is a value that ranges between 0 (no growth) to 1 (maximum growth) and is calculate using Eq. 5 above. During the winter, it is assumed that no growth or mortality as a result of light starvation occurs (plants are typically in a state of stasis at this time), but mortality due to desiccation is still possible. Once summarized for the period of simulation, the PM value is reported in units of hectares of shoreline habitat that have a growth potential of 0.2 (20 per cent of maximum) or more.

The calculation of the PM is as follows:

1) Calculate growth potential for period of simulation

FOR EACH YEAR 'Y' OF SIMULATION

During the Growing Period

FOR EACH DAY 'D' DURING THE GROWING PERIOD (1 MARCH TO 30 OCTOBER)

FOR EACH DEPTH 'Z' FROM 125.0 M TO 90.0 M AT 0.1 M INTERVALS

CALCULATE G_Z USING EQ. 5

NEXT Z

NEXT D

During the Winter Period

FOR EACH DAY 'D' DURING WINTER (1 NOVEMBER TO 28 FEBRUARY)

FOR EACH DEPTH 'Z' FROM 125.0 M TO 90.0 M AT 0.1 M INTERVALS

CALCULATE G_Z USING EQ. 3

NEXT Z

NEXT D

NEXT Y

2) Standardize growth potential to a scale of 0 to 1 and average for the period of simulation

FOR EACH DEPTH 'Z' FROM 125.0 M TO 90.0 M AT 0.1 M INTERVALS

LET $G_Z = G_Z/[\text{TOTAL NUMBER OF DAYS IN SIMULATION} * \text{MAX}(E^{-0.383z} - E^{-10z})]$

NEXT Z

3) Calculate PM where G_z is at least 0.2 (or 20% of maximum)

FOR EACH DEPTH 'Z' FROM 125.0 M TO 90.0 M AT 0.1 M INTERVALS

GET SUBSTRATE AREA (HA) AT Z TO (Z + 0.1)

IF $G_Z > 0.2$ THEN

LET PM = PM + SUBSTRATE AREA (HA) AT Z TO (Z + 0.1)

NOTE UPPER AND LOWER BOUNDARIES OF THE PM

END IF

NEXT Z

As noted earlier, the ELZ PM is reported as a single number, integrating the effects of reservoir operations over multiple years. This aspect is important to note as it takes into account the fact that macrophytes grow over a period of several years, thus rendering annual measures of the ELZ PM meaningless.

Data Needs

The only data needs required for this PM are the daily reservoir elevation data from the simulation model, and a table of substrate areas at 0.1 m intervals. Both are available.

Critical Uncertainties

There are two critical uncertainties associated with the use of this performance measure:

Critical Uncertainty	Implications to Decision Making Process
1. Alouette Lake Reservoir water surface elevation data generated from BC Hydro's operations simulation model may not necessarily reflect actual operating practice.	Inaccuracies in the operations simulation model are likely to be small relative to the volume of flow that must be managed. Model biases (error) are also likely to be similar between operating strategies. As a result, relative differences in the PM between strategies should be accurate, though absolute values may not be.
2. Though conceptually sound, the ELZ performance measure remains untested and it is uncertain whether the PM accurately reflects the potential for littoral zone development.	Biases in the PM are similar between operating strategies. As a result, relative differences in the PM between strategies should be accurate, though absolute values may not be.

References

Wetzel, R.G. 2001. Limnology: Lake and River Ecosystems. 3rd Ed. Academic Press. New York. 1006 pp.

Flood Risk

Description

The impacts of modeled Alouette Lake Reservoir operations on the risk of flooding are captured in a performance measure (PM) that tracks the number of free-crest spill events from Alouette Dam. The PM statistic is reported as a return period (in years) of free-crest spill events based on a 45-year simulation model run.

Means Objective

The Flood Risk PM is associated with the primary objective of minimizing the occurrence of flood events capable of damaging downstream property.

Rationale

Current operating practice identifies 56.5 m^3s^{-1} as the critical flood discharge at which damaging flood conditions start to occur. Given that the spillway gate is only capable of releasing a maximum discharge 42.5 m^3s^{-1}, the critical flood discharge can occur only at times of free crest spill. As a result, only free crest spills are tracked for PM calculation.

The duration of free crest spill typically ranges from three to five days. Because spill events tend to be similar in duration, only the event itself is counted through time and not the total number of spill days.

Methodology

Calculation

The calculation of the PM is as follows:

```
FOR EACH YEAR 'Y' OF SIMULATION
    FOR EACH DAY 'D' OF YEAR 'Y'
        IF FREE CREST DISCHARGE EXCEEDS 0 M3S-1
        IDENTIFY START OF SPILL AS A FLOOD EVENT AND ADD TO THE PM STATISTIC
        LET PM = PM + 1
    NEXT D
NEXT Y
CALCULATE RETURN PERIOD OF FLOOD EVENTS
LET PM = NUMBER OF SIMULATION YEARS (45)/PM
```

Data Needs

The only data needs required for this PM are the daily reservoir elevation data from the simulation model.

Critical Uncertainties

There is only one critical uncertainty associated with the use of this performance measure:

Critical Uncertainty	Implications to Decision Making Process
1. Alouette Lake Reservoir water surface elevation data generated from BC Hydro's operations simulation model may not necessarily reflect actual operating practice.	Inaccuracies in the operations simulation model are likely to be small relative to the volume of flow that must be managed. Model biases (error) are also likely to be similar between operating strategies. As a result, relative differences in the PM between strategies should be accurate, though absolute values may not be.

Reservoir Recreation

Description

The impacts of modeled Alouette Lake Reservoir operations on recreation value is captured in a performance measure (PM) that tracks recreation value on the reservoir based on the product of weights (scores ranging from 0 to 1 reflecting the worst and best condition) that rate seasonal differences in recreational activity and the preferred water level in the reservoir. The sum of these products is calculated for each day of the year and when summed, will form the PM statistic for that year.

The PM statistic is calculated as a single value for each year of simulation and is reported in units of weighted recreation days. The annual PM statistics are summarized using the 10^{th}, 50^{th}, and 90^{th} percentile statistics[3] to reflect the degree to which these PM data can vary from year to year.

Means Objective

The Reservoir Recreation PM is associated with the primary objective of maximizing recreation potential and boating safety in the reservoir. The means objectives by which this is achieved are as follows:

1. *Aesthetics:* Have the reservoir look as lake-like as possible, i.e., have the reservoir as high as possible to minimize exposure of the draw down zone.
2. *Beach use:* Have the reservoir as high as possible to maximize the utility and aesthetics of the Golden Ears Park beach.
3. *Drawdown access:* Have the reservoir as high as possible to minimize drawdown zone access to motorbikes and other off road vehicles.
4. *Canoe access:* Have the reservoir as high as possible to maximize canoe access to campsites and hiking trails through out the reservoir.
5. *Canoe launch:* Have the reservoir as high as possible to allow easy launching and retrieval of canoes from the park day use area.
6. *Boating safety:* Have the reservoir as high as possible to maximize boating safety by ensuring that all stumps are sufficiently submerged under water.

Rationale

The peak recreation season occurs between 15 June and 5 September. There are also two short shoulder periods, the first occurring roughly three weeks prior to the peak season (20 May to 14 June) and the other three weeks after (6 September to 30 September). The early shoulder season is believed to be more important than the latter shoulder period (Tom Blackbird MOE Parks, pers. comm.). To capture this difference in relative importance, the following seasonal weights are used to calculate the performance measure:

[3] These summary statistics reflect the expected 1 in 10 year worst case, most likely case, and expected 1 in 10 year best case respectively.

Season	Weight
Early Shoulder	0.75
Peak	1.00
Late Shoulder	0.50

All means objectives are believed to be similarly linked to changes in reservoir elevation. As a result, only one set of critical elevations are used to track the likelihood of success, which is captured in the following weighting scheme:

Reservoir Elevation	Weight
< 121.25	0
121.3 to 122.5	0.5
122.6 to 123.5	1
123.6 to 125.5	0.75

The recreation PM is calculated as the sum of the products of seasonal and elevation weights:

$$\text{Recreation PM} = \sum_{day=1}^{365} Seasonal\_Wt(day) \times Elevation\_Wt(El_{day})$$

The performance measure is calculated for each year of simulation and summarized across all years (n = 45 years) using 10th, 50th and 90th percentile statistics, where

1. the 10th percentile value represents a 1 in 10 year worst case,
2. the 50th percentile value represents the minimum PM value 5 out of every 10 years (the typical outcome), and
3. the 90th percentile value represents a 1 in 10 year best case.

Methodology

Calculation

The calculation of the PM is as follows:

FOR EACH YEAR 'Y' OF SIMULATION

FOR EACH DAY 'D' OF YEAR 'Y'

Determine the seasonal weighting value

IF EARLY IN THE SEASON (MAY 20 TO JUN 14), SET SEASON_ WT = 0.75

IF DURING THE PEAK SEASON (JUN 15 TO SEP 5), SEASON_ WT = 1

IF LATE IN THE SEASON (SEP 6 TO SEP 30), SEASON_ WT = 0. 5

IF DURING THE OFF SEASON, SET SEASON_ WT = 0

Determine the water level weighting value

IF WATER LEVEL < 121.3, SET WL_WT = 0

IF 121.3 < WATER LEVEL < 122.5, SET WL_WT = 0.5

IF 121.6 < WATER LEVEL < 123.5, SET WL_WT = 1

IF WATER LEVEL > 123.5, SET WL_WT = 0.75

Add PM score for day D to yearly total

PM(Y) = PM(Y) + SEASON_WT X WL_WT

NEXT D

NEXT Y

CALCULATE SUMMARY PERCETILE STATISTICS OF PM(Y) DATA

As noted earlier, the ELZ PM is calculated for each year of simulation and is reported as 10th, 50th and 90th percentile summary statistics for the period of simulations (n = 45 years).

Data Needs

The only data needs required for this PM are the daily reservoir elevation data from the simulation model, and a weighting scheme to reflect seasonal differences in recreational activity and corresponding preferences for certain reservoir water levels. Both are available.

Critical Uncertainties

There are two critical uncertainties associated with the use of this performance measure:

Critical Uncertainty	Implications to Decision Making Process
1. Alouette Lake Reservoir water surface elevation data generated from BC Hydro's operations simulation model may not necessarily reflect actual operating practice.	Inaccuracies in the operations simulation model are likely to be small relative to the volume of flow that must be managed. Model biases (error) are also likely to be similar between operating strategies. As a result, relative differences in the PM between strategies should be accurate, though absolute values may not be.
2. There is some uncertainty in what the critical reservoir levels are that define water level preferences.	Biases in the PM will be similar between operating strategies. As a result, relative differences in the PM between strategies should be accurate, though absolute values of recreation preference may not be.

References

Wetzel, R.G. 2001. Limnology: Lake and River Ecosystems. 3rd Ed. Academic Press. New York. 1006 pp.

Power

Description

The impacts of modeled Alouette Lake Reservoir operations on the production of electricity (Megawatt•hours) is captured in a performance measure (PM) that tracks the change in annual average annual revenue loss from the Alouette-Stave-Ruskin generating system relative to that of current operations as defined by the 1996 Alouette WUP and the recently implemented 2005 Stave WUP. The PM statistic is calculated based on 45 years of simulated operation of the entire system and is reported in $ million per year.

It should be noted that operational changes were restricted to only those constraints associated with Alouette facility and that operating conditions at the Stave and Ruskin facilities were held constant as per the 2005 Stave WUP.

Details of the hydro operations model used to estimate power production and calculate average annual revenue differences are provided in BC Hydro Engineering Report No. E460 (2006).

Means Objective

The Power PM is linked to the primary objective of maximizing average annual revenue from power generation at the Alouette Lake powerhouse.

Rationale

Electricity consists of three major components: energy, capacity, and ancillary services. Energy is the amount of electricity the plant can produce over a given time and capacity is the maximum amount of electric power that can be produced at any instant. The distinction is important because the market price of electricity varies hourly, daily and seasonally, and the value of a plant's electrical output depends upon, among other things, its ability to generate when prices are high. Electricity production is viewed as important to B.C. because it supports the economic development of the province and provides a stream of Annual Revenue from energy sales.

Constraining operations at the Alouette Facility reduces BC Hydro's overall electricity generation capability. This generation would need to be replaced in order to keep supply in balance with demand. This can be achieved through increased market purchases at market prices, or by the addition of new generating facilities to BC Hydro's system. The majority of new generating facilities in B.C. at this time are expected to be gas-fired thermal power plants. These plants will operate at or near the market price of electricity. Thus, whether replacement electricity is purchased or produced in new facilities, the financial cost to the province to replace electricity production foregone can be estimated by the long-term market price.

BC Hydro pays a rental fee for water used to generate electricity and the fees go into general revenue for the provincial government. Regulations under the Water Act provide for a remission of water rental fees when, under the direction of the Comptroller of Water Rights, there is a reduction in electricity produced in favour of other non-power benefits. Therefore if there is a reduction in the value of electricity produced within Alouette system, resulting from either a reduction in electricity generated or a shift from higher value to lower value electricity, the cost of implementing water use plans will be borne by B.C. taxpayers.

Methodology

Calculation

The Annual Revenue will be calculated by multiplying the amount of electricity generated for a given operating alternative by the "Value of Energy (VOE1)". The VOE methodology, which represents the long-term value of a unit of energy that is generated by the BC Hydro system, includes three components:

- Heavy Load Hour (HLH) generation value – calculated for 6 days/week x 16 hours/day.
- Dispatch Premium – used to inflate the value of flexible operations.
- Light Load Hour (LLH) generation value.

Hence the VOE methodology, which was approved for water use planning in B.C. by the WUP Interagency Management Committee, considers the long run price forecast and price premiums based on plant flexibility. It should be noted that the VOE methodology contains commercially sensitive information and is confidential.

To calculate of the annual revenue for each alternative, the number of megawatts generated for the entire Alouette-Stave-Ruskin system was converted to a total revenue value using the VOE methodology and then subtracted from the "base case value" derived using current operations as defined in the 1996 Alouette WUP and the 2005 Stave WUP. The difference in total revenue was averaged across the 45 year simulation period to estimate relative average annual revenue loss. A positive PM value indicated a loss in revenue while negative value indicated a net gain. All PM values are reported in $ Million per year.

Data Needs

The only data needs required for this PM are the MW•h data from the operations simulation model and current VOE forecasts.

Critical Uncertainties

There is only one critical uncertainty associated with the use of this performance measure:

Critical Uncertainty	Implications to Decision Making Process
1. Alouette Lake powerhouse electricity production data generated from BC Hydro's operations simulation model may not necessarily reflect actual operating practice.	Inaccuracies in the operations simulation model are likely to be small relative to the volume of flow that must be managed. Model biases (error) are also likely to be similar between operating strategies. As a result, relative differences in the PM between strategies should be accurate, though absolute values may not be.
2. VOE data may not accurately forecast the true future cost of power generation	The VOE methodology is being used here as a standard approach to revenue estimation to highlight relative differences between alternative operating strategies, and not as a predictor of future revenue potential. Because biases (error) will likely be similar between operating strategies, relative differences in the PM between strategies should be accurate, though absolute values may not be.

APPENDIX H: ALOUETTE RIVER WUP REVIEW PROJECT – UNCERTAINTIES IDENTIFIED BY THE FTC

FISH – South Alouette River

Area of Uncertainty	Study Issue(s)	Proposed Action/Study Methodology
Habitat Suitability	Validate habitat modeling to measured fish response	Deemed unnecessary because future decisions would likely be driven by measured fish responses, and given infrastructure constraints and the present good health of the system, changes to base flow are unlikely in the near future.
	Use WUA habitat modeling to identify limiting factors for spawning species	Deemed unnecessary because future decisions would likely be driven by measured fish responses and habitat changes. Because of infrastructure constraints and the present good health of the system, changes to base flow are unlikely in the near future to deal with identified habitat constraints.
	Continue monitor to evaluate effectiveness of flushing flow regime - validate substrate quality methodology	Continue with the present monitor, recognizing that the data is inherently biased. As long as bias is maintained, relative changes in substrate composition can be successfully tracked. Data and corresponding reports will need to be peer reviewed to ensure accuracy. Revise methodology to lessen potential bias and ensure smooth transitions should observers change in the future (e.g., always collect data in pairs by separate observers). Use chum fry escapement data as corroborating evidence of spawning substrate quality.
Smolt Enumeration	Continue monitor to evaluate effectiveness of base flow regime and help identify potential limiting factors to production.	Maintain level of monitoring effort as in the past to evaluate effectiveness of the base-flow regime. Data will also be used to identify potential limiting factors and corroborate findings of other monitoring studies.
Coho	Uncertain whether Coho have benefited from increase in base flow, or whether they have reached there full potential for production.	Given the infrastructure constraints and general good health of the system, changes in base flow are unlikely. Activities to improve Coho production will more likely encompass physical works such a habitat complexing. This is considered to be more of a habitat restoration project than a WUP monitor and therefore should be funded by BCRP. Effectiveness of such programs will be assessed through the smolt enumeration monitor at no additional cost.
Steelhead Rearing	Uncertainty about what is limiting parr production in the system. Smolt data suggest that steelhead production is at capacity, but given the low adult escapement numbers, looking for means to increase that capacity.	Given the infrastructure constraints and general good health of the system, changes in base flow are unlikely. However, it has been hypothesized that boulder habitat may be disappearing due to changes in sediment movement as a result of the new flow regime. The FTC suggests that the substrate quality monitor include a systematic boulder habitat assessment to the program. If deemed necessary, restoration work can be done to enhance this habitat through BCRP. Effectiveness of such programs will be assessed through the smolt enumeration monitor at no additional cost.

FISH – South Alouette River cont'd

Area of Uncertainty	Study Issue(s)	Proposed Action/Study Methodology
Longnose / Nooksack Dace	Are they present in the system? If present, what is the state of their population? If present, what are the factors limiting production, are there critical habitats that need to be protected? If present, can flows be manipulated to optimize abundance and/or habitat?	The possibility that Nooksack dace exist in the system has been acknowledged by the FTC. WUA modeling suggests that if present, existing flow conditions are unlikely to be detrimental to their production or overall species survival. The FTC recommends that the uncertainties associated with this species be dealt with in a regulatory (SARA) context and that they are considered outside the scope of the present WUP review process. The FTC recommends that no action be taken at this time except to acknowledge that if Nooksack dace are found in the system, a regulatory process will be launched that may supersede the WUP process.
Sockeye	There is considerable uncertainty about the flow conditions that would lead to successful out migration of smolts. Aspects to consider include, timing, duration and magnitude of surface release from the dam.	The FTC recommends an adaptive management approach to determine surface release conditions that lead to successful out migration at least cost. The treatment conditions include 3 vs. 6 m^3s^{-1} release magnitudes, and durations ranging from four to eight weeks. Smolt migration will be monitored by rotary screw trap located near the confluence of Mud Creek, which will last the duration of the dam surface release (i.e., an effectiveness monitor for smolt releases)
	Assuming that sockeye return to the system, what is their periodicity of immigration and are there any barriers (low flow, high temperatures)?	The FTC recommends that the existing annual adult trapping program carried out by the Alouette Hatchery be started earlier in order to evaluate the possibility of an early summer return period. Genetic analysis should be done on a random subset of sockeye returns to determine whether they are strays from elsewhere in the Fraser river system or indeed re-anadromized Alouette Lake kokanee.
Predation	Does higher sediment load provide more cover and less predation during the out-migration period? Do higher freshet pulses of water provide more cover and hence less predation through faster moving water in the lower river.	The ability to control river hydraulic and sediment conditions downstream of the 216th bridge is very limited, particularly during the freshet period when smolt out-migration occurs. Because of this lack of control, this uncertainty cannot be addressed through WUP.
Water temperature	Water temperatures in August typically approach tolerance limits for salmonids and could in some years, impact smolt production. The frequency of such warm water events are uncertain, as well as the likelihood those reservoir operations could be manipulated to mitigate these events.	The FTC recommends that a water temperature monitor be implemented the records river temperatures at several downstream locations, in the plunge pool area to track its influence on LLO releases, and n the reservoir near the LLO inlet to track the accessibility of cool waters. Where significant drops in annual smolt counts occur, the data set will be used to determine the likelihood that it is a temperature related event.

FISH – South Alouette River cont'd

Area of Uncertainty	Study Issue(s)	Proposed Action/Study Methodology
Water temperature cont'd	It was hypothesized that if water events are of sufficient duration, it can cause a shift in the river's ecology from a cold-water ecosystem to a warm water ecosystem. The likelihood of this occurring n the Alouette River is unknown.	No specific monitor is recommended for this uncertainty as evidence to date suggests that this is unlikely an issue. Also, it is unlikely that dam operations could significantly mitigate the issue if it were to arise given the distance of the dam from the lower sections of the river (the area where this would most likely occur).
Aquatic Species Diversity	How to track accrued benefits or accumulated impacts?	This issue was raised by BC Hydro as part of a broader question dealing with the accumulated benefits of the BC Hydro's environmental program through the years. This was deemed outside the scope of WUP.
Invasive Species	Can the control of invasive species be achieved through changes in reservoir operations?	Invasive species of concern are primarily terrestrial, located below 216th St bridge, and therefore not directly influenced by dam operations. If there were a linkage, the ability to control river hydraulic and sediments is very limited. As a result, this issue is considered to be outside the scope of WUP.
Productivity in lower reach of the Alouette River	Are there impacts of reservoir operations below 216th bridge, and can they be mitigated through operational changes?	The ability to control river hydraulic and sediment conditions downstream of the 216th bridge beyond flood control measures is very limited. As well, there are likely other factors involved that cannot be controlled by WUP (fertilization, irrigation, dikes etc.) that likely have a more significant impact on productivity. As a result, this issue is considered to be outside the scope of WUP.

FISH – Alouette Lake

Area of Uncertainty	Study Issue(s)	Proposed Action/Study Methodology
Shoal Spawning	Kokanee – preferred spawning areas, carrying capacity, limiting factors. Do reservoir operations affect spawning success?	FTC recommends that the WUP use the population data currently collected by the fertilization monitor to evaluate likelihood that spawning success is limiting smolt production. Funds should be provided to analyze data and prepare reports that are outside the scope of the fertilization monitor. If spawning is found to be limiting, then a monitor should be carried out to determine whether there are remedial operational changes that could be made.
Littoral Zone	ELZ performance measure has yet to be validated	There is currently a detailed monitor on the Stave/Hayward system. The FTC believed that it is unnecessary to extend the monitor to Alouette Lake as its outcome can be extrapolated to the Alouette system.

FISH – Alouette Lake cont'd

Area of Uncertainty	Study Issue(s)	Proposed Action/Study Methodology
Tributary access	All other anadromous species and lamprey are believed to be tributary spawners and early rearers. Critical tributary flows and reservoir elevations are uncertain. Frequency and duration is presently assumed not to be detrimental to these populations, though there is considerable uncertainty in that assumption	The FTC recommends that a reconnaissance level monitor be carried out to determine the frequency and duration of interrupted tributary access. The monitor should include observations to determine periodicity of salmonids and lamprey (if possible) spawning activities. Presently, the frequency and duration is not believed to be detrimental to any of the population under consideration. *FTC has since removed this monitor for the list because little can be done operationally *in a timely manner* to mitigate the impact.
Productivity losses through powerhouse tunnel	Fish productivity losses into Stave Lake Reservoir through the Alouette powerhouse tunnel	The magnitude of fish loss is not believed to be significant because of the limited area of high velocities created by the tunnel and its depth. Also, the size at age of Kokanee in the reservoir is presently stable or decreasing (G. Wilson of MOE pers. comm.), indicating a high degree of competition for limited food resources. It is presently believed that the fertilization program more than compensates for the potential loss in fish productivity. As a result, no monitoring program is recommended unless size at age begins to increase dramatically and there is little or no Kokanee out-migration with the surface release in Spring.

Other

Area of Uncertainty	Study Issue(s)	Proposed Action/Study Methodology
Wildlife	For the purposes of this WUP, it is assumed that operational change that benefit fish will also benefit aquatic wildlife.	Because the drawdown zone is of limited area and contains no wetland habitat, direct operational impacts are not believed to be significant. There is considerable anecdotal evidence downstream of the dam that suggests wildlife use has increased dramatically since the 1996 LLO release. As a result, no monitor is recommended, as operational changes strictly for wildlife values are unlikely in the future.
Traditional Ecological Knowledge	There is some uncertainty as to how TEK can be used to compliment monitoring activities and *visa versa*	This is not itself the subject of a monitor. Rather TEK should be an integral part of each monitoring program (e.g., can include regular *in situ* relationship building activities with elders)

APPENDIX I: WATER USE PLAN TECHNICAL MEMO – SPECIES AT RISK ACT (SARA) SPECIES CONSIDERATIONS IN THE ALOUETTE WUP REVIEW PROCESS

BC hydro

reliable power,
at low cost,
for generations

WUP Technical Memo

To:	Alouette WUP Review Consultative Committee	February 10, 2006
From:	James A. Bruce, M.Sc.	
CC:		
Subject:	SARA species considerations in the Alouette WUP review process	

The purpose of this memo is to document and evaluate the potential impacts on SARA Schedule 1 listed species due to changes in Alouette Dam and powerhouse operations as they relate to the Alouette River Water Use Plan review process.

Background

In 1996, BC Hydro implemented a change in Alouette Dam operations that increased base flow in the Alouette River to a year round average of 2.6 m^3s^{-1}. The change in operation was also accompanied by a monitoring program to determine whether the expected fish benefits of the new operating strategy would be realized. The monitoring program was to last for a period of 10 years and concludes with review process to determine whether further changes would be required.

The water license review process has since evolved into a formal water use planning (WUP) process that has been implemented throughout the province. Under this formal process, operational changes and their associated habitat consequences are considered to be incremental in nature. Historical impacts that cannot be mitigated though operational change, either as a result of physical constraints or increased risk to public, safety are considered to be footprint issues and are explicitly not addressed in the WUP process.

Since implementation of the WUP process, the regulatory environment has changed considerably. The most notable has been the Species at Risk Act (SARA), which came into force in June 2004. Unlike prior WUP projects, the Alouette River Water Use Plan review process now explicitly integrates SARA within the restricted scope of WUP.

Species at Risk

Fourteen fish and wildlife species that are listed under Schedule 1 of SARA or proposed for listing on that schedule may occur in the general vicinity of the Alouette Dam (i.e., have some geographical overlap) have been listed or are about to be listed in the near future on Schedule 1 of the Species at Risk Act (SARA). These include four fish species, four amphibian species, two plant species and one each of a mammalian, avian, reptilian and insect species. Their common name, SARA status, and general habitat requirements are summarized in Table 1.

Proposed Operational Changes & Habitat Consequences

Though a final decision on a preferred operating strategy has yet to be made, the range of operational changes under consideration during the Alouette water license review process are such that no large scale changes in habitat area, community structure or complexity are anticipated.

Downstream of the dam, no changes are proposed from the 1996 decision to fully open the Low Level Outlet (LLO) year-round. As a result, riverine habitat conditions are expected to remain unchanged from their present state, which is considered to be good to excellent given the smolt enumeration study results and anecdotal observations of increased wildlife use (Cope 2005).

Though some changes in target reservoir elevations are expected, the normal operating range is not likely to change. As a result, the extent and nature of the drawdown zone is not expected to change either.

Flood control will continue to be a priority. As a result, no operational change will be considered that significantly increases the risk of flooding. Consequently, riparian habitat on the shores of the Alouette River will likely continue along its normal path of successional growth because the frequency and magnitude of inundation, a key driver of species community structure, will remain the same.

Impact Assessment

To determine the impact of changes in Alouette facility operations on the species listed in Table 1, geographic and habitat overlap between the species and the zone of operational influence are considered. This assessment only considers the incremental change in operations relative to the water license revision implemented in 1996. Impacts arising from historical operations, as well as those associated with the facility's footprint, are outside the scope of this assessment and deemed not relevant to the WUP process.

For the purposes of this assessment, geographic overlap, habitat overlap, and habitat risk are defined as follows:

Geographic Overlap: Likelihood of occurrence within the general vicinity of the facility and zone of potential operational influence based on general species distribution information. Determines list of species that require assessment.

Habitat Overlap: Likelihood that usable habitats are partially or completely found within the general vicinity of the facility and/or zone of potential operational influence.

Habitat Risk: Likelihood that the facility and/or operations adversely impact usable habitats within the zone of influence.

The following steps were taken to assess the impact on listed species at risk of changes in Alouette facilities operations:

Step 1. Determine Geographic Overlap

Geographic overlap is reported as a binary yes/no value based on the possibility that the species in question could reside in the area given the current state of knowledge. This parameter determines whether a species is to be included in the assessment or not.

Step 2. Determine habitat overlap and level of risk

The habitat overlap and risk parameters are reported using the following rating scheme:

None: Known not to occur
Unlikely: Uncertain, but current state of knowledge limits the possibility
Possible: Uncertain, insufficient knowledge to make a judgment
Likely: Uncertain, but current state of knowledge suggests high likelihood
Known: Known to occur

Step 3. Determine the potential for adverse impacts

Potential Impact ratings are defined as follows using the habitat overlap and risk rating values:

Habitat Risk	**Habitat Overlap**				
	None	**Unlikely**	**Possible**	**Likely**	**Known**
None	None	None	None	None	None
Unlikely	None	Very Low	Very Low	Low	Moderate
Possible	None	Very Low	Moderate	Moderate	High
Likely	None	Low	Moderate	High	Severe
Known	None	Moderate	High	Severe	Critical

For each species in Table 1, a habitat overlap and habitat risk rating is given based on the current state of knowledge as provided by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) Stratus Reports and available through the website www.sararegistry.gc.ca. The potential for adverse impact is given based on the rating scheme provided above.

Table 1: Impact Assessment Summary of SARA Listed Species within the Range of Impact of Alouette Facility Operations

Species Common Name	SARA Status[4]	Habitat Requirements	Habitat Overlap[5]	Habitat Risk	Potential For Adverse Impact	Comments
Nooksack Dace	E	Riffle habitats with gravel/stony bottom	P	U	Very Low	Current operations judged to be benefiting overall ecosystem function, thus providing adequate amounts of suitable habitat for Nooksack dace
Oregon Spotted Frog	E	Shallow, warm water, ephemeral pools associated with permanent water bodies	U	N	None	Suitable habitat does not exist in the area due to dyking, urban development, and steep topography
White Sturgeon	S	Large pools and sloughs in main channel large rivers	U	U	Very Low	If in zone of influence, likely restricted to the Pitt River confluence where operational impacts are limited to flood events
Salish Sucker	E	Coastal small rivers with fairly slow currents; riffles for spawning	P	U	Very Low	Current operations judged to be benefiting overall ecosystem function, thus providing adequate amounts of suitable habitat for Salish Suckers, particularly below 232nd St Bridge.
Green Sturgeon	S	Usually in salt water; in brackish water at the month of large rivers for spawning	U	U	Very Low	If in zone of influence, likely restricted to the Pitt River confluence where operational impacts are limited to flood events
Pacific Water Shrew	T	Riparian and marshy habitats	P	U	Very Low	Extent and nature of riparian habitats in operational zone of influence is unlikely to change from its present state, except for the normal successional growth.
Coast Tailed Frog	S	Cold, clear mountain streams	N	N	None	No geographical overlap
Red Legged Frog	S	Stream, ponds or marshes with emergent vegetation	P	U	Very Low	Current operations judged to be benefiting overall ecosystem function, which may include the formation of suitable habitats, though believed to be scarce. (Presently listed on Schedule 3)

[4] Current species on SARA Schedule 1 or proposed for Schedule 1 – Endangered (E) or Threatened (T) or Special Concern (S) or Extirpated (X)

[5] (N) None, Unlikely (U), Possible (P), Likely (L), Known (K)

Table 1: Impact Assessment Summary of SARA Listed Species within the Range of Impact of Alouette Facility Operations cont'd

Species Common Name	SARA Status[6]	Habitat Requirements	Habitat Overlap[7]	Habitat Risk	Potential For Adverse Impact	Comments
Western Toad	S	Ponds and wetlands for breeding, otherwise non-specific habitat requirements	P	U	Very Low	Current operations judged to be benefiting overall ecosystem function, which may include the formation of suitable habitats, though believed to be scarce. No changes anticipated.
Great Blue Heron	S	Aquatic habitats in general for feeding	K	N	None	Dramatic increase in fish production as a result on current operations has increased food supply. No changes are anticipated with new WUP
Vancouver Island Beggars Tick	S	Generally in narrow band of habitat around ponds, lakes and stream margins	P	U	Very Low	Extent and nature of riparian habitats in operational zone of influence is unlikely to change from its present state, except for the normal successional growth.
Poor Pocket Moss	E	Wet, silty outcrop site in a streamlet within a Douglas Fir/Western Hemlock forest	U	U	None	Only known population in Canada found in a single patch in North Vancouver
Pacific Pond Turtle	X	Slow moving streams, large rivers and sloughs, preferring areas with emergent vegetation	U	U	Very Low	Last recorded in BC in 1959
Stream bank Lupine	E	Wet to moist meadows and river banks with little ground cover. Tends to colonize recently disturbed areas such as from flood events	P	U	Very Low	Believed to benefit from occasional low level flooding, as provided by current operations.

[6] Current species on SARA Schedule 1 or proposed for Schedule 1 – Endangered (E) or Threatened (T) or Special Concern (S) or Extirpated (X)

[7] (N) None, Unlikely (U), Possible (P), Likely (L), Known (K)

Conclusions

Because little or no change in habitat structure and complexity is expected following implementation of a new operating strategy for the Alouette system, the potential for adverse impacts to the usable habitats of SARA listed species is considered to be non-existent to very low. The primary reason that there is some low level risk is due to uncertainty that usable habitats are either available within the zone of operational influence, or if available, whether they are potentially impacted by the range of operational change being considered.

APPENDIX J: WATER USE PLAN TECHNICAL MEMO – PITT MEADOWS FLOOD CONTROL ISSUES

BC hydro

reliable power,
at low cost,
for generations

WUP Technical Memo

To:	Alouette WUP Review Consultative Committee	January 30, 2006
From:	James A. Bruce, M.Sc.	
CC:	District of Pitt Meadows	
Subject:	Pitt Meadows Flood Control issues	

The purpose of this memo is to document the flood control issues of the District of Pitt Meadows as they pertain to the Alouette River Water Use Plan review process.

BACKGROUND

The District of Pitt Meadows have 2 pump houses and 3 gate systems on the lower sections of South Alouette River that are used to help control flood damage on lands adjacent to the rivers dyking network. At risk during flood events are the area's crops, residential homes and out buildings, including greenhouses. The area in question and the location of the pump houses and gates are shown in Figure 1.

ISSUE OF CONCERN

The gates and pump houses are used mainly to control flooding during periods of high inflow by allowing the accumulating waters to drain into the Alouette River through the adjacent dykes. In most cases, the gates and pumps work well and achieve their intended gaol. However, during periods of high Alouette flow, combined with high tide events and a backwatered Fraser River confluence, the elevation of the river can rise to a point where the water directed into the Alouette system does not drain away as intended. In such instances, the gates cannot be opened without allowing water to flow into the already impacted lands (i.e., opposite the intended direction). The concern is that BC Hydro operations, particularly with respect to flood contol, may at times exacerbate the problem.

CONSTRAINTS TO FLOOD CONTROL

BC hydro is often faced with several constraints when attempting to prevent/control a potential downstream flood event:

- Limited ability to direct flood waters to the Stave Lake system (maximum rate of diversion is 57 m^3s^{-1}).
- Limited reservoir strorage to hold back incoming flows, which may be impacted by prioir storm events.
- Rapid rise in water level because of the small reservoir size compared to the magnitude of peak flood inflows.
- Limited ability to forcaste the likelihood, timing and magnitude of inflow flooding events.

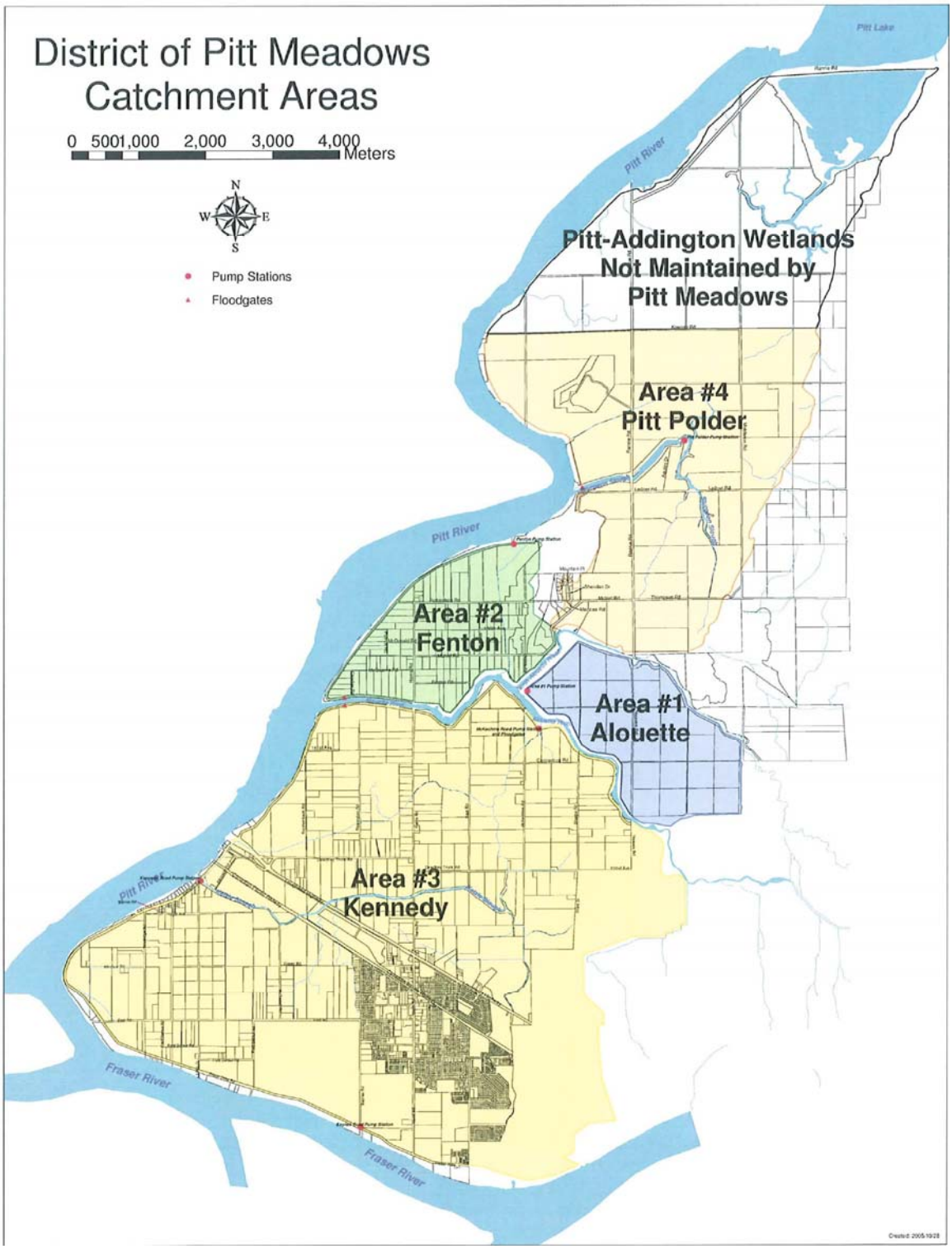
In addition to the adit gate, a key tool used in the prevention and control of potential flood events is the use of pre-spill procedures. Pre-spilling not only helps reduce the likelihood of a free crest spill, it can also help attenuate the peak magnitude of an unavoidable flood event. The ability to pre-spill however is also limited. The maximum capacity of the gate is only 42.5 m^3s^{-1}.

It is important to note that, because of these constraints, the risk of flooding can never be elminiated from the system. Also, these constraints often severely limit the flexibility in time with which flood management actions must take place.

CONCLUSIONS

The Dstrict of Pitt Meadows recognizes that BC Hydro has limited ability to control the course of a potential flood event, including the ability to adjust the timing of flood management actions. Nevertheless, should there be some ability to do so, the district requests that BC Hydro considers the possibility of advancing the timing of pre-spill events so that they are initiated at the onset of a tide's ebb. This would help minimise, but not eliminate, the time during which flood waters potentially impact the District's ability to carry out its own flood management activities in the area.

No performance measures are requested pertaining to this issue. However, the general objective of minimising the occurance of damaging flood events, as determined by the means objective of minimising the occurance of free crest spills, is coincident with the districts concerns regarding flood control. WUP alternatives that best meet this objective would also meet the flood control needs of the district.


District of Pitt Meadows
Catchment Areas
0 500 1,000 2,000 3,000 4,000 Meters
N
W
E
S
Pump Stations
Floodgates
Pitt Lake
Pitt River
Pitt-Addington Wetlands
Not Maintained by
Pitt Meadows
Area #4
Pitt Polder
Pitt River
Area #2
Fenton
Area #1
Alouette
Area #3
Kennedy
Pitt River
Fraser River
Fraser River

APPENDIX K: BC HYDRO INTER-OFFICE MEMO RE: SUBSTRATE FLUSHING FLOW OPERATIONS SCENARIO

BC hydro ENGINEERING

Inter-office memo

TO: Paul Vassilev **DATE:** January 17, 2006

FROM: Chris Caryula **FILE:** REGWUP-ALC300

SUBJECT: **Substrate Flushing Flow Operations Scenario**

This memo summarizes the 3 day - 32 m3/s substrate flushing flow operations scenario between September and February as requested by the Alouette WUP Review Consultative Committee.

Introduction

A sustained substrate flushing flow of 32 m^3/s from Alouette Dam downstream to the Alouette River requires a reservoir elevation equal to or greater than El. 123.5 m during the release period to provide the flush. However, the reservoir level is maintained below El. 122.6 between October and April for flood protection. Thus an increase in the reservoir level creates additional days of flood risk depending on the time of year that the fish flush occurs.

Methodology

The 10^{th}, 50^{th} and 90^{th} percentile inflows for each month between September and February were used to determine the reservoir operation required to produce the requested substrate flushing flow. Since the flush is required for 3 days, the final elevation at the end of the flush is set to El. 123.5 m and the storage volume obtained, **Rf**. The required storage, $\mathbf{S_{ff}}$, at the start of the flush is equivalent to 32 m^3/s less the inflow for each particular month, summed over three days. The result is the reservoir storage required at the start of the flushing period, **Rs:**

$$\mathbf{Rs = Rf + S_{ff}}$$

The number of days required to raise the initial reservoir storage, **Ri**, at El. 122.6 m to the flush starting storage, **Rs**, is calculated using the storage difference, $\mathbf{S_{raise}}$, divided by the daily inflow for the particular month:

$$\mathbf{Rs = Ri + S_{raise}}$$

The number of days required to draw the reservoir back down to El. 122.6 m from El. 123.5 m depends on whether the turbine is used in conjunction with the Adit Gate since the inflow to Alouette Lake Reservoir may exceed the capacity of the turbine which is 24.1 m^3/s. The combined capacity of the turbine and Adit Gate is 57 m^3/s. The volume difference between El. 122.6 m and El. 123.5 m is divided by the difference between inflow and outflow, which is the daily volume discharge capacity, to determine the number of days to draw the reservoir back down to El. 122.6 m.

Table 1 summarizes the additional days of flood exposure for each month between September and February.

The results indicate that the Adit Gate would likely be used in conjunction with the turbine to minimize the days of flood exposure associated with a reservoir level above El. 122.6 m; particularly since the turbine discharge in often exceeded by the inflow to the reservoir. Figure 1 shows an example of the reservoir operation for 50th percentile inflow in October.

Lost generation is based on an incremental 29 m3/s per day (due to current Low Level Outlet discharge) to each plant in the system during the substrate flush and incremental flow lost at Alouette Plant during reservoir drawdown with the Adit Gate. The loss in generation in MWh at each plant is calculated per m3/s using the following ratios:

ALU: 0.338 MWh/m^3/s
SFN: 0.337 MWh/m^3/s
RUS: 0.280 MWh/m^3/s

The lost revenue is valued at approximately $50/MWh and results in a range of $140,000 to a maximum of $167,674 for the3 day - 32 m3/s substrate flushing flow. The Adit Gate generally takes 5 to 6 days to draw the reservoir down to El. 122.6 m from El. 132.5 m, regardless of the month between October and February, 50th percentile monthly inflow. However, a drawdown attempt in months of significant inflow (90th percentile inflow) could result in an extended period of Adit Gate operation. While this increases the number of flood risk days, the cost does not increase since inflows greater than the turbine capacity would have been passed through the Adit Gate regardless.

Therefore, the cost of the 3 day - 32 m3/s substrate flushing flow can be considered to be $170,000 for the purpose of discussion.

Prepared by: _____
C. Caryula, EIT

Reviewed by: _____
K. Groves, P. Eng.

Attachments

c: J. Bruce

wr508

TABLE 1: Flood Exposure

Flushing Flow	Duration	Start	Monthly Inflow	elevation Initial	elevation start of flush	elevation end of flush	elevation Final	Inflow days to raise reservoir to Flush Starting Elevation (min. El. 123.5 m)	Release days to draw reservoir down to El. 122.6 m		Additional days of flood exposure above El. 122.6 m	Incremental System Revenue Loss
m3/s	days	month	m3/s	m	m	m	m		turbine (24.1 m3/s)	turbine + adit gate (57 m3/s)		$50/MWh
	A							B	C	D	A+B+D	
			10th Percentile									
32	3	9	2.4	122.6	123.9	123.5	122.6	107	8	3	113	$140,784
32	3	10	5.5	122.6	123.9	123.5	122.6	45	9	3	51	$143,262
32	3	11	16.8	122.6	123.7	123.5	122.6	13	23	4	20	$155,488
32	3	12	13.4	122.6	123.7	123.5	122.6	17	16	4	23	$151,206
32	3	1	14.0	122.6	123.7	123.5	122.6	16	17	4	23	$151,883
32	3	2	10.4	122.6	123.8	123.5	122.6	22	12	4	29	$147,798
32	3	3	9.6	122.6	123.8	123.5	122.6	25	12	4	31	$146,988
			50th Percentile									
32	3	9	7.4	122.6	123.8	123.5	122.6	33	10	3	39	$144,895
32	***3***	***10***	***21.5***	***122.6***	***123.6***	***123.5***	***122.6***	***9***	***65***	***5***	***17***	***$162,943***
32	3	11	32.9	122.6	123.5	123.5	122.6	5	insufficient release	7	15	$167,674
32	3	12	29.9	122.6	123.5	123.5	122.6	6	insufficient release	6	15	$167,674
32	3	1	27.8	122.6	123.5	123.5	122.6	6	insufficient release	6	15	$167,674
32	3	2	23.6	122.6	123.6	123.5	122.6	8	331	5	16	$166,848
32	3	3	21.4	122.6	123.6	123.5	122.6	9	63	5	17	$162,794
			90th Percentile									
32	3	9	17.2	122.6	123.7	123.5	122.6	12	24	4	20	$156,041
32	3	10	38.9	122.6	123.5	123.5	122.6	4	insufficient release	9	17	$167,674
32	3	11	54.9	122.6	123.5	123.5	122.6	3	insufficient release	81	87	$167,674
32	3	12	51.4	122.6	123.5	123.5	122.6	3	insufficient release	30	36	$167,674
32	3	1	48.8	122.6	123.5	123.5	122.6	3	insufficient release	20	27	$167,674
32	3	2	38.5	122.6	123.5	123.5	122.6	4	insufficient release	9	16	$167,674
32	3	3	35.7	122.6	123.5	123.5	122.6	5	insufficient release	8	16	$167,674

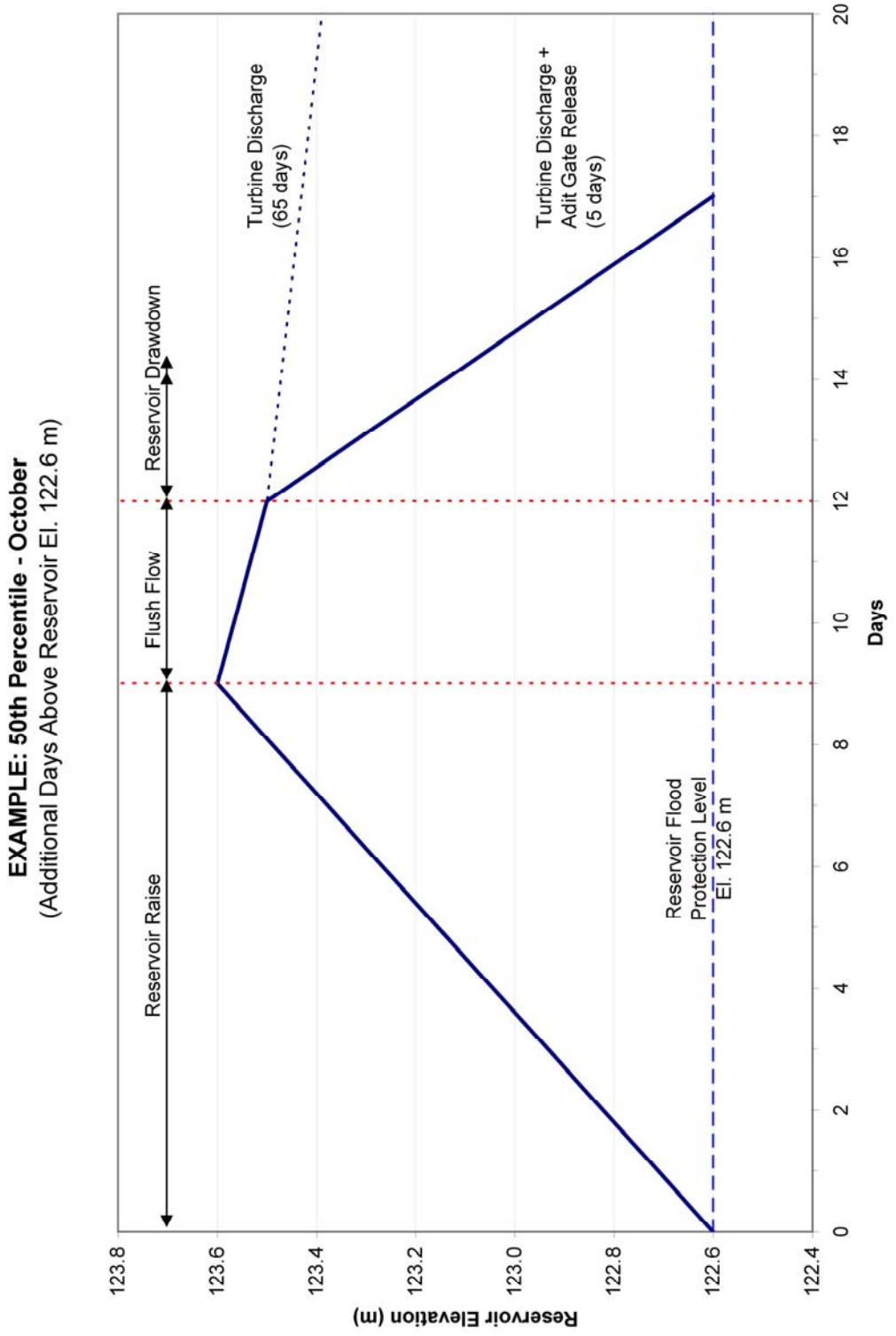

EXAMPLE: 50th Percentile - October
(Additional Days Above Reservoir El. 122.6 m)
Reservoir Drawdown
Flush Flow
Reservoir Raise
Turbine Discharge
(65 days)
Turbine Discharge +
Adit Gate Release
(5 days)
Reservoir Flood
Protection Level
El. 122.6 m
Reservoir Elevation (m)
123.8
123.6
123.4
123.2
123.0
122.8
122.6
122.4
Days
0
2
4
6
8
10
12
14
16
18
20

FIGURE 1

APPENDIX L: TERMS OF REFERENCE FOR THE ALOUETTE MONITORING COMMITTEE

Alouette Monitoring Committee Terms of Reference

Prepared by James Bruce, BC Hydro Regulatory Relations Water Use Plan Implementation, on behalf of:

Alouette River Water Use Plan Review Fish Technical Subcommittee:

Mat Foy	Department of Fisheries and Oceans
Suzanne Thorpe	Department of Fisheries and Oceans
Hugh Smith	BC Hydro
Greg Wilson	Ministry of Environment
Ron MacLean	Alco Hatchery
Ross Davies	Community Representative

The Alouette Water Use Plan Consultative Committee (WUP CC) recommended that a Monitoring Committee (MC) be established with the following membership:

- BC Hydro
- Alouette River Management Society
- Ministry of Environment
- Alco Hatchery
- Fisheries and Oceans Canada
- Katzie First Nations
- City of Maple Ridge

A committee custodian will ensure continuity in the monitoring program. The custodian will ensure consistent experimental/sampling methods and locations providing the ability to draw meaningful conclusions from study findings. This function will be served by the BC Hydro monitoring program study lead.

Committee Membership

Alternates:

Agencies may identify alternate representatives. These alternates may attend meetings on the same basis as delegates; however the representatives must put forward “one voice” representing their agency’s, organization’s or constituent’s views.

Alternates must maintain their familiarity with the discussions occurring at the consultative committee tables; or be briefed by the main delegate prior to attending on their behalf.

Observers:

Observers are welcome to attend the Monitoring Committee meetings. However, information available to the public will be placed on the web site. Observers are required to only speak when asked by the facilitator. During breaks Observers may ask delegates to put forward their comments or concerns to the Monitoring Committee members.

Purpose:

The Monitoring Committee's purpose is to:

- Ensure the continuity of expertise and knowledge derived from the CC WUP consultative process and the proposed study program
- Ensure transference of knowledge to those responsible for the 2014 WUP review process
- Make study program adjustments within the preset budget, scope, and time limits approved by, or constraints ordered by, the Comptroller of Water Rights.

The Comptroller of Water Rights is responsible for approving the proposed study program (within the set time period and budget) and will also be responsible for approving any program changes which result in budget increases or adjustments or have any operational impacts beyond what is originally directed by the Comptroller.

Meeting Schedule:

Annual Monitoring Committee meetings will take place in March of each year until the WUP review period in 2014. It will be ensured that the March meeting is held with sufficient time to incorporate Monitoring Committee comments into the annual submittal to the Comptroller of Water Rights in April.

The BC Hydro program "custodian" will coordinate the meeting and will assist with committee member understanding of study findings to date and implications to overall WUP objectives.

Mandate:

The Consultative Committee recommended that the mandate of the Monitoring Committee should be to:

- Based on approved monitoring program terms of reference decision criteria, review monitoring program results and provide advice on recommended actions.
- Recommend improvements to the monitoring program within existing WUP budgets, scope and time limits.
- Support periodic communication with the public (e.g., newsletters, annual reports, and information sessions).
- Provide comment on annual April monitoring program submissions to the Comptroller of Water Rights
- Liaise with Katzie First Nation on heritage management issues and the incorporation of TEK into the monitoring program
- Liaise with the Stave Monitoring committee on an as needed basis

APPENDIX M: TERMS OF REFERENCE FOR THE ALOUETTE MONITORING PROGRAM

ALOUETTE LAKE WATER USE PLAN REVIEW:

Monitoring Program Terms of Reference

Prepared by:

James Bruce
BC Hydro, Regulatory Relations
Water Use Plan Implementation
Burnaby, BC

On behalf of:

Alouette River Water Use Plan Review Fish Technical Subcommittee:

Mat Foy	Department of Fisheries and Oceans	**Greg Wilson**	Ministry of Environment
Susan Thorpe	Department of Fisheries and Oceans	**Ron MacLean**	Alco Hatchery
Hugh Smith	BC Hydro	**Ross Davies**	Community Representative
Geoff Clayton	Alouette River Management Society	**Debbie Miller**	Katzie First Nation
Jenny Ljunggren	Alouette River Management Society	**Ken Wilson**	Katzie First Nation

1.0 INTRODUCTION

As the Alouette Lake Water Use Plan (WUP) reached completion, a number of uncertainties were identified regarding the effect of BC Hydro operations on aquatic resources. The primary consequence of these uncertainties was a limited ability to predict the response of fish and wildlife populations to operational changes as a result of WUP implementation. This in turn highlighted the general uncertainty surrounding the likelihood that the expected fish and wildlife benefits of the WUP operation will be realized.

The framework for WUP process requires that it be reviewed on a periodic and ongoing basis. Therefore, in the years subsequent to the implementation of the WUP, there will be a need for compliance monitoring and effectiveness monitoring to gain the information necessary to address these uncertainties. Compliance monitoring consists of monitoring activities to ensure that BC Hydro complies with the conditions of its water licence. Effectiveness monitoring is more complex. It involves the observation, measurement, and evaluation of streamflows, fish and wildlife habitat, and population changes to test the efficacy of the WUP.

Effectiveness monitoring for the Alouette Lake system will require the collection of data in order to quantify relationships between specific fish population parameters and different aspects of BC Hydro operations. Monitoring will assess whether a predicted biological response to changes in operations actually occurred as predicted, and thereby assess whether the objectives of greater abundance and/or diversity were met.

2.0 OVERVIEW

At the conclusion of the Alouette Lake WUP Review process, the Consultative Committee (CC) recommended several key changes to the way Alouette Dam is operated. They are believed to have at least some impact to the ecology of resident fish species. The proposed changes are in addition to the operational changes made in 1996 as part of the original water licence review process:

1. Spring surface release starting 15 April and ending 14 June.
2. A higher reservoir elevation (122.5 m) during the peak recreation season starting 15 June and ending Labour Day (5 September).
3. Short recreation shoulder season ending 15 September when water levels are above 121.25 m.
4. Removing the need for a prescribed flushing flow to clear fine sediments.

When recommending these operational changes, the CC acknowledged that there was a need for additional fish related information that would add greater certainty to their decision-making, but could not be collected at the time of the WUP review process or had to be monitored in situ to confirm their assumed consequences. In particular, the CC identified the following critical uncertainties:

1. Long term impact on Alouette River smolt output.
2. Success of surface release in allowing kokanee to leave the reservoir and begin their seaward migration.
3. Long term impact on the transport of fine sediments in Alouette River.
4. Success of the kokanee re-anadromization initiative, and hence an evaluation of the need for the surface release.
5. Water temperature impacts on the Alouette River.
6. Long term impact on the kokanee reproductive success.

In addition to the uncertainties above, the CC also recommended that an Alouette Monitoring Review Committee be created to oversee the general progress of the monitor, review all reports before general release, and recommend changes regarding the monitoring program's implementation as deemed necessary. Committee membership is to include representatives from BC Hydro, BC Ministry of Environment, Fisheries and Oceans Canada, Katzie First Nation, District of Maple Ridge, and Alouette River Management Society.

3.0 COST

The total cost of the monitoring program, which is to be carried out over a period of eight years, is estimated to be roughly $1,370,000 (in 2006 dollars). When incorporating a future annual inflation rate of 2 per cent, the anticipated cost of the program is expected to be closer to $1,500,000. Average annual cost for the entire program is expected to be $171,200 (in 2006 dollars), but will vary between $161,000 and $188,700 depending on the tasks to be completed or the equipment to be purchased.

As illustrated in Table 1, the majority of this cost will be comprised of labour ($1,099,000). The program estimate also includes $216,000 for the purchase of equipment and crew support and a 5 per cent contingency fund totaling $55,000.

Table 1. Annual cost summary of the Alouette WUP monitor. All costs are in 2006 dollars unless otherwise indicated.

Monitor	Distribution	Annual Cost (2005 dollars)								Program Total
		2007	2008	2009	2010	2011	2012	2013	2014	
Smolt Enumeration	Labour	$ 82,350	$ 82,350	$ 82,350	$ 82,350	$ 82,350	$ 82,350	$ 82,350	$ 87,350	**$ 663,800**
	Expenses	$ 13,910	$ 13,910	$ 13,910	$ 13,910	$ 13,910	$ 13,910	$ 13,910	$ 14,010	**$ 111,380**
Kokanee Out-migration	Labour	$ 28,475	$ 28,475	$ 28,475	$ 28,475	$ 28,475	$ 28,475	$ 28,475	$ 32,475	**$ 231,800**
	Expenses	$ 5,050	$ 5,050	$ 5,050	$ 5,050	$ 5,050	$ 5,050	$ 5,050	$ 5,150	**$ 40,500**
Substarte Quality	Labour	$ 9,975	$ 6,975	$ 6,975	$ 6,975	$ 6,975	$ 6,975	$ 6,975	$ 9,375	**$ 61,200**
	Expenses	$ 478	$ 478	$ 478	$ 478	$ 478	$ 478	$ 478	$ 578	**$ 3,924**
Sockeye Adult Enumeration	Labour	$ 21,425	$ 21,425	$ 21,425	$ 6,375	$ 6,375	$ 6,375	$ 6,375	$ 8,175	**$ 97,950**
	Expenses	$ 9,100	$ 7,600	$ 5,600	$ 5,100	$ 5,100	$ 5,100	$ 5,100	$ 5,200	**$ 47,900**
Water Temperature	Labour	$ 4,400	$ 2,400	$ 2,400	$ 2,400	$ 2,400	$ 2,400	$ 2,400	$ 4,200	**$ 23,000**
	Expenses	$ 3,746	$ 1,046	$ 1,046	$ 1,046	$ 1,046	$ 1,046	$ 1,046	$ 1,146	**$ 11,168**
Kokanee Age Structure Analysis	Labour	$ 2,250	$ 2,250	$ 2,250	$ 2,250	$ 2,250	$ 2,250	$ 2,250	$ 5,250	**$ 21,000**
	Expenses	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 200	**$ 900**
Total Labour		$ 148,875	$ 143,875	$ 143,875	$ 128,825	$ 128,825	$ 128,825	$ 128,825	$ 146,825	**$ 1,098,750**
Total Expenses		$ 32,384	$ 28,184	$ 26,184	$ 25,684	$ 25,684	$ 25,684	$ 25,684	$ 26,284	**$ 215,772**
Contigency		$ 7,444	$ 7,194	$ 7,194	$ 6,441	$ 6,441	$ 6,441	$ 6,441	$ 7,341	**$ 54,938**
2% Inflation Adjustment		$ 3,773	$ 7,241	$ 10,848	$ 13,266	$ 16,751	$ 20,305	$ 23,930	$ 30,975	**$ 127,089**
Program Total		**$ 192,476**	**$ 186,494**	**$ 188,101**	**$ 174,217**	**$ 177,701**	**$ 181,255**	**$ 184,880**	**$ 211,425**	**$ 1,496,549**

Monitor 1

Smolt Enumeration

1.0 PROGRAM RATIONALE

1.1 Background

Since 1998, smolt output from South Alouette River has been monitored to track changes in the river's smolt carrying capacity following implementation of a new base flow regime from Alouette Dam in 1996. Results of the program to date are summarized in Cope (2005), which to date seem to suggest that salmonid smolt production is nearing capacity in the system. The duration of the monitor however, is still considered too short to assure certainty in these results. Consequently, the CC has recommended that the monitor continue until the next WUP review period in 2014. In addition, the CC has recommended that the scope of the program be expanded to include tracking of out-migrating kokanee smolts released from the dam and the use of relative egg to smolt survival estimates as a diagnostic indicator of general substrate quality.

1.2 Management Questions

The FTC identified three management questions that are to be addressed through the smolt enumeration monitor:

1. Is the average base-flow release of 2.6 m^3s^{-1} from the Alouette Dam (obtained by fully opening the low level outlet) adequate to sustain or improve current levels of salmonid smolt production downstream of the dam? The species of interest include chum, pink, chinook, and coho salmon as well as steelhead and cutthroat trout.
2. Following their migration out of Alouette Lake, do the kokanee smolts immediately continue their migration out of the Alouette River or do they delay their seaward migration for a period of time?
3. Using chum salmon counts at the Alco Park Hatchery as an indicator of run strength and the results of the substrate quality monitor, is there evidence of a persistent, declining trend in egg to smolt survival that would suggest a degrading condition in spawning substrate quality?

1.3 Summary of Hypotheses

The management questions identified in Section 1.2 are to be addressed through tests of the following set of hypotheses. The first group of hypotheses pertain to Management Question 1 and are tested individually for each species:

$H_0$1: Annual estimates of smolt abundance remain stable through time as indicated by a lack of a significant correlation between the two variables. *(To be tested separately for each species)*

If $H_0 1$ is rejected, the data will be analyzed for possible correlations with river discharge (from the Water Survey of Canada gauging Station No. 08MH005), water temperature (from Monitor 5), substrate quality (from $H_0 5$ below and Monitor 3) and relative run strength (from Monitor 4) using multiple regression techniques (Zar 1974). Where data are available, this will lead to tests of the following four sub-hypotheses:

$H_0 1_A$ The partial regression coefficient (B_A) of average (or some other summary statistic) river discharge is equal to 0.

$H_0 1_B$ The partial regression coefficient (B_B) of average (or some other summary statistic) water temperature is equal to 0.

$H_0 1_C$ The partial regression coefficient (B_C) of average (or some other summary statistic) substrate quality is equal to 0.

$H_0 1_D$ The partial regression coefficient (B_D) of relative spawner count is equal to 0.

It should be noted that it will not be possible to test all sub-hypotheses for all salmonid species (e.g., relative spawner count data will only be available for chum salmon). Because this analysis is exploratory in nature, success will be partly dependent of the choice of statistic used to summarize the discharge, temperature and substrate quality independent variables. The underlying rationale behind the choice of summary statistic will have to be clearly described for the analysis to be meaningful.

If $H_0 1$ is not-rejected, then the following null hypothesis will be tested to determine whether there is sufficient between-year variance in annual smolt abundance to warrant further analysis;

$H_0 2$: The between-year variance in annual estimates of smolt abundance is equal to or less than the average within year-variance of each annual smolt abundance estimate (or some other threshold level that may be indicative of an unstable rearing environment and or a susceptibility to low seeding conditions).

If $H_0 2$ is not rejected, then no further action/analysis is required. However, if $H_0 2$ is rejected, then tests of sub-hypotheses $H_0 1_A$ to $H_0 1_D$ will be carried out as described above.

The next hypothesis pertains to the out migration of kokanee smolts and relates to a perceived ancillary benefit of a 6 $m^3 s^{-1}$ post surface release flush to promote the movement of "reluctant" migrants. It is believed that the flush could also help promote the continued migration of kokanee smolts out of the Alouette system. There are two hypotheses to test:

$H_0 3$: Kokanee smolts, following their release from Alouette Lake, continue their migration out of the Alouette system without delay. i.e., the time difference in peak out-migration between the Mud Creek trap and 216th Bridge trap is less than a few weeks.

Rejection of $H_0$3 would suggest that the kokanee smolts may reside in the river for a time before continuing on with their seaward migration, leading to the next hypothesis:

$H_0$4: The time difference in peak out-migration between the Mud Creek trap and 216th Bridge trap is the same with or without the 6 m^3s^{-1} post surface release flush.

Rejection of $H_0$4 would suggest that a 3 m^3s^{-1} base-flow is inadequate to ensure continued movement of the kokanee smolts, and that the experimental 6 m^3s^{-1} post surface release flush may have to become an integral part of the surface release operation.

The final null hypothesis relates to substrate quality and its potential to impact egg to fry survival. The intent of this monitor is to provide data to compliment the substrate quality monitor described in later in Monitor 3.

$H_0$5: Relative egg to smolt survival of chum salmon, as determined from the annual smolt enumeration data and Alco Hatchery annual catch data (an indicator of run strength), is not correlated with fine sediment levels recorded in the substrate quality monitor.

Rejection of $H_0$5 would suggest that there is a relationship between the substrate quality data and egg to smolt survival, from which threshold sediment levels can be derived as triggers for prescribed flushing flow events.

It should be noted that the hypotheses listed above are considered the minimum to be tested and that other hypotheses may become evident as the data is collected and analyzed.

1.4 Key Water Use Decision

The smolt enumeration monitor is linked to three water use decisions. The first concerns the base-flow and whether is it adequate to sustain or increase smolt production levels. It is an effectiveness monitor tracking the changes in smolt output numbers to confirm expected benefits. In the future, the results of the monitor could be used to develop a case for a variable flow release regime at the dam where the LLO release is allowed to vary according to water flow measurements taken downstream, and thus maintain some critical level rather than be kept fully open year-round.

The second water use decision impacted by the results of this monitor is the need to provide a week long 6 m^3s^{-1} post surface release flush once the kokanee smolts have left the reservoir. Presently, the post surface release flush is experimental in nature (to occur every second year until monitoring results are conclusive), but if the monitor shows that it is necessary for continued seaward migration, it may have to be re-evaluated as an integral part of the WUP.

The egg to smolt survival data will be used to determine whether there exists a threshold sediment level in the system above which impacts reproductive success occur. If such a threshold is found, then it may be used to trigger prescribed sediment flushes (surface releases 32 m^3s^{-1} or greater), which were abandoned

during the WUP review process but may be reinstituted depending on the outcome of this and the substrate quality monitor.

2.0 PROGRAM PROPOSAL

2.1 Approach

The general approach to the monitor is to continue with the smolt enumeration monitor first established in 1998 (Cope 2005), but with a few changes in methodology to reduce the instream hazard of the traps and streamline the enumeration procedure to reduce the crew size and hence overall cost the program. These include:

1. The use of one five-foot rotary screw trap at the 216th St. Bridge location instead of two traps and the use of sandbags to deflect a greater proportion of the stream's discharge towards the trap.
2. Greater use of sub-sampling procedures to collect morphometric data on captured fish.
3. Increase reliance on past measurements of trap efficiency (in a Bayesian framework) to reduce frequency of measurement.

There are to be no changes in the location and use of the incline plane traps at the 224th St. Bridge. The program duration, intensity of sampling effort, level of trap maintenance, and procedures to estimate trap efficiency are not to change from the protocols established prior to the WUP review process.

2.2 Objective and Scope

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

1. The study area will consist primarily of the riverine habitat located downstream of the Alouette Lake Dam, and will consist of two sites where fish traps will be installed and fished; two incline plane traps just upstream of the 224th St. Bridge, and a single rotary screw trap immediately downstream of 216th St. Bridge.
2. The monitor will be carried out annually until the next WUP review period in 2014.
3. When possible, the traps will be fished continuously for the duration of the enumeration period starting the last week of February and ending the first week in June.
4. The contractor will ensure the all traps are in proper working order for the duration of the program.
5. A data report, including a comprehensive executive summary and 15 min presentation, will be prepared annually summarizing the data collected to

date, as well as discuss inferences and present conclusions as they pertain to the impacts of the WUP over time.

6. 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 from the data pertaining to the impacts of the WUP over time, and presents conclusions concerning the hypotheses and the management questions in Section 1.2.

2.3 Methods

2.3.1 Field Methods

Field methods will follow that described in Cope (2005) so that all collected data are consistent with those in prior years of monitoring (1998 to 2005). This includes the following elements:

1. Use of two incline plane traps located just upstream of the 224th St. Bridge. These are to be fished continuously from the last week of February until the end of the chum out-migration period (usually the first week of May).
2. Use of a single 1.8 m rotary screw trap located just downstream of the 216th St. Bridge. Installation is to include the appropriate use of sand bags to improve volume and direction of flow to the trap. It will be fished continuously from the last week of February to the first week of June which is typically the end of the smolt out-migration period.
3. The traps will be maintained and adjusted as required to ensure consistent trapping conditions through time.
4. Gear efficiency will be determined twice weekly for both fry (0+ fish < 70 mm FL) and smolts (fish > 70 mm FL that have over-wintered at least one year). Fry will be marked using Bismark Brown dye (1–2 hour immersion in 10 ppm solution) while smolts will be caudal fin clipped. Fry will be released at the 232 St. Bridge, smolts will be released at the 224th St. Bridge. If possible, the frequency of measurement will be reduced to once a week if it is determined that precision and accuracy will not be compromised by the action.
5. Captured fish will be sub-sampled for measurement of fork length (mm FL) and wet weight (g). Sub-sampling will be done daily to ensure an even distribution of effort through time. Intensity of sub-sampling will be at the discretion of the crew (e.g., at least a minimum of ten individuals/day) but must be based on a standard sub-sampling protocol (e.g., every x^{th} individual or be evenly distributed among the catch) and be consistent through time to minimize error.
6. All incidental catches from upstream studies will be noted, including the presence and type of marks.

Included in the monitor will be daily measures of water level at the 224th St. Bridge and 216th St. Bridge locations, as well as daily water temperature from

TimbitsTM temperature data loggers at each trap location, and daily discharge from the Water Survey of Canada gauging station at the 232nd St. Bridge (Station No. 08MH005).

2.3.2 Safety Concerns

A safety plan will have to be developed for all aspects of the study in accordance to BC Hydro procedures and guidelines. It is important to note that monitors must always be carried out by crews of at least two members, that appropriate safety equipment is available at the site, and that appropriate check-in and checkout procedures are followed.

2.3.3 Data Analysis

All data will be entered into a common database in a standard format for analysis. This will ensure that all data collected over the years of monitoring are compatible and can be analyzed without transformation.

Data analysis will proceed as described by Cope (2005) to ensure consistency with the results in prior years. It is to include the following components:

1. Use of both pooled and stratified Peterson approaches to population estimation of each species (Ricker 1975, Schwarz and Taylor 1998), and hence trap efficiency.
2. Calculation of confidence intervals for all population estimates.
3. Use of summary statistics and plots for all morphometric and physical data.

Hypothesis testing related to $H_0$1 will involve the use of simple regression techniques to identify the direction and likelihood of a time trend. Appropriate transformations will be used to ensure that assumptions of normality, homoscedasticity, and linearity are met. Because variance estimates are available, bootstrapping methods should be used to account for this measure of error in the analysis (Manly1997).

If hypothesis $H_0$1 is rejected, then multiple linear regression techniques will be used to identify possible correlates with annual smolt counts from among the physical data collected in this monitor. This analysis will be exploratory in nature, so care must be taken when developing statistics to summarize the temporal as dependent variables in the analysis. The choice of summary statistic should always be accompanied with a clearly stated biological rationale or hypothesis. It should be noted that the primary objective of the monitor is to identify significant correlates and the direction of the trends. It is not necessarily to develop a predictive model, though the end result of the analysis may lead to one. As above, data transformations will be used to ensure that assumptions of normality, homoscedasticity, and linearity are met.

Hypothesis $H_0$2 will be tested using a simple coefficient of variance (CV) ratio F-test where the between-year CV for annual smolt abundance is compared to the average within-year CV of the smolt abundance estimate (Zar 1974). Rejection of $H_0$2 will lead to the same multiple regression analysis described above should $H_0$1 be rejected.

Both hypotheses $H_0$3 and $H_0$4 will be tested by comparing cumulative distributions of migrant counts past the trap over time. The comparisons will be mainly descriptive for $H_0$3, but may involve a simple t-test (or the non-parametric equivalent) for tests of $H_0$4 that looks for significant treatment differences in the number of days that separate the 50 %-tile marks between upper and lower traps.

Chum relative egg to fry survival will be calculated each year by dividing annual fry estimates with the product of the number of chum females captured at the Alco Hatchery (Monitor 5) and average number of eggs per female (derived from bio-standards). The analysis will assume that the hatchery counts are proportional to the total run size, thus avoiding the need to extrapolate the count data to the whole river. Hypothesis $H_0$5 will be tested using simple correlation analysis with the annual substrate quality data collected in Monitor 3. The test will be carried out annually, but only after a minimum of three years of data have been collected. The test of $H_0$5 will be most meaningful at the conclusion of the monitor when the greatest number of observations is available for testing.

It is important to note that the analyses described above are considered to be the minimum necessary, and that the nature of the data, as well as the results of studies outside the scope of this monitor, may lead to alternative or additional statistical procedures to test the hypotheses in Section 1.3 and ultimately address the management questions in Section 1.2.

2.3.4 Reporting

Project reporting will consist of annual data reports and a comprehensive final report at the conclusion of the monitor. The annual data reports will summarize the year's findings and include a short discussion of how the year's data compare to that collected in previous years. It will include a brief description of methods, present the data collected that year, and report on the results of all analyses.

At the conclusion of the monitor, a final comprehensive report will be prepared from all of the annual reports written to date that:

1. Re-iterates the objective and scope of the monitor.
2. Presents the methods of data collection.
3. Describes the compiled data set and presents the results of all analyses.
4. Discusses the consequences of these results as they pertain to the current WUP operation, and how it may or could factor into future decision making.

All reports will be submitted to regulatory agencies for review and comment prior to being finalized for general release.

2.4 Interpretation of Results

2.4.1 Smolt enumeration

For each species, rejection of $H_0$1 would indicate that there may be indeed be a temporal tend in the long term smolt enumeration data. Analysis of the regression parameters and summary statistics, whether it be linear or non-linear, will

provide the data necessary to determine whether the smolt population trend is positive (increasing through time) or negative (decreasing through time) and assess the rate of change trough time. A positive trend would suggest that habitat conditions are continuing to improve and/or the population is still hasn't reached a state of equilibrium. A negative trend would indicate that one or more constraints to population growth still persist in the system. An analysis of what are deemed to be key environmental factors (e.g., water level/habitat area, water temperature, substrate quality, and relative run strength) governing population size will help isolate the primary limiting factor(s). One of the key outcomes of the limiting factor analysis is a determination whether an observed declining trend is linked to Alouette Project operations.

Failure to reject $H_0$1 would suggest the population has reached a relatively stable state given the range of prevailing environmental conditions. If the variance about the time-averaged smolt population size is small, then the measured population can be viewed as being indicative of the system's carrying capacity, that the habitat condition(s) which define this capacity is/are relatively stable through time, and that the population is fully seeded each year. If there is a large degree of variance, then one or more factors that define the rivers carrying capacity varies significantly and has an impact on smolt output (e.g., water level/habitat area, water temperature, substrate quality, and relative run strength). Regression analysis, both linear and non-linear, will help identify what those factors may be. A key outcome of the regression analysis will be a determination of whether fluctuations in annual smolt production are linked to operations of the Alouette Project.

If linkages to Alouette Project operations are found, whether it be to a persistent deterioration of downstream habitats, or to highly variable between-year habitat states which impact carrying capacity, they will form the basis for the development of alternative, and perhaps more sophisticated operating regimes for downstream releases to the South Alouette River during the next Water Use Plan Review Period. Evidence of a catastrophic trend in fish population may illicit a more immediate remedial response.

2.4.2 Kokanee Out-migration – River Residence Time

Hypothesis $H_0$3 is designed to test the general hypothesis that kokanee, once in the South Alouette River, immediately continue their seaward migration out of the river and onwards to the ocean via the Pitt and Fraser Rivers. Presently, that is believed to be the case, but it is uncertain whether a proportion of individuals fail to make the journey. Failure to reject $H_0$3 would suggest that the majority of individuals do indeed continue their seaward migration. However, rejection of $H_0$3, would suggest that the base surficial release regime may not adequate to meet the kokanee's hydraulic needs. It is hoped that there would be sufficient inter-annual variably in release timing to be able to tease out ideal timing windows. Test of $H_0$4, would in turn help assess whether there is an adequate downstream flow to sustain the seaward movement (i.e., does a higher pulse flow trigger or sustain downstream movement in these fish?). Failure to reject $H_0$3 and $H_0$4, despite inter-annual variability in flow conditions, would suggest that the

proposed surface release regime is ineffective at promoting reliable out-migration responses in the Alouette kokanee population, or that the propensity of these fish to migrate seaward has been lost since impoundment. Either way, this result would require a re-evaluation of the current approach to re-introducing sockeye salmon to the Alouette Lake system, including the need for an annual surficial release operation.

2.4.3 Relative Egg to Smolt Survival of Chum Salmon

A key concern in the river is the quality of spawning substrate. During the WUP, it was accepted that naturally occurring flood events, along with the redd-building activity of the salmonids themselves, have created what are believed to be excellent spawning habitat conditions. However, there is some uncertainty as to whether this condition can persist through time with the new WUP. Though this issue is being evaluated directly in a separate monitor (Monitor 3), uncertainty in the methodology requires that an independent corroborative measure be used as well. Because at the Alco Hatchery brood-stock collection fence are already collected through separate monitors, the CC recommended that the chum fry counts and the chum adult counts from Monitor 4 be combined to create a relative measure of egg-fry survival to track relative reproductive success during the egg incubation phase.

Rejection of $H_0 5$ would suggest incubation conditions are at least in part dependent on substrate quality. If a drop in relative egg to fry survival over time corresponds with a drop in substrate quality as indicated in Monitor 3, then a strong case may be made that spawning conditions in the river are deteriorating and that remedial action may be required (possibly a prescribed flushing flow). Failure to reject $H_0 5$, even if results of Monitor 4 seem to suggest deteriorating substrate conditions, would indicate that there is no causal relationship and that spawning conditions are still sufficiently high to sustain high relative egg to fry survival rates. No action would then be required.

Care should be used when interpreting the relative egg to fry ratio data. It assumes that the catch of chum spawners at the Alco Hatchery fence is consistently proportional to the total number of spawners in the river when this may not always be the case. This may require independent verification in a separate study. Also problematic with the data is that egg to fry survival tends to drop when the number of spawners reaches and exceeds the capacity of the system due to the damaging effects of redd superimposition. Both of these issues need to be taken into account when using this data to corroborate the substrate quality monitoring results.

2.5 Schedule

The enumeration program will be carried out annually until the next WUP review period in 2014. Fry enumeration will begin in the last week in February, and continue until the end of the out-migration period (usually the first week of May). A data report, executive summary and presentation of the year's data will be due the first week of February the following year. The final report will be due just

prior to the start of the next UP review process in 2014, though the precise due date will be set at BC Hydro's discretion.

2.6 Budget

The total cost of the eight-year smolt enumeration monitor is estimated to be $808,400 in 2006 dollars. It includes $663,800 for labour, $111,400 in expenses, and a 5 per cent contingency totaling $33,200. Taking into account an average inflation rate of 2 per cent, the total cost is expected to be closer to $885,000 over the eight-year period. The average annual cost of the monitor, not taking into account inflation, is expected to be $101,000 per year. The temporal distribution of costs is summarized in Table 2.

2.7 References

Cope, S. 2005. Alouette River Salmonid Smolt Migration Enumeration: 2005 Data Report. *Prepared by* Westlope Fisheries Ltd. *for the* Alouette Management Committee and BC Hydro Generation. September 2005. 48 pp.+ App.

Manly, B.F.J. 1997. Randomization, Bootstrap and Monte Carlo methods in Biology. 2nd Ed. Chapman and Hall. New York, NY. 399 pp.

Zar, J.H. 1974. Biostatistical Analysis. Prentice-Hall, Inc. Englewood Cliffs, N.J. 620 pp.

Table 2. Estimated costs for the smolt enumeration monitor. Contingency is calculated on field labour and covers safety planning, regulatory approvals (permits), field logistics and unforeseen weather delays.

Task	Labour	Daily Rate	Units per year								Program Total
			2007	2008	2009	2010	2011	2012	2013	2014	
Project Management	Project Biologist	$ 500	1	1	1	1	1	1	1	1	$ 4,000
Field work	Project Biologist	$ 500	60	60	60	60	60	60	60	60	$ 240,000
	Lead Technician	$ 300	60	60	60	60	60	60	60	60	$ 144,000
	Technician 1	$ 225	60	60	60	60	60	60	60	60	$ 108,000
	Technicien 2	$ 225	60	60	60	60	60	60	60	60	$ 108,000
Data Entry	Technicien 1	$ 225	4	4	4	4	4	4	4	4	$ 7,200
Data Analysis	Project Biologist	$ 500	4	4	4	4	4	4	4	4	$ 16,000
Data Report	Project Biologist	$ 500	6	6	6	6	6	6	6	6	$ 24,000
	Technicien 1	$ 225	2	2	2	2	2	2	2	2	$ 3,600
Presentation	Project Biologist	$ 500	1	1	1	1	1	1	1	1	$ 4,000
Final Report	Project Biologist	$ 500								10	$ 5,000
	Contingency	5%	$4,118	$4,118	$4,118	$4,118	$4,118	$4,118	$4,118	$4,368	$ 33,190
	Total Labour		$86,468	$86,468	$86,468	$86,468	$86,468	$86,468	$86,468	$91,718	$ 696,990

Expenses	Unit Cost									
Meals	$ 45	60	60	60	60	60	60	60	60	$ 21,600
Accomodation (Brk & Dnr)	$ 300	12	12	12	12	12	12	12	12	$ 28,800
Mileage (per km)	$ 0.46	8500	8500	8500	8500	8500	8500	8500	8500	$ 31,280
Sampling Gear	$ 5	120	120	120	120	120	120	120	120	$ 4,800
Trap Maintenance	$ 3,000	1	1	1	1	1	1	1	1	$ 24,000
Preport reproduction	$ 100	1	1	1	1	1	1	1	2	$ 900
Total Expenses		$ 13,910	$ 13,910	$ 13,910	$ 13,910	$ 13,910	$ 13,910	$ 13,910	$ 14,010	$ 111,380
Program Total		$100,378	$100,378	$100,378	$100,378	$100,378	$100,378	$100,378	$105,728	$ 808,370
Inflation Adjustment	2%	$102,384	$104,432	$106,520	$108,651	$110,824	$113,040	$115,301	$123,876	$ 885,028

Monitor 2

Kokanee Out-migration

1.0 PROGRAM RATIONALE

1.1 Background

In the early spring of 2005, a 3 m^3s^{-1} test surface release from the Alouette Dam was carried out to determine whether stocked coho smolts would cue to the surface currents near the gate and migrate out of the reservoir. The unexpected result was an out-migration of kokanee smolts, prompting the CC to recommend the surface release be done annually with the expectation this could re-establish an Alouette River sockeye run extirpated since the mid 1920s following impoundment of the reservoir. Because of uncertainty in run timing, the CC recommended that the surface release be carried out for a period of eight weeks. To shorten the duration of this release, and hence reduce the flood risk that it entails, the CC also recommended that a monitor be implemented to identify the typical start of the out-migration run, its duration, and identify its peak.

The FTC expressed uncertainty in whether the magnitude of the release would be sufficient to promote migration among all smolts driven to move seaward. To address this uncertainty, an experimental post-surface release flush was proposed every second year for the duration of the monitor to determine whether additional migrants could be induce to move out of the reservoir with a doubling of flows. The post-surface release flush will consist of a 6–9 m^3s^{-1} release from the spillway gates lasting a period of seven days following the tail end of the out-migration period as determined by a downstream smolt enumeration monitor (located adjacent to the confluence of Mud Creek). The total duration of the surface release regime is not to exceed the eight week period identified above.

A possible ancillary benefit of the surface release is a cue for the out-migrating kokanee to continue their seaward migration out of the Alouette system. The CC recommended a monitor to test this hypothesis as well, but this is considered part of Monitor 1, as it entails the use of downstream traps located at the 224th and 216th St. Bridges.

1.2 Management Questions

The FTC identified three management questions that are to be addressed through the kokanee out-migration monitor:

1. Is the surface release of at least 3 m^3s^{-1} from the Alouette Dam (obtained through the spillway gate) adequate to promote the downstream migration of kokanee smolts out of the Alouette Reservoir?
2. Does a post-surface release flush of 6–9 m^3s^{-1}, lasting seven days following the tail end of the out migration period, encourage more smolts to leave the system?

3. How long should the surface release last to ensure out-migration of all smolts prepared to leave the system?

1.3 Summary of Hypotheses

The management questions identified in Section 1.2 are to be addressed through tests of the following set of hypotheses. Management Question 1 is to be addressed through the following hypothesis statement:

$H_0$1: The seaward movement of kokanee smolts, as identified from rotary screw trap data collected at the confluence of Mud Creek, has a start, peak and end that is characteristic of kokanee/sockeye smolts found in other coastal systems (e.g., Cultus Lake stocks).

For Management Question 2, the following hypothesis is to be tested:

$H_0$2: The seaward movement of kokanee smolts, as identified from rotary screw trap data collected at the confluence of Mud Creek, has a second start, peak and end (i.e., a bimodal out-migration pattern) during those years when a post-surface release flush of 6–9 m^3s^{-1} is implemented. (The post-surface release flush will be implemented on average every two years.)

Management Question 3 will be addressed through a weight of evidence approach that considers the results of the two hypotheses identified above, the start, peak and end dates of the migration period, the duration of the surface release, the results of the downstream movement pattern assessment in Monitor 1, and the smolt out-migration data of other coastal systems. This will form the basis for an alternative surface release regime to be considered at the next WUP review in 2014.

1.4 Key Water Use Decision

The kokanee out-migration monitor is linked to the effectiveness of the surface release operation designed to promote the seaward movement of kokanee smolts out of the Alouette Reservoir. Management Question 1 and Hypothesis $H_0$1 is concerned primarily with whether the operation consistently results in this seaward movement every year, and contributes valuable information concerning the duration and shape of the release. Management Question 2 and $H_0$2 is designed to test the utility, and hence need, for a post surface release flush where the outflow through the spillway gate is doubled or more for a period of one week. It also is designed to provide valuable information concerning the duration and shape of the release regime, which will collectively be used to design an alternative surface release regime (if necessary) for consideration at the next WUP review in 2014.

2.0 PROGRAM PROPOSAL

2.1 Approach

The general approach to the monitor will be to install and operate a rotary screw trap in the vicinity of the Mud Creek confluence and using sand bags to deflect more water towards the trap as necessary. The trap will be operated for the duration of the spring 3 m^3s^{-1} surface release, starting the middle of April and ending the last week of May. Fishing procedures for the trap, including general maintenance, trap efficiency estimation and catch sub-sampling will be identical to that used in the downstream rotary screw trap below the 216th St. Bridge. In addition, a sub-sample of the catch (maximum 50 individuals) will be held for stock identification through genetic analysis, which will carried out at the Pacific Biological Station laboratory in Nanaimo, BC.

2.2 Objective and Scope

The objective of this monitor is to collect the data necessary to test the 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:

1. The study area will consist primarily of the riverine habitat located downstream of the Alouette Lake Reservoir to the confluence of Mud Creek, where a rotary screw trap will be installed and fished for the duration of the surface release period.
2. The monitor will be carried out annually until the next WUP review period (2014).
3. Part of the monitor in Year 1 will consist of a literature review on kokanee/sockeye out-migration behaviour in coastal lake systems, including a collation of known out-migration timing data.
4. The scope of this monitor should include provision to collect a yearly sub-sample of kokanee smolts (maximum 20 individuals per year based on price of $100 per sample) for genetic analysis to clearly define Alouette stock membership. The analysis be done at Pacific Biological Station laboratory in Nanaimo, BC.
5. A data report, include a detail executive summary and short presentation, will be prepared annually summarizing the data collected to date, as well as discuss inferences and present conclusions as they pertain to the impacts of the WUP over time. The Year 1 report will include a summary section on kokanee out-migration behaviours in coastal lake systems.
6. 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 from the data pertaining to the impacts of the WUP over time, and presents conclusions concerning the hypotheses and the management question in Section 1.2. Included in the conclusion will be a proposal for an alternative surface release regime should it be deemed necessary.

2.3 Methods

2.3.1 Field Methods

Field methods will follow that described in Cope (2005) so that all data collected will be consistent with prior years of monitoring. This includes the following elements:

1. Use of a single 1.5 m rotary screw trap located just upstream of the Mud Creek Confluence. Installation is to include the appropriate use of sand bags to improve volume and direction of flow to the trap. It will be fished continuously for the duration of the spring release period (15 April to 14 June, or earlier depending the results of the monitor).
2. The traps will be maintained and adjusted as required to ensure consistent trapping conditions through time.
3. Gear efficiency will be determined twice weekly using caudal fin clipped smolts released far enough upstream to ensure adequate dispersion in the system.
4. Fish morphology data will not be collected (it will be collected as part of Monitor 1).
5. Collection and preservation of a sub-sample of the catch (maximum 20 individuals per year based on price of $100 per sample) to be kept for stock identification through genetic analysis, which will be carried out at the Pacific Biological Station laboratory in Nanaimo, BC (to be used on Monitor 5).
6. All incidental catches from upstream studies will be noted.

2.3.2 Safety Concerns

A safety plan will have to be developed for all aspects of the study in accordance to BC Hydro procedures and guidelines. It is important to note that the monitor must always be carried out by crews of at least two members, that appropriate safety equipment is available at the site, and that appropriate check-in and checkout procedures are followed.

2.3.3 Data Analysis

All data will be entered into a common database in a standard format for analysis. This will ensure that all data collected over the years on monitoring are compatible and can be analyzed with transformation.

Hypotheses will be tested by comparing plots cumulative distributions of migrant count data over time. The comparisons will be largely descriptive in nature, but may incorporate formal statistical procedures where warranted (e.g., comparisons of 50 %-tile values or goodness-of-fit tests that compare whole distributions) (Zar 1974).

2.3.4 Reporting

Project reporting will consist of annual data reports and a comprehensive final report at the conclusion of the monitor. The annual data reports will summarize the year's findings and include a short discussion of how the year's data compare to that collected in previous years. It will include a brief description of methods, present the data collected that year, and report on the results of all analyses.

At the conclusion of the monitor, a final comprehensive report will be prepared from all of the annual reports written to date that:

1. Re-iterates the objective and scope of the monitor.
2. Presents the methods of data collection.
3. Describes the compiled data set and presents the results of all analyses.
4. Discusses the consequences of these results as they pertain to the current WUP operation, and how it may or could factor into future decision making.

All reports will be submitted to regulatory agencies for review and comment prior to being finalized for general release.

2.4 Interpretation of Results

Results of this monitor are linked directly to the utility and value of the proposed spring surficial release operation designed to promote the seaward migration of kokanee smolts. Rejection of $H_0$1 would suggest that the pattern, timing and or magnitude of release may be insufficient to promote the expected "normal" pattern of emigration experienced in sockeye salmon stocks elsewhere. It should be noted that this response could also be the result of a loss in propensity for migration among the Alouette kokanee stock, and may not be related to the pattern of release. It is hoped that there would be sufficient inter-annual variability in the patterns of surficial release that the latter alternative hypothesis can be tested.

Test of Hypothesis $H_0$2, would also provide valuable information to help assess the stock's propensity for migration. Rejection of $H_0$2 would suggest that the pattern of migration is relatively insensitive to the range of surface release conditions experienced at the dam. This combined with a rejection of $H_0$1 would suggest that there may be a reduction in propensity to emigrate since that dam was impounded almost than 80 years ago. Conversely, it may be inferred that the range of surficial releases at the dam is inadequate to promote and sustain high levels of seaward migration among the Alouette kokanee population.

When combined with the acceptance of $H_0$1, rejection of $H_0$2 would indicate a lack of sensitivity to the nature of the surface release, that the post surface release flush is unnecessary and can be abandoned at the next WUP review period (provided that the results of Monitor 1 are consistent with this as well).

Given the range of surface release patterns experience on the river, along with the corresponding pattern of migration response, there may be sufficient information

to develop an alternative more efficient surface release pattern for consideration at the next WUP review period.

2.5 Schedule

The kokanee smolt enumeration program will be carried out annually until the next WUP review period in 2014. Enumeration will begin in the second week in April and continue until roughly the last week in May to coincide with the spring surface release operation. A data report, executive summary and presentation of the year's data will be due the first week of February the following year. The final report will be due just prior to the start of the next WUP review process in 2014, though the precise due date will be set at BC Hydro's discretion.

2.6 Budget

The total cost of the eight-year kokanee out-migration monitor is estimated to be $283,900 in 2006 dollars and assumes that it will be carried out in coincidently with Monitor 1 to reduce costs. It includes $231,800 for labour, $40,500 in expenses, and a 5 per cent contingency totaling $11,600. Taking into account an average inflation rate of 2 per cent, the total cost is expected to be closer to $311,000 over the eight-year period. The average annual cost of the monitor, not taking into account inflation, is expected to be about $35,500 per year. The temporal distribution of costs is summarized in Table 3.

Genetic analysis assumes a price of $100 per sample for a total genetic analysis budget of $16,000 for the eight year period. This price could not be verified at the time this terms of reference was written. Should the price differ for the assumed value, the number of samples collected and analyzed will be adjusted accordingly.

2.7 References

Cope, S. 2005. Alouette River Salmonid Smolt Migration Enumeration: 2005 Data Report. *Prepared by* Westlope Fisheries Ltd. *for the* Alouette Management Committee and BC Hydro Generation. September 2005. 48 pp.+ App.

Zar, J.H. 1974. Biostatistical Analysis. Prentice-Hall, Inc. Englewood Cliffs, N.J. 620 pp.

Table 3. Estimated costs for the kokanee out-migration monitor. Contingency is calculated on field labour and covers safety planning, regulatory approvals (permits), field logistics and unforeseen weather delays.

Task	Labour	Daily Rate	Units per year								Program Total
			2007	2008	2009	2010	2011	2012	2013	2014	
Project Management	Project Biologist	$ 500	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	$ 2,000
Field work	Project Biologist	$ 500	4	4	4	4	4	4	4	4	$ 16,000
	Lead Technician	$ 300	25	25	25	25	25	25	25	25	$ 60,000
	Technician 1	$ 275	30	30	30	30	30	30	30	30	$ 66,000
	Technicien 2	$ 225	30	30	30	30	30	30	30	30	$ 54,000
Data Entry	Technicien 1	$ 225	1	1	1	1	1	1	1	1	$ 1,800
Data Analysis	Project Biologist	$ 500	2	2	2	2	2	2	2	4	$ 9,000
Data Report	Project Biologist	$ 500	4	4	4	4	4	4	4	2	$ 15,000
Presentation	Project Biologist	$ 500	1	1	1	1	1	1	1	1	$ 4,000
Final Report	Project Biologist	$ 500								8	$ 4,000
	Contingency	5%	$1,424	$1,424	$1,424	$1,424	$1,424	$1,424	$1,424	$1,624	$ 11,590
	Total Labour		$29,899	$29,899	$29,899	$29,899	$29,899	$29,899	$29,899	$34,099	$ 243,390
Expenses		**Unit Cost**									
	Mileage (per km)	$ 0.46	2500	2500	2500	2500	2500	2500	2500	2500	$ 9,200
	Sampling Gear	$ 5	60	60	60	60	60	60	60	60	$ 2,400
	Trap Maintenance	$1,500	1	1	1	1	1	1	1	1	$ 12,000
	Genetic Analysis	$ 100	20	20	20	20	20	20	20	20	$ 16,000
	Preport reproduction	$ 100	1	1	1	1	1	1	1	2	$ 900
	Total Expenses		$ 5,050	$ 5,050	$ 5,050	$ 5,050	$ 5,050	$ 5,050	$ 5,050	$ 5,150	$ 40,500
	Program Total		$ 34,949	$ 34,949	$ 34,949	$ 34,949	$ 34,949	$ 34,949	$ 34,949	$ 39,249	$ 283,890
	Inflation Adjustment	2%	$ 35,647	$ 36,360	$ 37,087	$ 37,829	$ 38,585	$ 39,357	$ 40,144	$ 45,985	$ 310,993

Monitor 3

Substrate Quality

1.0 PROGRAM RATIONALE

1.1 Background

In 1995, a substrate quality monitor was initiated that comprised of Toe-Pebble count assessments of substrate composition at 23 randomly selected sites (using a stratified random sampling design) downstream of the Alouette Dam to the 216th St. Bridge (Higgins 2005). The monitor was successful in tracking changes in surface sediment composition through time, and was able to demonstrate a net improvement through time since the start of the monitor. This occurred despite the fact the prescribed substrate flushes were not implemented in the years following the 1996 as per the WUP agreement. Most of the flushing activities occurred incidentally and followed periods of high salmonid escapements whose spawning activity was believed to contribute significantly to the improved substrate condition. This in turn led to the conclusion that prescribed flushes were perhaps unnecessary, especially if the high salmonid escapement numbers were to continue.

The FTC however, expressed some unease regarding this decision to abandon the concept of a prescribed flush. This uneasiness stemmed primarily from uncertainty in the accuracy of the Toe-Pebble count procedure in reflecting substrate quality within the deeper layers of the channel bed. Also contributing to this uneasiness was some uncertainty in the < 20 per cent fines threshold that was used to judge whether substrate quality was an issue or not. Finally, there was some uncertainty in whether the incidental flushing events experienced in the past would continue in to the future and therefore maintain or further improve the current level of substrate quality.

To address these uncertainties, the CC recommended that the substrate quality monitor done in the past ten years be continued annually until the next WUP review in 2014. The CC recommended that the monitor also include a literature search component to clarify some of the uncertainties identified in the monitor's methodology, and to include a provision to carry out a second methodology to specifically quantify spawning gravel quality if deemed necessary. The latter would be used to qualify/calibrate the Toe-Pebble count results.

1.2 Management Questions

The FTC identified three management questions that are to be addressed through the kokanee out-migration monitor:

1. Do the results of the Toe-Pebble count procedure reflect the general composition of bed materials within the channel downstream of the Alouette Dam?

2. Is the < 20 per cent fines threshold adequate to distinguish a state in substrate quality that would require a prescribed flushing event?
3. Is an alternative methodology required to qualify/calibrate the results of the Toe-Pebble count procedure?
4. For each year of the monitor, is a prescribed flushing flow necessary given the current state of substrate quality?

1.3 Summary of Hypotheses

The first three management questions identified in Section 1.2 do not easily lend themselves to hypothesis testing. Rather, they are issues to be addressed through weight of evidence. The first two management questions will rely primarily on literature reviews to carry out the assessment. The second management question, pertaining to the 20 per cent fines threshold criterion, will also rely on relative egg to smolt data collected in Monitor 1 as part of the assessment. The results of the first two management questions will form the basis of assessment for the third management question. The only management question that does lead itself to hypothesis testing pertains to the need for annual assessments of substrate quality:

$H_0$1: The proportion of fine sediments < 2 mm in size measured in the substrate monitor does not exceed 20 per cent of the total composition of bed materials.

The hypothesis is based on the current definition of "quality substrate", but can be reframed to accommodate changes that may arise from the literature search results.

1.4 Key Water Use Decision

Results of this monitor are linked to the decision to abandon the prescribed flushing flow regimes described in the 1996 WUP and to rely on incidental flush events that arise through pre-spilling operations for flood control (believed to occur every two years on average). Because of uncertainty as whether these incidental flushes would indeed occur as predicted, the CC recommended that the possibility of prescribing a flush not be fully abandoned, but be linked to the accumulation of fine sediments above the a threshold (presently set at 20 per cent of total bed material composition) in the context of an effectiveness monitor.

Results of the literature search and the chum relative egg to smolt survival will be used to address Management Questions 1 to 3 with the aim of confirming the validity of the 20 per cent threshold value, and possibly propose an alternative threshold value should it be necessary.

2.0 PROGRAM PROPOSAL

2.1 Approach

The substrate monitor will continue as was established in 1996 where a Toe-Pebble procedure is used to quantify the distribution of sediments throughout the

South Alouette River between the dam and 216th St. Bridge. Details of the methodology are as described by Higgins (2005), but will be carried out more frequently and at regular of sampling intervals. Rather than be opportunistic, the monitor will be carried out each year during mid summer when water levels are typically low and there are no incubating eggs or alevins in the substrate. For safety reasons, the annual assessment will be carried out by a crew of two people. Where possible, the same crew should be used each year to control the effects of observer bias.

The first year of assessment will include a literature review to address some of the uncertainties in the Toe-Pebble count methodology. This information, along with the relative egg to fry survival estimates of chum salmon, will be used to determine whether calibration is necessary for future WUP monitoring.

2.2 Objective and Scope

The objective of this monitor is to collect the data necessary to test the 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:

1. The study area will consist primarily of the riverine habitat located downstream of the Alouette Dam to the 216th St. Bridge.
2. All sites will be the same as those used for monitoring during the last ten years. To minimize the effect of observer bias, the same survey crew should be used to collect the data.
3. Year 1 of the monitor will include an assessment of the Toe-Pebble count procedure based on a review of published literature.
4. The monitor will be carried out annually until the next WUP review period (2014).
5. A data report, including an executive summary and short presentation, will be prepared annually summarizing the data collected to date, as well as discuss inferences and present conclusions as they pertain to the impacts of the WUP over time. Included will be an assessment whether a prescribed flush would be necessary. Year 1 of the monitor will include a section on the precision and accuracy of the Toe-Pebble count methodology.
6. 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 from the data pertaining to the impacts of the WUP over time, and presents conclusions concerning the hypotheses and the management questions in Section 1.2.

2.3 Methods

2.3.1 Field Methods

Field methods will be the same as that described in Higgins (2005), which incorporates a modified Toe Pebble count procedure to quantify relative sediment

distribution at pre-selected sites long the length of the South Alouette River. These sites are to be the same used since the start of the monitor almost ten years ago and are described in detail by Higgins (2005). Where possible, the same observer will be used as in the past so as to minimize the effect of observer bias in the monitor.

The only difference in methodology from that of Higgins (2005) is a change in the frequency and timing of sampling. Unlike the opportunistic strategy described in the Higgins (2005) report, sediment quality assessments will now be carried out annually during the low flow summer period (August/September). Such a standardized sampling regime will greatly improve the resolution and robustness of the monitor.

To further improve the monitor's resolution and robustness, the field crew is encouraged to develop a standard method of substrate sampling that can be repeated each year. One such method could involve the use of shoreline benchmarks and two lines to triangulate the location of set sampling locations (Figure 1). Water filled buckets can serve as the benchmark anchors so that they are easy to carry, yet be heavy enough not to move when in use. Light weight ropes with triangulation markings can be used as triangulation lines. A survey staff equipped with a pointed tip and level can be used to transfer the triangulated position to a location of the stream bed.

Triangulated points can be chosen at random by computer, which can then be used to determine the length of line needed for triangulation in the field. A set of "triangulation lines" can be developed for each sample site where each line may have several (all) triangulation lengths marked on it. The order of marks on the triangulated lines can be set in advance to optimize the movement of the crew through the site.

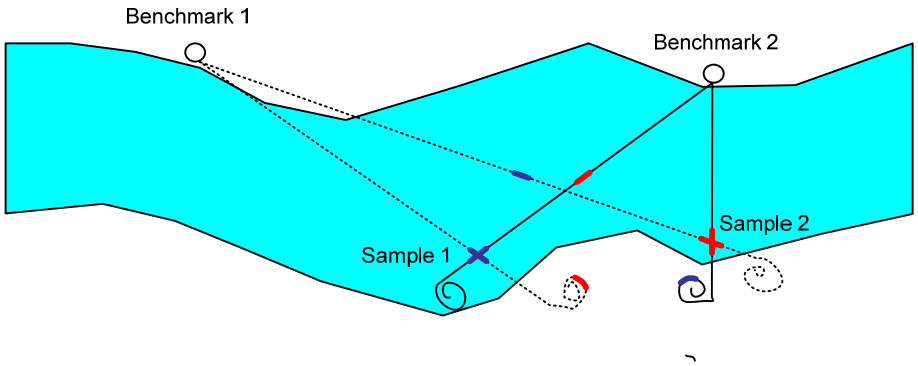


Figure 1: Schematic diagram illustrating the use of benchmarks and triangulation lines to determine sampling locations in the field by matching like-colored or marked segments.

2.3.2 Safety Concerns

A safety plan will have to be developed for all aspects of the study in accordance to BC Hydro procedures and guidelines. It is important to note that the substrate quality assessment must always be carried out by two crew members and that appropriate check-in and checkout procedures must be followed.

2.3.3 Data Analysis

Data analysis will follow the same procedures described in Higgins (2005) for testing the presence of temporal and spatial trends. Where possible, attempts should be made to link these trends to known hydrological or geological events in the basin (e.g., spills, floods events, bank erosion, construction activities). This will require that a log of potentially significant watershed events be kept for each year. This component of the analysis will determine the extent to which data can be pooled for further analysis, as well as aid in the interpretation of results.

Test of $H_0 1$ will be qualitative within any given year (a pass/fail test of whether the proportion of fines is below the 20 per cent threshold) and will rely primarily on the pooled data for river as a whole, though the analysis can be segregated based on habitat type (pool, run, riffle, cascade) or river reach/segment. As a time series of test data develops, a test for serial randomness will be carried out to determine the likelihood that there is a persistent trend of deteriorating substrate quality (Zar 1974). Because there is some uncertainty in the linkage between the substrate quality index above and spawning success, independent corroboration is needed to draw conclusions with certainty. In this case, it is the pattern of chum relative egg to fry survival rate (Monitor 2). Should a correlated trend in substrate quality become evident, it a may trigger the need for a prescribed flushing flow.

It should be noted that the threshold level of sediments (presently set at 20 per cent fine materials less than 2 mm in diameter) is subject to change depending on the results of a literature review. The way the data will be analyzed however, will remain the same.

2.3.4 Literature Review

A cursory review of published literature will be carried out to evaluate the merits and shortcomings of the Wolman Toe-Pebble count methodology, particularly as it relates to spawning gravel quality, and how it is used in the context of the present monitor. An attempt should be made to relate Wolman Toe-Pebble count data to meaningful ecological events (spawning success, quality of cover, over-wintering survival etc.)

2.3.4 Reporting

Project reporting will consist of annual data reports and a comprehensive final report at the conclusion of the monitor. The annual data reports will summarize the year's findings and include a short discussion of how the year's data compare to that of previous years. It will include a brief description of methods, present the data collected that year, and report on the results of all analyses. During the first year of the monitor, the data report will also contain the results of a literature review on the utility of the methodology used here, its possible shortcomings, and its biological relevance. Results of the review are to include recommendations on how to appropriately tailor the methodology to the context of the present monitor.

At the conclusion of the monitor, a final comprehensive report will be prepared based on all of the annual reports written to date that:

1. Re-iterates the objective and scope of the monitor.
2. Presents the method of data collection and analysis.
3. Describes the compiled data set and presents the results of all analyses.
4. Describes the outcome of all hypothesis testing and address the management questions described in Section 1.2.
5. Discusses the consequences of these results as they pertain to the current WUP operation, and how it may factor into future decision making.

All reports will be submitted to the Alouette Monitoring Committee for review and comment prior to being finalized for general release.

2.4 Interpretation of Results

A persistent state of gravel quality that is less than the threshold deemed suitable for successful spawning (presently set at < 20 per cent of material < 2 mm diameter, though this may change following the results of the literature review), in conjunction with declining chum relative egg to fry survival (Monitor 1), would indicate the need to consider remedial action, in particular the need for a prescribed flushing flow. The magnitude and duration of such a flow regime would have to be developed in consultation with the Alouette Monitoring Committee to balance the need for a flush with its potential impact on other values in the watershed, particularly on the risk of downstream flooding.

2.5 Schedule

The substrate quality will be carried out annually until the next WUP review period in 2014. The monitor will be carried during mid summer when flows are low and there are no incubating embryos in the gravel. A data report, executive summary and presentation of the year's data will be due the first week of February in the following year. The final report will be due just prior to the start of the next WUP review process in 2014, though the precise due date will be set at BC Hydro's discretion.

2.6 Cost Estimate

The total cost of the eight-year substrate quality monitor is estimated to be $68,000 in 2006 dollars. It includes $61,200 for labour, $4,000 in expenses, and a 5 per cent contingency totaling $2,900. Taking into account an average inflation rate of 2 per cent, the total cost is expected to be closer to $74,400 over the eight-year period. The average annual cost of the monitor, not taking into account inflation, is expected to be $8,500 per year. The temporal distribution of costs is summarized in Table 4.

2.7 References

Higgins, P. 2005. An assessment of the effectiveness of flushing flows for managing fine sediment in fish habitat of the South Alouette River. *Prepared for* the Alouette Management Committee. October 2005. 33 pp.

Zar, J.H. 1974. Biostatistical Analysis. Prentice-Hall, Inc. Englewood Cliffs, N.J. 620 pp.

Table 4. Estimated costs for the substrate quality monitor. Contingency is calculated on field labour and covers safety planning, regulatory approvals (permits), field logistics and unforeseen weather delays.

Task	Labour	Daily Rate	Units per year								Program Total
			2007	2008	2009	2010	2011	2012	2013	2014	
Project management	Project Biologist	$ 500	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	$ 2,000
Literature review	Project Biologist	$ 500	4								$ 2,000
Field work	Lead Technician	$ 300	8	8	8	8	8	8	8	8	$ 19,200
	Field helper	$ 100	8	8	8	8	8	8	8	8	$ 6,400
Data Entry	Technician	$ 225	1	1	1	1	1	1	1	1	$ 1,800
Data Analysis	Lead Technician	$ 300	2	2	2	2	2	2	2	2	$ 4,800
Data Report	Lead Technician	$ 300	8	8	8	8	8	8	8	8	$ 19,200
	Project Biologist	$ 500	2								$ 1,000
Presentation	Lead Technician	$ 300	1	1	1	1	1	1	1	1	$ 2,400
Final Report	Lead Technician	$ 300								8	$ 2,400
	Contingency	5%	$386	$336	$336	$336	$336	$336	$336	$456	$ 2,860
	Total Labour		$10,361	$7,311	$7,311	$7,311	$7,311	$7,311	$7,311	$9,831	$ 64,060

Expenses	Unit Cost								
Meals	$ 10	16	16	16	16	16	16	16	16	$ 1,280
Mileage (per km)	$ 0.46	300	300	300	300	300	300	300	300	$ 1,104
Sampling Gear	$ 5	16	16	16	16	16	16	16	16	$ 640
Preport reproduction	$ 100	1	1	1	1	1	1	1	2	$ 900
Total Expenses		$ 478	$ 478	$ 478	$ 478	$ 478	$ 478	$ 478	$ 578	$ 3,924
Program Total		$ 10,839	$ 7,789	$ 7,789	$ 7,789	$ 7,789	$ 7,789	$ 7,789	$ 10,409	$ 67,984
Inflation Adjustment	2%	$ 11,055	$ 8,103	$ 8,265	$ 8,430	$ 8,599	$ 8,771	$ 8,946	$ 12,195	$ 74,365

Monitor 4.

Adult Sockeye Enumeration

1.0 PROGRAM RATIONALE

1.1 Background

A spring surface release operation, where 3 m^3s^{-1} is released through the spillway gate rather than the LLO for the months of April and May, has been integrated into the Alouette WUP to provide a means by which kokanee smolts can migrate out of the reservoir and to the ocean via the Alouette River. This operation forms part of a longer term strategy in the watershed to re-establish a sockeye salmon run that was extirpated soon after the construction of the Alouette dam. A key assumption that was made when adopting the operation is that the kokanee smolts are fully capable of successfully "re-anadromizing" to ocean rearing conditions, i.e.,

- successfully adapt to salt water conditions,
- adopt behavioural strategies to successfully compete and avoid predation in an ocean environment, and finally
- retain their ability recognize and return to their native lake/stream system to spawn.

The FTC however, expressed some uncertainty in this assumption and in turn has recommended that a monitor be carried out to confirm the return of released Alouette kokanee as adult sockeye.

1.2 Management Questions

The FTC recommended that the following management question be addressed through the adult sockeye enumeration monitor:

1. Are the Alouette Lake kokanee smolts successfully adapting to an anadromous existence by returning from the ocean environment to spawn in Alouette Lake?

This question cannot be answered without first addressing the following three critical data gaps:

2. What is the run timing of adult sockeye returns so that an appropriate enumeration study can be carried out?

   Run timing can vary considerably from stock to stock depending on prevailing freshwater and ocean conditions. Too little is known at this time to predict the run timing of Alouette kokanee/sockeye. It will have to be determined empirically.

3. Are adult sockeye caught during the monitor members of the "Alouette stock" or are they strays from other nearby coastal systems?

4. Are ocean survival rates of returning re-anadromized kokanee comparable to that of sockeye stocks found elsewhere?

It should be noted that the issue of what to do with the sockeye adults that return to the base of the dam falls outside the scope of WUP, and is more appropriately addressed through BC Hydro's Bridge Coastal Restoration Program (BCRP). In the short term, the FTC have recommended that a trap and truck approach be implemented to get returning sockeye adults past the Alouette Dam so that they can complete their lifecycle. The CC fully endorses such an approach and recommends that a letter of support be issued with a proposal to BCRP for project funding.

1.3 Summary of Hypotheses

The management questions concerning sockeye run timing and genetic composition is largely descriptive in nature and does not readily lend itself to hypothesis testing. However, Management Question 4 can be addressed through the follow null hypothesis:

$H_0$1: Estimated annual ocean survival rate of re-anadromized kokanee (calculated using total kokanee returns and the smolt abundance data from Monitors 1 and 2) is within 95 per cent of values observed in other stocks (Bradford 1995).

Management Question 1 will be addressed largely through inference based on the pattern of annual test results of Hypothesis $H_0$1 through time.

1.4 Key Water Use Decision

Results of the sockeye adult enumeration monitor are linked to the need for a benefit assessment of spring surface release operation and the decision whether to continue the operation should the Alouette kokanee stock (or a proportion of it?) fail to successfully switch life cycle strategies to an anadromous existence. It is recognized that it may take several years for a measurable response to manifest, but it is expected that some indication of success will be evident by the 2014 WUP review period.

2.0 PROGRAM PROPOSAL

2.1 Approach

The general approach to the sockeye/kokanee adult enumeration program will be to extend the period that the Alco hatchery brood stock collection fence is operated to a year-round operation for the first three years of the monitor (commencing the year the first release of Alouette kokanee is expected to return). The fence is located in the upper watershed and is in position to intercept all migrating adult sockeye on their way to the reservoir. This will provide the data needed to determine the run timing of adult, re-anadromized kokanee and stray sockeye so that in subsequent years, the fence operation can be coordinated between both functions; brood stock collection and sockeye adult enumeration.

Included in the monitor will be the collection of tissue samples (up to 50 individuals per year) for stock identification through genetic analysis, which will be carried out at the Pacific Biological Station laboratories in Nanaimo, BC. To accomplish this, the monitor will include funds to set up and maintain a temporary holding facility for captured sockeye. Choice of what to do with the captured sockeye falls outside the scope of WUP, though they will likely be trucked to the reservoir to continue with their migration and spawning activity.

2.2 Objective and Scope

The objective of this monitor is to collect the data necessary to test the 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:

1. The study area will consist primarily of the riverine habitat located downstream of the Alouette Lake Reservoir, and particularly the brood collection fence operated by the Alco Hatchery.
2. The monitor will be an addition to the current brood collection operation conducted annually by the Alco Hatchery which will consist of the following:
    a. Year round fence operations, starting the year that the first returns from the 2005 kokanee release are expected, for a period of three years.
    b. Extended fence operations to cover the sockeye adult return period once the run timing has been established.
3. The scope of the monitor shall include provision for genetic analysis of a maximum 50 randomly selected adult returns per year, and include the development/construction of a sockeye adult holding facility outside the perimeter of the hatchery.
4. The monitor will also cover the increased cost of maintenance and operation associated with the extend use of the Alco Hatcher fence.
5. The monitor will be carried out annually until the next WUP review period (2014).
6. A data report, including a detailed executive summary and short presentation, will be prepared annually summarizing the data collected to date, as well as discuss inferences and present conclusions as they pertain to the impacts of the WUP over time.
7. 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 from the data pertaining to the impacts of the WUP over time, and presents conclusions concerning the hypotheses and the management questions in Section 1.2.

2.3 Methods

2.3.1 Field Methods

Fence operations and associated field activities will continue unchanged from those normally used for Alco Hatchery brood stock collection and adult enumeration. The only difference is that all captured sockeye salmon will be held in a separate holding facility for processing.

All captured fish will be assigned a unique identification number, have the date and time of capture noted, and will be measured for fork length (mm FL) and wet weight (g). Tissue samples will also be taken, which will be stored in sealable containers, clearly labeled and frozen till the end of the run. Of the tissue samples collected, only 50 will be sent to the Pacific Biological Station laboratories in Nanaimo, BC for genetic analysis. Sample selection will occur at the end of the run and will be done randomly should the total number of samples exceed the cap for analysis.

2.3.2 Safety Concerns

A safety plan will have to be developed for all aspects of the study in accordance to BC Hydro procedures and guidelines. It is important to note that the adult sockeye enumeration monitor must always be carried out by at least two crew members and that appropriate daily check-in and checkout procedures must be followed.

2.3.3 Data Analysis

All data will be entered into a common database in a standard format for analysis. This will ensure that all data collected over the years on monitoring are compatible and can be analyzed with transformation.

Data analysis will consist primarily of descriptive statistics and the use of inference to draw conclusions regarding management questions and hypotheses. Hypothesis $H_0 1$ will be tested using a simple z-test where the probability distribution function of published ocean survival estimates will be derived from the work of Bradford (1995).

Although morphometric data will be collected from all the captured sockeye/re-anadromized kokanee, its analysis beyond simple descriptive summaries is considered to be outside the scope of this monitor.

2.3.4 Reporting

Project reporting will consist of annual data reports and a comprehensive final report at the conclusion of the monitor. The annual data reports will summarize the year's findings and include a short discussion of how the year's data compare to that collected in previous years. It will include a brief description of methods, present the data collected that year, and report on the results of all analyses.

At the conclusion of the monitor, a final comprehensive report will be prepared from all of the annual reports written to date that:

1. Re-iterates the objective and scope of the monitor.
2. Presents the methods of data collection.
3. Describes the compiled data set and presents the results of all analyses.
4. Discusses the consequences of these results as they pertain to the current WUP operation, and how it may or could factor into future decision making.

All reports will be submitted to regulatory agencies for review and comment prior to being finalized for general release.

2.4 Interpretation of Results

Annual ocean survival rates that are consistently outside the 95 per cent range of published values for other sockeye stocks for the duration of the monitor, and show no sign of increasing through time, will be considered an indication that the re-anadromization strategy may not be successful. It is possible that the duration of the monitor is insufficient to detect a response, and that a much longer time frame is needed. The likelihood of that being the case will be evaluated at the time of the next WUP review based on the data collected to date, observed sockeye ocean survival estimates since the start of the monitor for other stocks in BC, and the extent of departure from these values. Data from other studies done in the watershed may also be useful in this assessment (e.g., Baxter and Bocking 2006).

It should be noted that the introduction of river caught sockeye adult strays to the Alouette Lake Reservoir may confound the results of this monitor and should be taken into account when drawing inferences regarding the management questions in Section 1.2.

2.5 Schedule

The sockeye adult enumeration monitor will be carried out year-round for the first three years of the monitor, and then be more closely matched to the sockeye run timing for the remainder of monitor till the next WUP review period in 2014. A data report, executive summary and presentation of the year's data will be due the first week of February in the following year. The final report will be due just prior to the start of the next WUP review process in 2014, though the precise due date will be set at BC Hydro's discretion.

2.6 Budget

The total cost of the eight-year adult sockeye enumeration monitor is estimated to be $150,700 in 2006 dollars. It includes $98,000 for labour, $47,900 in expenses (including funding to cover the cost of increased fence wear and tear), and a 5 per cent contingency totaling $4,800. Taking into account an average inflation rate of 2 per cent, the total cost is expected to be closer to $162,000 over the eight-year period. The average annual cost of the monitor, not taking into account

inflation, is expected to be $18,900 per year. The temporal distribution of costs is summarized in Table 5.

Genetic analysis assumes a cost of $100 per sample, but this could not be verified at the time this terms of reference was written. Should the per sample price of the analysis be less than the assumed value, the budget will be adjusted accordingly. Should the price exceed the assumed value, the maximum number of samples per year will be adjusted accordingly.

The purchase and maintenance of a holding facility is only budgeted for a three year period. It is expected that a permanent facility will be in operation as part of the sockeye trap-and-truck program being planned for the remainder of the monitoring period.

2.7 References

Baxter, B.E. and R.C. Bocking. 2006. Field Trials to Assess Coho smolt migration success through the Alouette Reservoir, 2005. *Prepared for*: BC Hydro Bridge Coastal Fish and Wildlife Restoration Program. BCRP Report No. 05.A1.02. February 2006. 24 pp. + App.

Bradford, M. J. 1995. Comparative Review of Pacific Salmon Survival Rates. Can. J. Fish. Aquat. Sci. 52: 1327-1338.

Table 5. Estimated costs for the sockeye adult enumeration monitor. Contingency is calculated on field labour and covers safety planning, regulatory approvals (permits), field logistics and unforeseen weather delays.

Task	Labour	Daily Rate	Units per year								Program Total
			2007	2008	2009	2010	2011	2012	2013	2014	
Project management	Project Biologist	$ 500	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	$ 1,200
Field work	Trap Operator (BC Corrections)	$ 70	275	275	275	60	60	60	60	60	$ 78,750
Data Entry	Technician	$ 225	1	1	1	1	1	1	1	1	$ 1,800
Data Analysis	Lead Technician	$ 300	1	1	1	1	1	1	1	1	$ 2,400
Data Report	Lead Technician	$ 300	4	4	4	4	4	4	4	4	$ 9,600
Presentation	Lead Technician	$ 300	1	1	1	1	1	1	1	1	$ 2,400
Final Report	Lead Technician	$ 300								6	$ 1,800
	Contingency	5%	$1,064	$1,064	$1,064	$311	$311	$311	$311	$401	$ 4,838
	Total Labour		$22,489	$22,489	$22,489	$6,686	$6,686	$6,686	$6,686	$8,576	$ 102,788

Expenses	Unit Cost									
Fence Maintenance	$ 5,000	1	1	1	1	1	1	1	1	$ 40,000
Holding Facility	$ 500	4	1	1						$ 3,000
Genetic Analysis	$ 100	20	20	0	0	0	0	0	0	$ 4,000
Preport reproduction	$ 100	1	1	1	1	1	1	1	2	$ 900
Total Expenses		$ 9,100	$ 7,600	$ 5,600	$ 5,100	$ 5,100	$ 5,100	$ 5,100	$ 5,200	$ 47,900
Program Total		$ 31,589	$ 30,089	$ 28,089	$ 11,786	$ 11,786	$ 11,786	$ 11,786	$ 13,776	$ 150,688
Inflation Adjustment	2%	$ 32,220	$ 31,303	$ 29,807	$ 12,757	$ 13,012	$ 13,272	$ 13,538	$ 16,140	$ 162,049

Monitor 5

Water Temperature

1.0 PROGRAM RATIONALE

1.1 Background

Water temperature downstream of the Alouette Dam continues to be a concern for FTC members. Though some data has been collected since the LLO was fully opened in 1996, it was considered incomplete and tended to raise more questions than provide answers. There was general agreement among the FTC members that temperature conditions in the river have improved considerably since the 1996 change in LLO operation. However, there remained some uncertainty as to whether conditions improved to the extent that high water temperature impacts were fully mitigated. Two particular impacts were identified:

1. High summer temperatures approaching incipient lethal limits of rearing salmonids that impact survival and growth during the summer critical rearing period.
2. A general increase in stream temperatures that shifts fish community structure from a cold-water, primarily salmonid system to a warm-water primarily cyprinid system.

To address these uncertainties, the FTC recommended that a formal water temperature monitor be implemented that measures water temperature throughout the watershed, including the reservoir, to better assess the possible range of operational actions that can be taken to mitigate measured impacts.

1.2 Management Questions

The FTC identified the following management questions that are to be addressed by the water temperature monitor:

1. How often are water temperatures $\geq 25°C$, the incipient lethal temperature of most stream rearing salmonid species, including the duration of each event and the frequency of occurrence?
2. Is the duration of observed warm water events less than one day, thus limiting exposure to warm waters and therefore thermal stress impacts?
3. Are warm temperature events restricted to certain sections of river, indicating the inflow of cooler waters into system (most likely ground water)?

   It is assumed that ground water inputs provide thermal refugia, allowing fish to escape periods of excessively warm water.

4. Is the duration and frequency of warm water events such that it would promote a shift in fish community structure and/or reduce summer survival and growth of rearing juvenile salmonids, as indicated by a change in salmonid smolt numbers?

   It is assumed that a shift in community structure cannot occur without observing a loss in salmonid rearing capacity.

5. Given the extent of thermal stratification in the reservoir and the location of the LLO, is there an operational change that can be implemented to mitigate the occurrence of warm water events?

1.3 Summary of Hypotheses

Management Question 1 is descriptive in nature and therefore does not readily lend itself to hypothesis testing. Management Questions 2 and 3 lead to the following six testable hypotheses:

$H_0$1: The duration of warm water events are greater than the tolerance threshold (maximum temperatures that can be tolerated for periods less than one day) for rearing salmonids.

A literature search will have to be carried out to determine the length of exposure that salmonid juveniles are able to tolerate with little or no impact. Alternatively, a maximum weekly average temperature statistic can be used (Armour 1991, Eaton et. al. 1995)

$H_0$2: Average daily peak water temperatures are similar between sections.

$H_0$3: Average daily water temperatures are similar between sections.

$H_0$4: Average duration of warm water events is similar between sections.

$H_0$5: The frequency of warm water events is similar between sections.

Management Question 4 will require use of the smolt enumeration data collected during Monitor 1 to test for correlations between smolt output and the occurrence of warm water events:

$H_0$6: Variability in smolt output, as measured in Monitor 1, is correlated with the occurrence of warm water events.

It is assumed that a persistent loss in smolt enumeration, correlated with a high occurrence of warm water events, would be indicative of a potential shift in fish community structure.

It may be necessary to define "warm water events" in different ways to fully explore the nature of the relationship. The choice of definition should be accompanied with a clear description of the underlying rationale.

Management Question 5, like Question 1, is descriptive in nature and does not lend itself to hypothesis testing. Rather, the information will be used in a modeling exercise (conceptual and/or numerical) to determine the range of operational actions, if any, that can be taken to mitigate the occurrence of warm water temperature events.

1.4 Key Water Use Decision

The water temperature monitor is designed to address a number of uncertainties regarding the occurrence of water temperatures ≥ 25°C that can impact both the growth and survival of rearing salmonids, as well as create a shift in community structure if persistent through time. There is also uncertainty in whether the impact, if found to occur, could be mitigated by changes in reservoir operations by taking advantage of the reservoirs' thermal structure and the location of the LLO. Results of this monitor would help resolve these uncertainties, and hence provide the information necessary to address the issue during the next WUP review in 2014.

2.0 PROGRAM PROPOSAL

2.1 Approach

The water temperature monitor will consist primarily of temperature data loggers installed at six locations along the length of the Alouette River, starting with the plunge pool immediately downstream of the dam, and ending downstream at the 216th St. Bridge. This will break the river into five sections to explore the possible mitigating effects of ground water sources and local inflows. In the reservoir near the inlet of the LLO pipe, a vertical array of temperature data loggers will be installed to track the thermal stratification process near the entrance to the LLO. All temperature loggers will be downloaded twice annually, and analyzed at the end of each calendar year.

Included in the monitor is a cursory literature review to establish threshold temperatures and durations that define events that may have significant impact to the fish community. This is to build on the work already completed by Bruce (2005).

2.2 Objective and Scope

The objective of this monitor is to collect the data necessary to test the 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:

1. The study area will consist of both the Alouette Lake Reservoir (at the LLO inlet) and the river downstream of the dam to 216th St. Bridge.
2. The scope of the monitor will include a literature search of threshold water temperatures and exposure levels for rearing salmonids.
3. The scope of the monitor will include the development of a simple model to evaluate the range of possible operations that may mitigate the impact.
4. The monitor will be carried out annually until the next WUP review period (2014).
5. A data report will be prepared annually summarizing the data collected to date, as well as discuss inferences and present conclusions as they pertain to the impacts of the WUP over time.

6. 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 from the data pertaining to the impacts of the WUP over time, and presents conclusions concerning the hypotheses and the management questions in Section 1.2.

2.3 Methods

2.3.1 Literature Review

At the start of the monitor, a cursory literature review will be carried out to establish threshold temperatures and durations that define events that may have significant impact to the fish community during the critical summer growth period (July to September). This is to build on the work already completed by Bruce (2005) and is to include the following temperature criterion in tabular form:

1. Upper Lethal Temperature (ULT)

   The maximum temperature that 50 per cent of fish could survive for very short periods for a given acclimation temperature (e.g., 10 min).

2. Short Term Maximum Survival Temperature (SMT)

   The maximum temperature that 50 per cent of fish could survive for less than a day for a given acclimation temperature (equivalent to the incipient lethal temperature).

3. Ultimate Upper Incipient Lethal Temperature (UUILT)

   The maximum temperature that 50 per cent of fish could survive for less than a day irrespective of acclimation temperature.

4. Final Thermal Preferendum (FTP)

   Temperature selected when given the choice that is independent of acclimation temperature – thought to correspond to the temperature that maximizes overall physiological function.

5. Maximum Weekly Average Temperature That Should Not Be Exceeded (MWAT)

   A calculated thermal maximum criterion that attempts to account for variable stream temperature conditions (Armour 1991). It is calculated as;

$$MWAT = FTP + \frac{UUILT - FTP}{3}$$

The species of interest are to include the fry and parr life stages of cutthroat trout, steelhead trout, coho salmon, and Chinook salmon.

2.3.2 Field Methods

Reservoir Temperature

The vertical profile of reservoir water temperature will be tracked through time using a vertical array of six temperature data loggers suspended in the vicinity of the inlet structure of the LLO. The data loggers will be spaced 2 m apart, the lowest of which will be placed at an elevation of 114 m (corresponding to the top of the LLO inlet). The top data logger will sit at elevation 124 m.

The data loggers will be programmed to measure water temperature once every hour and will be down loaded twice annually. All temperature loggers will be calibrated for precision and accuracy so that they all measure the same value for a given temperature).

River Temperature

Temperature data loggers will be installed at five locations on the South Alouette River between Alouette Dam and the 216th St. Bridge. They are to correspond to those of previous data collection efforts (Bruce 2005) including:

1. At the LLO (to measure water a temperature leaving the Alouette Dam).
2. Immediately downstream of the Alouette Dam plunge pool (approx 50 m downstream of the LLO to evaluate the effect of plunge pool residence time on outflow temperatures).
3. At the confluence of the Mud Creek.
4. At Alco Park Hatchery.
5. At 216th St. Bridge.

The data loggers will be programmed to measure water temperature once every hour and will be down loaded twice annually. All temperature loggers will be calibrated for accuracy (i.e., ensure that they read the same value for a given temperature or provide a correction factor).

2.3.3 Safety Concerns

A safety plan will have to be developed for all aspects of the study in accordance to BC Hydro procedures and guidelines. It is important to note that the installation and downloading of temperature data loggers must always be carried out by at least two crew members and that appropriate daily check-in and checkout procedures must be followed. Installation of the vertical array of temperature data loggers will require prior approval by BC Hydro to ensure that it does not interfere in any way with the facilities' operation

2.3.4 Data Analysis

All data will be entered into a common database in a standard format for analysis. This will ensure that all data collected over the years on monitoring are compatible and can be analyzed with transformation.

Reservoir Temperatures

Data analysis will consist primarily of the development of annual depth – time plots of temperature isotherms to identify the elevations that define the reservoirs epilimnion, metalimnion, and hypolimnion (Wetzel 2003), as well as plot annual water temperature at the entrance of the LLO.

River Temperatures

Data analysis will consist primarily of summary statistics, including annual plots of daily average, minimum and maximum temperatures for each site, average monthly differences of site temperatures relative to that of the LLO, annual frequency and duration of water temperature events that exceed critical threshold values, and the calculation of seven day moving averages (i.e., 168 hours) to prepare annual plots of observed MWAT for comparison with critical threshold values (Section 2.3.1).

Hypothesis $H_0$1 will be tested using a simple z-test to determine the proportion of events that lie blow the threshold value for the temperature criterion of interest, including ULT, SMT, UUILT and MWAT (Zar 1974). Between section differences will be explored using analysis of variance (ANOVA) and will involve data that are pooled across all years of data collection. Where necessary, the data will be transformed to ensure that assumptions of normality and homoscedasticity are not violated.

Hypotheses $H_0$2 to $H_0$4 will be tested using two-way analysis of variance (ANOVA) to explore differences between sections by month (Zar 1974). As in $H_0$1, the data will be transformed where necessary to ensure that assumptions of normality and homoscedasticity are met.

Because frequency data are being compared in $H_0$5, this analysis will be done using the Chi Square statistic.

At a minimum, Hypothesis $H_0$6 will be tested through regression analysis using annual smolt abundance data collected in Monitor 1 as the dependent variable. Independent variables can include a number of the summary statistics used above, though care must be taken to avoid the risk of spurious correlations. The analysis may be carried out for each species of interest, or as a group. Because other factors may mask or confound the temperature response, it may be necessary to explore the effect of other possible limiting factors such as average discharge, occurrence of flooding, over-wintering temperatures, and run strength, using multiple regression techniques. Where necessary, data transformations will be used to ensure that assumptions of normality, linearity and homoscedasticity are met.

2.3.5 Reporting

Project reporting will consist of annual data reports and a comprehensive final report at the conclusion of the monitor. The annual data reports will summarize the year's findings and include a short discussion of how the year's data compare to that collected in previous years. It will include a brief description of methods, present the data collected that year, and report on the results of all analyses.

At the conclusion of the monitor, a final comprehensive report will be prepared from all of the annual reports written to date that:

1. Re-iterates the objective and scope of the monitor.
2. Presents the methods of data collection.
3. Describes the compiled data set and presents the results of all analyses.
4. Discusses the consequences of these results as they pertain to the current WUP operation, and how it may or could factor into future decision-making.

All reports will be submitted to regulatory agencies for review and comment prior to being finalized for general release.

2.4 Interpretation of results

Tests of $H_0$1 will provide the information necessary to assess the occurrence and extent of warm water events and to evaluate the potential risk to rearing salmonid populations. This evaluation however, will be theoretical in nature as it relies on published thermal criterion. Verification of impacts, if any, will be done by testing $H_0$6, which looks for correlations between summer rearing temperatures and smolt output. A strong correlation would be indicative of a causal link and would trigger investigation into measures that could be taken to mitigate the impact, particularly with respect to operations (Management Question 5).

Hypotheses $H_0$2 to $H_0$5 all relate to Management Question 3 which is concerned about spatial differences in temperature response. Rejection of some or all of these hypotheses would suggest that the occurrence of harmful warm water events may be localized, and that impacts may not be so widespread as to affect smolt output if no water temperature correlations are found (i.e., $H_0$6 is not rejected). It may be inferred that the localized drops in water temperature are the result of cooler groundwater entering the system (at least through an interchange or mixing of hyporheic and surface streamwater, Wetzel 2001), and that in turn, there exists the possibility of thermal refugia.

2.5 Schedule

The water temperature monitor will be carried out annually for the duration of the monitor until the next WUP review period in 2014. A data report, executive summary and presentation of the year's data will be due the first week of February in the following year. The final report will be due just prior to the start of the next WUP review process in 2014, though the precise due date will be determined at BC Hydro's discretion.

2.6 Budget

The total cost of the eight-year water temperature monitor is estimated to be $35,200 in 2006 dollars. It includes $23,000 for labour, $11,200 in expenses, and a 5 per cent contingency totaling $1,000. Taking into account an average inflation rate of 2 per cent, the total cost is expected to be closer to $38,300 over the eight-year period. The average annual cost of the monitor, not taking into

account inflation, is expected to be $4,400 per year. The temporal distribution of costs is summarized in Table 6.

2.7 References

Armour, C. L. 1991. Guidance for evaluating and recommending temperature regimes to protect fish. U.S. Fish and Wildlife Service, Biol. Rep. 90(22). 13 p.

Bruce, J. A. 2005. River Temperature Data. Memo to: Alouette WUP Review Fish Technical Subcommittee. November 2005. 9 p.

Eaton, J.G., J.H. McCormick, B.E. Goodno, D.G. O'Brien, H.G. Stefany, M.Hondzo, and R.M. Scheller. 1995. A field information based system for estimating fish temperature tolerance. Fiesheries 20:10-18.

Wezel, R.G. Limnology: Lake and River Ecosystems. 3rd Edition. Academic Press. New York. 1006 p.

Zar, J.H. 1974. Biostatistical Analysis. Prentice-Hall, Inc. Englewood Cliffs, N.J. 620. pp.

Table 6. Estimated costs for the water temperature monitor. Contingency is calculated on field labour and covers safety planning, regulatory approvals (permits), field logistics and unforeseen weather delays.

Task	Labour	Daily Rate	Units per year								Program Total
			2007	2008	2009	2010	2011	2012	2013	2014	
Project management	Project Biologist	$ 500	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	$ 1,200
Literature Review	Project Biologist	$ 500	3								$ 1,500
Field work	Technician	$ 225	1	1	1	1	1	1	1	1	$ 1,800
Data Entry	Technician	$ 225	1	1	1	1	1	1	1	1	$ 1,800
Data Analysis	Lead Technician	$ 300	2	2	2	2	2	2	2	2	$ 4,800
Data Report	Project Biologist	$ 500	1								$ 500
	Lead Technician	$ 300	3	3	3	3	3	3	3	3	$ 7,200
Presentation	Lead Technician	$ 300	1	1	1	1	1	1	1	1	$ 2,400
Final Report	Lead Technician	$ 300								6	$ 1,800
	Contingency	5%	$138	$113	$113	$113	$113	$113	$113	$203	$ 1,015
	Total Labour		$4,538	$2,513	$2,513	$2,513	$2,513	$2,513	$2,513	$4,403	$ 24,015

Expenses	Unit Cost									
Temperature loggers	$ 300	12	3	3	3	3	3	3	3	$ 9,900
Mileage (per km)	$ 0.46	100	100	100	100	100	100	100	100	$ 368
Preport reproduction	$ 100	1	1	1	1	1	1	1	2	$ 900
Total Expenses		$ 3,746	$ 1,046	$ 1,046	$ 1,046	$ 1,046	$ 1,046	$ 1,046	$ 1,146	$ 11,168
Program Total		$ 8,284	$ 3,559	$ 3,559	$ 3,559	$ 3,559	$ 3,559	$ 3,559	$ 5,549	$ 35,183
Inflation Adjustment	2%	$ 8,448	$ 3,701	$ 3,775	$ 3,851	$ 3,928	$ 4,006	$ 4,087	$ 6,500	$ 38,296

Monitor 6

Kokanee Age-Structured Population Analysis

1.0 PROGRAM RATIONALE

1.1 Background

The FTC expressed some concern about the impacts of reservoir operations on kokanee spawning success. With the fertilization program, the population of kokanee in the reservoir has increased dramatically (almost 15 fold), indicating that the there is sufficient recruitment to fully seed the increased production potential of the reservoir. At issue however, is whether current level of production represents the full potential of the reservoir with the fertilization program in place, or whether further increases are hampered by what may be operations-based limitations to reproductive success. The issue is further complicated by the fact that smolt releases are being planned, which will remove a proportion of the spawning population each year. As well, a re-introduction of anadromized kokanee/sockeye is also planned. The success of both management activities however is uncertain, as are the potential consequences to the existing kokanee population.

Hydro-acoustic assessments of kokanee biomass collected since 1998 suggest that the population has responded well to the addition of fertilizer, and to date has shown no strong indication of a recruitment limitation to production (Greg Wilson, pers comm.). As well, the range of WUP operations being considered by the CC does not change significantly from current practice during the spawning and incubation period; as a result no incremental impact is expected from implementation of WUP operations. Furthermore, modeling done to date for the WUP process suggests that there may be limited opportunities to alter operations during the spawning/incubation period because it occurs during a period of high flood risk.

Given the confounding effects of smolt out-migration and sockeye re-introduction, the uncertainty that reproductive success is indeed limiting, and the fact that operations are unlikely to change with WUP implementation, the FTC recommended that the year to year variability in reservoir operations (both since 1998 and post WUP implementation) be examined for correlations with the ongoing hydro-acoustic kokanee population monitor. Specifically, the FTC recommended the following analysis:

1. Correlation analysis between the extent of reservoir fluctuation during the spawning and incubation period and age structure of the kokanee population.

   Should an impact arise due to reservoir fluctuation, it is assumed that it will show up as a drop in the number of Age 1 fish in the following year. It should be noted that there are likely to be compensatory mechanisms at play that may dampen the response over time and that the impact may not be carried over between years to create measurable response on the number of

spawners. Because of this, the analysis should involve all cohorts and include between year comparison.

2. Correlation analysis between the extent of reservoir fluctuation during the spawning and incubation period and size at age.

   This analysis takes advantage of the fact that size at age data can provide an indication of whether the population is approaching or moving away from the system's capability. As the size of fish for a given age class increases, it is generally indicative of reduced competition of food resources, and if the availability of food resources remain more or less constant (as one would expect in a fertilized lake system), it is also indicative of a decreasing population of fish. As the size of fish for a given age class decreases, it is generally indicative increasing competition for food resources, and therefore increasing fish abundance (again if food resources remain constant through time).

1.2 Management Questions

The FTC identified three management questions to be addressed through the kokanee age structure monitor:

1. Is the existing kokanee population in the Alouette Lake Reservoir recruitment limited?
2. If there is evidence of a recruitment constraint to productivity, can it be linked to reservoir operations, in particular the extent of reservoir fluctuation during the spawning and incubation period (deemed to be mid October to the end of February)?
3. If found linked to reservoir operation, what is the nature of the relationship and can it guide the development of possible mitigative reservoir operations?

1.3 Summary of Hypotheses

The management questions identified in Section 1.2 are to be addressed through tests of the following set of three hypotheses. The first hypothesis pertains to Management Question 1 while the last two relate to Management Question 2:

$H_0$1: Once standing crop has stabilized with the annual addition of fertilizer, the size at age of the kokanee population remains stable or decreases with time.

It is critical that standing crop has reached a state of equilibrium with the addition of fertilizer, i.e., the annual biomass of kokanee has hit a plateau following years of increase with the onset of the fertilization program. Once the state has been reached, rejection of $H_0$1 would indicate that the population may be recruitment limited.

$H_0$2: Drops in fry abundance, relative to estimates in previous years and to that predicted by estimates of mature kokanee, are correlated with increased reservoir fluctuations during the spawning and incubation period.

One way to integrate reservoir fluctuations through time and their impact on reproductive success is to calculate an effective spawning area over the range of possible reservoir elevations. Effective spawning area is the area that can be spawned in and remain wetted for the duration of the incubation period. This relative statistic has been successfully used in other WUPs to calculate between year differences in relative spawning success. Results of the test will establish a link between reservoir operations and relative spawning success.

$H_0$3: Drops in fry abundance observed in one year do not persist through time to cause an impact on the abundance of mature kokanee.

Test of this hypothesis will establish whether inter annual variability in fry abundance is with the population's capability to absorb without impact on the cohort's future reproductive potential. Failure to reject the hypothesis will indicate that the impact of reservoir operation may affect spawning success, the magnitude of the impact is insufficient to cause a population impact.

It should be stressed that the results of the monitor may be confounded by the release of smolts of the reservoir, as well as the introduction of re-anadromized kokanee and sockeye to the reservoir. Interpretation of the data should take into account these two factors.

Management Question 3 will be addressed through inference based on the results of Hypotheses $H_0$1 to $H_0$3.

1.4 Key Water Use Decision

This monitor is designed to address a key uncertainty in the nature of the relationship between reservoir operations and recruitment potential of kokanee in Alouette Lake Reservoir. With greater clarity on the issue, particularly in light of the confounding effects of kokanee smolt releases and the re-introduction of the anadromized kokanee spawners, the CC will be better informed to address this issue at the next WUP review period in 2014.

2.0 PROGRAM PROPOSAL

2.1 Approach

The kokanee age-structured population analysis will rely solely on the ongoing hydro-acoustic program and fish survey data currently being collected as part of the fertilization program monitor. The hydro-acoustic survey follows all of the provincial standards for such work and has been deemed adequate to meet the present monitor's needs (Greg Wilson, pers. comm.). Funding will be made available to cover the extra costs of data analysis and report writing to satisfy WUP requirements.

2.2 Objective and Scope

The objective of this monitor is to collect the data necessary to test the 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:

1. The study area will be restricted to the Alouette Lake Reservoir and rely on the annual hydro-acoustic work currently being done as part of the fertilization program monitor.
2. The monitor will be carried out annually until the next WUP review period (2014).
3. A data report, including a detailed executive summary and short presentation, will be prepared annually summarizing the data collected to date, as well as discuss inferences and present conclusions as they pertain to the impacts of the WUP over time.
4. 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 from the data pertaining to the impacts of the WUP over time, and presents conclusions concerning the hypotheses and the management question in Section 1.2.

2.3 Methods

2.3.1 Field Methods

No additional field work will be required to complete this monitor. All data will be obtained from the annual Alouette Lake Reservoir hydro-acoustic surveys already being carried out as part of the lake fertilization monitor program. This includes all hydro-acoustic survey data collected to date.

2.3.2 Data Analysis

All data will be entered into a common database in a standard format for analysis. This will ensure that all data collected over the years on monitoring are compatible and can be analyzed with transformation.

Hypothesis $H_0$1 will be tested using regression analysis on time trends of average adult size during late summer. Where it is possible to calculate variance for the size at age data, the analysis will employ analysis of variance (ANOVA) techniques (Zar 1974).

Tests of $H_0$2 will be carried out using simple regression analysis on the annual fry abundance estimates collected from Monitors 1 and 2 where the independent variable is a summary statistic of the reservoir condition during the cohort's incubation period. The use of a relative effective spawning area index value has proven to be successful in other WUP studies (Leake 2004) and is suggested for this application as well, though other summary statistics may be used.

Hypothesis $H_0$3 will be tested using a series of chi-square analyses that makes use of the concept that age class abundances in populations tend to approach a

stable ratio over time (Hastings 1997). The chi-square analyses will be used to detect significant deviations from the estimated stable ratios. The annual pattern of deviations will be used to determine whether a significant drop in fry recruitment (correlated with reservoir operations) has had a significant population impact. Here, a significant population impact is defined as an age class recruitment "loss" that persists for one or more generations.

Each year, the hydro-acoustic data will be entered into an age-structured population summary table as in Table 7. The first step of the analysis will be to estimate the stable age distribution ratio of age classes (fry, juvenile and adult classes are sufficient for this application) by summing annual abundance estimates within each class and dividing it by the grand total of all individuals in all years for that class (i.e., f1 to f3 in Table 7). The estimated stable age ratios will then be used in a chi-square goodness of fit test to determine which years of data, if any, have a pattern age of class abundance estimates that deviate significantly from expected values based on the estimation procedure. Rejection of a chi-square test would indicate a significant recruitment problem in at least one of the age classes that year. Where a significant chi-square value is found, the chi-square analysis can then be subdivided into component analyses to identify which age classes significantly deviate from the expected value (Zar 1974).

Table 7: Sample layout of an age structured population summary table set up for annual chi-square analysis that tests for significant difference from the population's stable age distribution.

	Abundance				
Year	Fry	Juvenile	Adult	Total	X^2
0	.	.	.		
1	.	.	.		
2	.	.	.		
3	.	.	.		
4	.	.	.		
5	.	.	.		
6	.	.	.		
Average Proportion of Total	f_1	f_2	F_3	100%	

Because the estimate of stable age ratios may change as new data are added, the chi-square analysis will have to be re-calculated in its entirety each year. As these new data are added, the estimate of stable age class ratios will become more robust over time.

The actual test of $H_0$3 occurs when the temporal pattern of significant deviation from the expected stable age class ratio is compared to three possible outcomes:

1. No significant deviations are observed indicating that recruitment to each age class is not significantly different from "background levels."
2. A significant deviation is observed in the "fry" age class and possibly into the next age class the following year, but no further. This pattern would be indicative of a possible problem during the spawning/incubation period of that year, but that the magnitude of the problem is within the compensatory capability of the population (i.e., the perturbation was small enough that the stable age distribution was re established within one generation).
3. A significant deviation is observed in the "fry" age class and is carried forward into the following age classes in subsequent years and affects the generation's spawning capability. In this particular case, the magnitude of impact is such that at least one or more generations are required to re-establish a stable age distribution.

It is important to note that the annual out-migration of kokanee smolts to the South Alouette River may confound the results of this analysis and that caution must used when attempting to draw inferences regarding operations related impacts on fry recruitment.

2.3.3 Reporting

Project reporting will consist of annual data reports and a comprehensive final report at the conclusion of the monitor. The annual data reports will summarize the year's findings and include a short discussion of how the year's data compare to that collected in previous years. It will include a brief description of methods, present the data collected that year, and report on the results of all analyses.

At the conclusion of the monitor, a final comprehensive report will be prepared from all of the annual reports written to date that:

1. Re-iterates the objective and scope of the monitor.
2. Presents the methods of data collection.
3. Describes the compiled data set and presents the results of all analyses.
4. Discusses the consequences of these results as they pertain to the current WUP operation, and how it may or could factor into future decision-making.

All reports will be submitted to regulatory agencies for review and comment prior to being finalized for general release.

2.4 Interpretation of Results

A significant upward trend in size at age would be considered indicative of a drop in adult recruitment, though it would not provide any information on whether the cause is the result of reservoir operations related spawning failure, the loss of smolts due to the spring surface release operation, or some other factor (e.g., intensive recreational fishing). Inferences on possible causal mechanisms will have to rely on the results of other studies or analyses, including the

correlation analysis of operational impacts on fry abundance (test of $H_0$2) and the chi-square analysis of age class structure (test of $H_0$3).

Rejection of $H_0$2 would imply that there is a strong causal link between reservoir operations during the spawning/incubation period of kokanee salmon and reproductive success. It would imply that significant spawning may be occurring within the drawdown zone area, and that drawdown events have the potential to cause significant egg mortality. Failure to reject $H_0$2 would indicate otherwise, that spawning for the most part lies below the drawdown zone, and that year to year variability in fry abundance is the result of some other factor(s) affecting fry recruitment success.

As noted Section 2.3.2, the pattern of significant deviations between age classes as determined from chi-square analyses of annual age class abundance data will serve as the indicator of impact severity. If the recruitment losses are found to persist for one or more generations (i.e., Condition 3 in Section 2.3.2), then the impact will be deemed significant. To reject $H_0$3, the persistent age class recruitment loss must begin with a significant drop in fry abundance compared to other years, and that drop must be related to a reservoir operations impact; implying that $H_0$3 cannot be rejected unless $H_0$2 is rejected as well.

Establishing a correlation between some measure of effective spawning area (a statistic to summarize potential reservoir impacts on the spawning and incubation periods of kokanee) and fry abundance would validate the index as a meaningful performance measure for use in future WUP processes. It would provide a means of gauging the impact of alternative operational strategies in simulation exercises, the results of which can be used to devise alternative operational constraints that are less harmful to the reservoir's kokanee population.

2.5 Schedule

The kokanee age-structured population monitor will be carried out annually until the next WUP review period in 2014. A data report, executive summary and presentation of the year's data will be due the first week of February in the following year. The final report will be due just prior to the start of the next WUP review process in 2014, though the precise due date will be determined at BC Hydro's discretion.

2.6 Budget

The total cost of the eight-year kokanee age-structured population monitor is estimated to be $23,000 in 2006 dollars. It includes $21,100 for labour, $900 in expenses, and a 5 per cent contingency totaling $1,000. Taking into account an average inflation rate of 2 per cent, the total cost is expected to be closer to $25,400 over the eight-year period. The average annual cost of the monitor, not taking into account inflation, is expected to be $4,000 per year. The temporal distribution of costs is summarized in Table 8.

2.7 References

Hastings, A. 1997. Population Biology: Concepts and models. Springer-Verlag New York Inc. New York, N.Y. 220 pp.

Zar, J.H. 1974. Biostatistical Analysis. Prentice-Hall, Inc. Englewood Cliffs, N.J. 620 pp.

Table 8. Estimated costs for the kokanee age-structured population monitor. Contingency is calculated on field labour and coverssafety planning, regulatory approvals (permits), field logistics and unforeseen weather delays.

Task	Labour	Daily Rate	Units per year								Program Total
			2007	2008	2009	2010	2011	2012	2013	2014	
Data Entry	Project Biologist	$ 500	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	$ 2,000
Data Analysis	Project Biologist	$ 500	1	1	1	1	1	1	1	1	$ 4,000
Data Report	Project Biologist	$ 500	2	2	2	2	2	2	2	2	$ 8,000
Presentation	Project Biologist	$ 500	1	1	1	1	1	1	1	1	$ 4,000
Final Report	Project Biologist	$ 500								6	$ 3,000
	Contingency	5%	$113	$113	$113	$113	$113	$113	$113	$263	$ 1,050
	Total Labour		$2,363	$2,363	$2,363	$2,363	$2,363	$2,363	$2,363	$5,513	$ 22,050

Expenses	Unit Cost									
Preport reproduction	$ 100	1	1	1	1	1	1	1	2	$ 900
Total Expenses		$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 200	$ 900
Program Total		$ 2,463	$ 2,463	$ 2,463	$ 2,463	$ 2,463	$ 2,463	$ 2,463	$ 5,713	$ 22,950
Inflation Adjustment	2%	$ 2,511	$ 2,561	$ 2,612	$ 2,664	$ 2,718	$ 2,772	$ 2,828	$ 6,692	$ 25,358