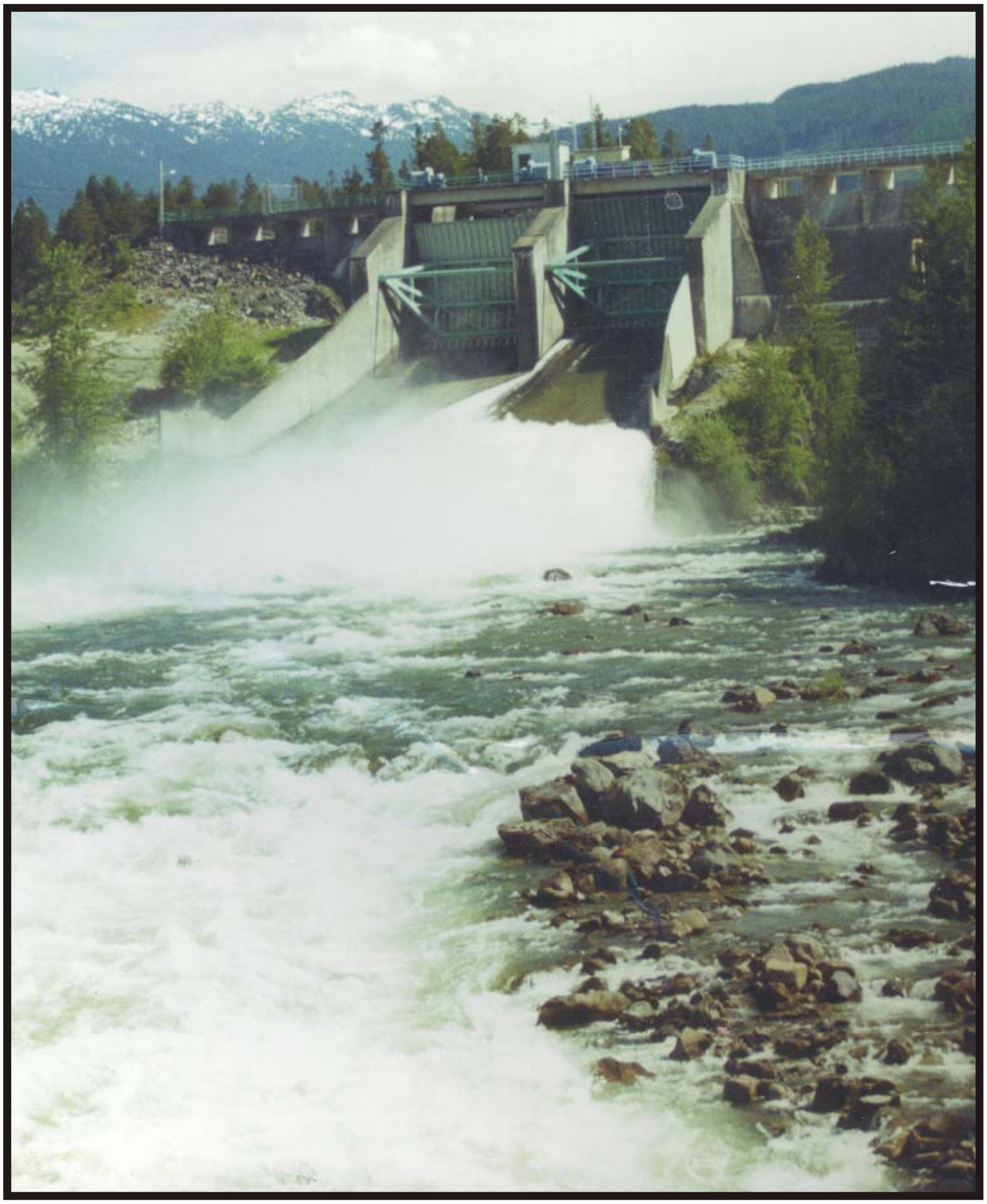
Cheakamus River Water Use Plan

Report of the Consultative Committee

May 2002



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Cheakamus River Water Use Plan

Report of the Consultative Committee

Prepared on behalf of the

Cheakamus River Water Use Plan Consultative Committee

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May 24, 2002

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

The report expresses the interests, values and recommendations of the Committee and is a supporting document to BC Hydro's Cheakamus 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 purposes of developing the aforementioned recommendations, and should not be relied upon other than for the purposes intended.

Acknowledgements

The Cheakamus Water Use Planning consultation process lasted nearly three years and involved the active participation of over 40 people. In a project of this scope it is difficult to recall all those who contributed to its outcome and we apologize in advance to anyone not mentioned below. There are, however, several groups and individuals that we interacted with most often and would like to clearly acknowledge here.

As the authors of their report and their facilitators we would first and foremost like to thank the Cheakamus Consultative Committee for the opportunity to work with them during 25 meetings and nearly three years of hard work. The process thrived on their active participation, creativity and stimulating debate. The latter, in particular, ensured that the many concerns and viewpoints associated with this multi-stakeholder, multiple-objective decision process received fair representation, both in the process and in this report. We think it is important to emphasize that many Consultative Committee members made significant commitments of personal time on a purely voluntary basis. This commitment is greatly appreciated by us, as it is this sort of dedication that makes a public process work well.

Secondly, we would like to thank the members of the Hydro Operations and Power Systems (HOPSC) and Fisheries (FTC) Technical Committees who provided much of the underlying data and analyses upon which to base performance measure calculations and evaluations. This information was often provided under tight deadlines made more pressing because many committee members also worked on other WUPs concurrently. The FTC in particular, worked hard to overcome gaps in our scientific understanding of the Cheakamus River and to prepare the most practical and useful performance measures for decision making within the time and budget available for the WUP process.

Thirdly, we thank the BC Hydro Project Team for their unflagging support of an open and fair process. In particular, we thank Gordon Boyd and Al Geisler (project managers) Michael Harstone (Resource Valuation, replacing Kristy Mcleod), Barry Wilkinson (Community Relations), Cam Matheson (Aboriginal Relations), Dave Wilson (FTC Chair) and Kathy Groves (HOPSC, operations modelling). Andrew Coupe deserves special mention. He provided stellar communication and coordination services for the Cheakamus WUP for more than two years before moving on within BC Hydro to another position.

Finally we thank the staff of ESSA who contributed to the process: David Bernard, the original facilitator for the Consultative Committee; Christine Pinkham, our research assistant; and Gwen Diaz and Kelly Robson who provided word processing and computer technical support.

May 23, 2002

David Marmorek and Ian Parnell

Executive Summary

Water Use Planning was introduced by the Minister of Employment and Investment (MEI)[1] and the Minister of Environment, Lands and Parks (MELP)[2] in 1998 as an approach to ensuring provincial water management decisions reflect changing public values and environmental priorities. A Water Use Plan (WUP) is a technical document that, once reviewed by provincial and federal agencies and approved by the provincial Comptroller of Water Rights defines how water control facilities will be operated. The purpose of water use planning is to understand public values and develop recommendations defining a preferred operating strategy using a consultative process. As such it involves the licensee, government agencies, First Nations, other key interested parties, and the general public. BC Hydro initiated a Water Use Planning process for the Cheakamus Generating facility in May 1999. This report describes the results of the consultative process (Steps 2-8).

The Cheakamus generating system consists of the Daisy Lake Dam and Reservoir and the Cheakamus Powerhouse in the Squamish Valley connected by a tunnel through Cloudburst Mountain. The Daisy Lake Dam and Reservoir are located on the Cheakamus River about 40 km north of Squamish. The generating station is located about 40 km north of Squamish along the upper Squamish River. Its twin turbines have a generating capacity of 157 megawatts. Power production has varied with both climate and regulation.

The Cheakamus plant produced approximately 790 GWh per year prior to implementation of the Interim Flow Agreement (IFA) in 1998. After implementation of the IFA, the Cheakamus plant produced approximately 590 GWh per year.

The Cheakamus watershed is in the Squamish-Lillooet Regional District and borders the community of Whistler to the north and the communities of Squamish and Brackendale to the South. The watershed is a major transportation corridor being bisected by both the Sea-to-Sky Highway and the BC Rail line to the interior. The Cheakamus River is productive by coastal standards providing spawning and rearing habitat for several salmon species that in turn support other wildlife, such as the large fall/winter congregations of bald eagles that feed on salmon carcasses. The river is a popular recreational destination that provides rafting, kayaking, and sportfishing opportunities. A portion of the watershed is within the Barrier Civil Defense Zone and is off-limits for recreational and domestic use. The Cheakamus watershed is entirely within the traditional territory of the Squamish Nation whose members have traditionally relied on the river and its watershed for food, transportation and cultural practices.

In June 1999, the Cheakamus Consultative Committee (CC) was created in accordance with Step 3 of the Provincial Water Use Planning guidelines and in conjunction with the announcement of the Cheakamus WUP. Its 20 members represented Federal, Provincial, Regional, and Municipal governments; the Squamish Nation; BC Hydro; environmental and recreational interests; and local stakeholders (Table ES.1). The CC agreed to a broad consultation process leading to identification of hydro operations that recognize multiple water uses in the Cheakamus and Squamish River systems, and competing interests and needs. Consultation was supplemented by field trips, expert presentations, a Fisheries Technical Committee and a Power Studies Technical Committee. A Facilitator was hired to assist the CC through the consultative process. The consultative process extended from June 1999 to January 2002 and

[1] The Ministry of Employment and Investment was renamed in 2001 to the Ministry of Energy and Mines.

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

included 25 meetings to work through the WUP steps outlined in the provincial *Water Use Plan Guidelines*. The length of the process was partially due to FTC needs; there was only one CC meeting between June 2000 and April 2001 while the FTC completed the field studies necessary to support development of the fisheries models for calculating performance measures.

Table ES.1: Cheakamus WUP Consultative Committee composition.

Group	Representatives
Fisheries and Oceans, Coast Guard (CCG)	1
Fisheries and Oceans, Water Use Section (DFO)	1
Ministry of Water, Land and Air Protection (WLAP)	1
District of Squamish (DoS)	1
BC Hydro (BCH)	2
Ministry of Energy and Mines (MEM)	1
Squamish Lillooet Regional District (SLRD)	1
Squamish Residents (SR)	1
North Vancouver Outdoor School (NVOS)	1
Ministry of Sustainable Resource Management (MSRM)	1
Squamish Nation (SN)	1
Sierra Legal Defense Fund (SLDF)	1
Squamish River Watershed Society (SRWS)	1
Cheakamus Residents (CR)	1
Angling: Whistler Angling Club (WAC), Steelhead Society (SS), Totem Fly Fishers (TFF)	3
Resort Municipality of Whistler (RMW)	1
Outdoor Recreation Council of BC (ORC)	1

In Steps 2 through 4 of the WUP process, the CC explored issues and interests affected by facility operations and agreed to the following six fundamental objectives for the Cheakamus Water Use Plan (not listed in order of importance).

1. Power: Maximise economic returns from power generated at Cheakamus Generating System.
2. First Nations: Protect integrity of Squamish First Nation's heritage sites and cultural values.
3. Recreation: Maximise physical conditions for recreation.
4. Flooding: Minimise adverse effects of flood events through operation of the Cheakamus Generating system.
5. Fish: Maximise wild fish populations.
6. Aquatic Ecosystem: Maximise area and integrity of the aquatic and riparian ecosystem.

At their meeting on April 30,2001, the CC agreed to a set of performance measures for evaluating how well different operating alternatives met these objectives. The performance measures were modelled quantitatively as a function of the flow, but varied in the strength of their linkage to particular values. The Squamish Nation evaluated the impact of flow on integrity of Squamish First Nation's heritage sites and cultural values in two separate studies to maintain confidentiality about the location of these sites.

The Consultative Committee accepted FTC recommendations and PMs based on the information and understanding as of April 30th, 2002. New issues and concerns came forward later in the process (e.g., groundwater linkages, off channel habitat and fish production linkages) for which no data existed to support development of performance measures. Hybrid dam operation alternatives and short- and long-term monitoring plans were developed to address these concerns, but not all CC members accepted this approach (see Section 6.5.1.1 and NVOS comments in Appendix 9).

In accordance with Step 5 of the WUP process, the CC and its supporting technical groups gathered the information and data necessary for developing the models used to calculate the performance measures. Part of this process included expert presentations to the CC on various aspects of the Cheakamus system (e.g., hydrology, flood control, ongoing studies). The Hydro Operations and Power Studies Committee (HOPSC) organised data required to develop a model of river flows, reservoir operations and power production. The Fisheries Technical Committee first conducted preliminary studies to understand the distribution of fish within the Cheakamus system. They then used this information to develop a set of impact hypotheses about the potential impacts of dam operations on attributes of fish populations and the aquatic ecosystem. The impact hypothesis process allowed the FTC to focus on important scientific uncertainties that affect decisions on operations, and prioritise studies that could provide the most useful information about these uncertainties within the timeframe and budget of the WUP process. They used the empirical field data from these studies to develop their models of fish and aquatic ecosystem performance measures. The key things learned about dam operations from FTC studies and modelling were:

- Dam operations do not affect the mainstem juvenile rearing area for salmon or steelhead except at very low dam releases. Two independent methods for calculating juvenile rearing area in relation to flow gave similar results: the cumulative weighted usable rearing area was relatively insensitive to flows greater than those associated with a 5 cms release from the Dam. This finding agrees with previous work by WLAP prior to the Cheakamus WUP process and is due mainly to two factors:
    1. Tributary inflows augment low releases from the Dam, particularly flow from Rubble Creek, which, during non-freshet periods, is fed by seepage through the porous lava dyke (the Barrier) from Garibaldi Lake and thus maintains a relatively constant base flow throughout the winter low flow periods (2.5-5.5 cms, average of 4 cms). Other tributaries show more varible inflows (BCH 2002b)
    2. The confined nature of a significant portion of the river channel below Daisy Dam (due to canyons, historical dyking and other works for flood and erosion protection built subsequent to the Dam) constrains the ability of flows to spread out over the flood plain to create more juvenile rearing habitat (See Section 4.7).
- Rainbow trout rearing area (in the reaches just downstream of the Dam) appears to be somewhat more sensitive to dam operations, though fewer field studies were conducted for this species.
- Dam operations probably affect chum spawning success. Using historical chum escapement records and the area required for spawning, the FTC found chum to be the only salmon species limited by spawning area. The chum effective spawning area performance measure was highest for lower flow operating alternatives.
    - Dam operations affect the benthic community, but fish are not currently food limited in the main rearing areas. Field studies found that the Cheakamus benthic community was depressed immediately below the Dam because it prevents the downstream movement of benthos, but that the community recovered quickly further downstream. These studies also found a relationship between benthic biomass, flow and flow variability. However, the Cheakamus River is rich in nutrients relative to most coastal rivers due to the volcanic geology of its watershed. Most nutrients below the Dam arrive through tributary inflow rather than from above the Dam.

Additionally, fish stomach content analyses showed that the fish ate the same organisms sampled in the benthic studies. For these reasons, the FTC concluded that while flow may affect the benthic community, the fish rearing in the Cheakamus River are not food limited.

In Step 6 of the WUP process, the CC created operating alternatives designed to meet various objectives. In total, twenty-five alternatives were run through the BC Hydro operations model. There were four types of alternatives:

1. alternatives that specified releases from Daisy Dam based on a certain percentage of previous reservoir inflows (e.g., as under the Interim Flow Agreement, or current operations);
2. alternatives that specified a minimum average daily release from Daisy Dam (e.g., “7Dam”);
3. alternatives that specified a minimum average daily flow at the Canada Water Survey gauge near Brackendale (e.g., “20Min”); and
4. alternatives that specified a combination of both a minimum release at Daisy Dam and a minimum flow at the Brackendale gauge (e.g., “20Min7Dam”). These constraints could vary by season.

In Step 7 of the WUP process the CC evaluated how well each alternative met the objectives using the performance measures. Evaluation proceeded as an iterative process of modelling, evaluation, and revision designed to narrow the range of alternatives. A key part of the process was making tradeoffs explicit and eliciting values and concerns, with the goal of reaching consensus. The evaluation process spanned six meetings from May 2001 to January 2002 (Figure ES.1). At the early meetings the CC was able to easily drop alternatives using the agreed to performance measures. As the range of flows within alternatives narrowed, distinctions based on performance measures were less clear for some CC members and values became more important in the discussions. Towards the end of the process, the CC divided. Some CC members accepted the performance measures approved by the CC at their April 30, 2001 meeting, and used these PMs for decision making. Other CC members felt that these performance measures were insufficient because they did not include engineered side channels as fish habitat. The first group favoured somewhat lower flow alternatives supported by the performance measures, which they considered to be sufficient for engineered side channels. The second group preferred somewhat higher flow alternatives they considered to be more precautionary for maintaining ground water flow to engineered side channels. The two groups also differed in the relative importance they placed on engineered side channels vs. the mainstem and its connected side channels. This split resulted in non-consensus at the penultimate meeting on October 24th, 2001. At this point the two most favoured alternatives were a hybrid 15_20Min3_7Dam option and a 20Min7Dam option.

As part of Step 8 of the WUP process, a final evaluation meeting was held on January 11th, 2002 to try once more to reach consensus and to clearly document areas of agreement and disagreement. This meeting was held because several CC members felt that another meeting would be fruitful. Only a narrow range of flows separated the two most preferred alternatives (15-20Min3-7Dam and 20Min7Dam), and the CC members who did not accept the performance measures had clearly expressed their concerns. The WUP Project Team reviewed the main concerns and proposed a 1-year monitoring and evaluation plan to address critical scientific uncertainties relating to groundwater in side channels, as well as two new hybrid alternatives designed to address CC concerns about the two most favoured alternatives from the October 24th meeting.

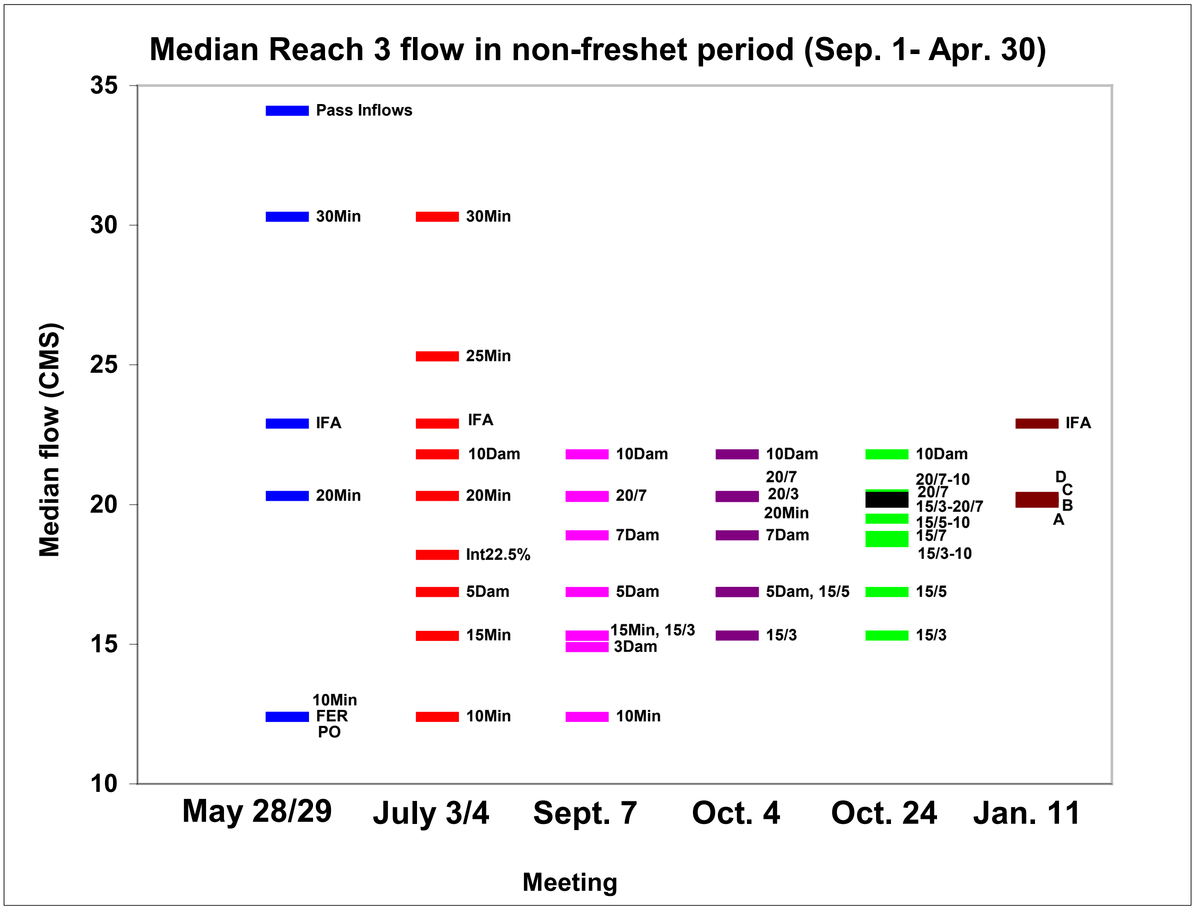

Figure ES.1: Narrowing the range of alternatives over the evaluation process. This figure shows the number and range of alternatives considered at each Cheakamus Consultative Committee evaluation meeting. IFA represents conditions under the Interim Flow Agreement. The 15_20Min3_7Dam option (abbreviated as 15/3_20/7) and the 20Min7Dam option (20/7) were the 2 most favoured alternatives at the October 24th, 2001 meeting (indicated by the darker bar). The A, B, C and D alternatives were the final four presented to the CC on January 11th, 2002. A and D are the 15/3_20/7 and 20/7 alternatives (Table ES.2).

The CC did not reach consensus on an operating alternative at their final meeting. Each of four alternatives presented for evaluation was blocked by at least four CC members (Table ES.2). Participants were permitted to express a preference for alternatives other than the four presented. Eight of 16 CC members preferred continuing the current Interim Flow Agreement (IFA) for approximately another 3-5 years to provide information to thoroughly assess its effects (8 CC members representing the following organizations: CR, NVOS, ORC SWRS, SN, SR, WAC, WLAP; Table ES.1 defines these abbreviations). The CC had previously agreed to drop this alternative at the second evaluation meeting held July 3rd/4th, 2001 (Figure ES.1). One of the 8 CC members preferring the IFA (WLAP) favoured an adaptive management program that monitored the IFA for about 5 years before switching to the 15Min3Dam alternative. One BCH CC member preferred that 15Min3Dam be implemented. Some CC members expressed concerns about re-instating the IFA given that it had previously been dropped (CC members representing BCH, DFO, MEM). These CC members were also concerned that two of the CC members favouring the IFA (the members for the CCG and the WAC) had not previously actively participated in the evaluation process.

Table ES.2: Summary of the Cheakamus Consultative Committee preferences at the final evaluation meeting (January 11th 2002). Cell contents show how many CC members assigned the indicated rating to each alternative. The acronyms in the cells below alternatives A, B, C and D indicate which CC representatives gave that rating. Table ES.1 provides a key to these acronyms.

	Alternative				
	A. Hybrid	**B. Revised Hybrid 'B'**	**C. Revised Hybrid 'C'**	**D. 20Min7Dam**	**Other Preferences**
Period: Nov. – Dec	15Min3Dam	15Min3Dam	15Min3Dam	20Min7Dam	
Jan. – Mar.	15Min3Dam	15Min5Dam	20Min7Dam	20Min7Dam	
Apr. – Oct.	20Min7Dam	20Min7Dam	20Min7Dam	20Min7Dam	
Preferred	**1** (BCH)	**1** (DFO)		**3** (SR, SLRD, SLDF)	1 (or 2*) 15Min3Dam 8 (or 7*) IFA
More Acceptable	**5** (or **4***) (BCH, DFO, DoS, MEM, WLAP*)	**4** (or **3***) (BCH, DoS, MEM, WLAP*)	**3** (or **2***) (SLRD, DoS, WLAP*)	**5** (or **4***) (DOS, WLAP*, CCG, SWRS, ORC)	3 did not prefer IFA, but did not block it
Less Acceptable	**3** (SR, SLRD, CCG)	**4** (SR, SLRD, CCG, BCH)	**7** (BCH, SR, DFO, MEM, CCG, ORC, SLDF)	**2** (WAC, NVOS)	
Not Part of Consensus if Selected (Block)	**5** (or **6***) (CR, NVOS, WLAP*, SWRS, ORC, SLDF)	**5** (or **6***) (CR, NVOS, WLAP*, SWRS, ORC, SLDF)	**4** (or **5***) (CR, NVOS, WLAP*, BCH, SWRS)	**4** (or **5***) (2xBCH, DFO, MEM, WLAP*)	4 blocked IFA
Total ratings possible for A, B, C, and D based on submitted rating forms. Not all ratings at the meeting were submitted by rating sheet.	**14**	**14**	**14**	**14**	

* Indicates that the WLAP rating is contingent on whether or not an adaptive management approach is used where the IFA is implemented first and then switched to 15Min3Dam. If this were to take place the WLAP member gave a rating of 2 to alternatives A, B, C, and D. If the IFA were not implemented first then the WLAP member gave a rating of 4 to alternatives A, B, C and D.

The main points of disagreement on the proposed alternatives were:

- Those who preferred or accepted the proposed alternatives (A, B, C or D) accepted the FTC models and PMs as a basis for decision making, and felt that these flows were sufficient to maintain engineered side channels.
- Those preferring the IFA did not accept the FTC models and PMs as a basis for decision making, primarily because of the exclusion of engineered side channels from fish habitat PMs; they also felt that there were too many remaining uncertainties to justify changing from current operations now.

The eight CC members who had not preferred the IFA were asked if they would object to bringing the IFA back onto the table for consideration. Four said they would not be part of a consensus that included the IFA (2 BCH, DFO, MEM) while three said they would not object (SLDF, SLRD, CCG). The member for the District of Squamish noted that the flood control concerns of the District were met by all alternatives (including the IFA); therefore he was comfortable supporting any of the proposed alternatives.

Table ES.3 summarizes the performance measures for the preferred alternatives at the end of the January 11th, 2002 meeting. This table shows only the results for the reduced set of objectives and performance measures used by the CC at that meeting.

Table ES.3: Consequence Table for the final preferred alternatives. This table shows only the reduced set of objectives and performance measures used at the final CC evaluation meeting, January 11th, 2002. Alternatives "A", "B", "C", and "D" were proposed to the CC prior to the meeting. Some CC members also preferred the 15Min3Dam and IFA alternatives at the meeting.

Fundamental Objectives	Performance Measures	Alternatives					
		15Min3Dam	15-20Min3-7Dam "A"	15-20Min3-5-7Dam "B"	15-20Min3-7Dam "C"	20Min7Dam "D"	IFA
1. Maximize economic returns from power generation.	Average power revenue ($M/yr)	35.6	34.3	34.0	33.0	32.3	26.9
2. Protect integrity of SFN heritage sites and cultural values.		Addressed by flood PMs and other studies					
3. Maximize physical conditions / access for recreation (kayaking, rafting, sportfishing).	Kayaking (Avg. #days/yr)	124	200	202	222	242	199
	Sportfishing (Avg. #days/yr)	58	83	142	125	193	107
5. Maximize wild fish populations	($m^2 \times 10^3$)						
RUA Resident Habitat	Rainbow Parr	35.8	42.5	42.5	42.5	42.5	40
Effective Spawning Area	Chum	9.8	9.7	9.7	9.5	7.3	6
6a. Maximize area and integrity of aquatic ecosystem	Resident Riffle Benthic Biomass ($g \times 10^6$)	3.4	2.9	2.9	3.0	2.9	2.2

At the final meeting, the CC also reviewed the monitoring plan and rated its components. This was done for two reasons. First, individual CC preferences for particular alternatives were potentially dependent on the ability to revise decisions based on monitoring. Second, it is important for the Provincial Comptroller of Water Rights to know which elements of the monitoring plan are most critical to future water management decisions. Fifteen CC members rated the components using two criteria: 1) the likelihood that their results would change their decisions and 2) the relative importance of the component for the monitoring plan. Table ES.4 below summarises the results. The CC generally endorsed all components of the monitoring plan. It gave the highest ratings to "Statistical Methods", "Salmon" and "Groundwater". An intermediate level of support was given to "Resident Trout" and "Squamish Stranding". Less support was given to the "Channel Morphology" and "Benthos" monitoring components, though about two thirds of the CC members who rated these components considered them to be of medium to high importance (Table ES.4).

Table ES.4: Summary results for Cheakamus Consultative Committee ratings of monitoring plan components at the final meeting (January 11th, 2002). The estimated costs per year for each component is shown below its main heading. These costs are split into the costs for the first year and the annual costs for subsequent years of monitoring. These costs include the costs of monitoring a control river.

	Statistical Methods	**Salmon**		**Resident Trout**		**Squamish Stranding**		**Ground water**		**Benthos**		**Channel Morph.**	
$/yr, year 1	**$25,000**	**$414,700**		**$32,300**		**$10,000**		**$41,000**		**$48,170**		**$70,000**	
$/yr, year 2 +	**--**	**$326,000**		**--**		**--**		**$3,200**		**$48,170**		**$10,000**	
Rating	**Importance**	**Likelihood**	**Importance**	**Likelihood**	**Importance**	**Likelihood**	**Importance**	**Likelihood**	**Importance**	**Likelihood**	**Importance**	**Likelihood**	**Importance**
High	14	13	14	9	9	6	8	11	12	4	6	6	6
Medium				4	5	4	4	1	2	3	3	3	4
Low						3	2			6	5	3	3
No rating recorded		1		1		1		1		1		2	2
Abstained	1	1	1	1	1	1	1	1	1	1	1	1	1

The CC also reviewed and rated a set of recommendations identified during the course of the WUP and designed to address concerns both within and beyond the scope of the WUP process. Recommendations within the scope of the WUP relate to issues that can be affected by dam operations. Recommendations beyond the scope of the WUP relate to actions identified that would likely have benefits, but do not relate to facility operations and therefore not the responsibility of BC Hydro. The CC members indicated whether they approved, were indifferent, or disapproved of each recommendation (Table ES.5). In general, most CC members approved of all the recommendations, though there were some concerns that adding sediment and woody debris could confound the ability to monitor the impacts of changes in hydro operations.

To complete Step 8 of the consultation process, this consultative report was prepared on behalf of the CC's. Its purpose is to summarise the consultation process for the Provincial Comptroller of Water Rights and to inform the development of BC Hydro's draft Cheakamus Water Use Plan (Step 9). It went through two rounds of revisions; the CC reviewed and commented on a draft- and draft-Final report. CC review comments, clarifications and additions were incorporated into the main body of the report where they were consistent with the written records and the facilitators' recollections of meetings. Commentary that did not meet these criteria was included in Appendix 9 and referenced in the main text.

Table ES.5: Summary results for the Cheakamus Consultative Committee's ratings of recommendations at the final meeting (January 11th, 2002).

Recommendation	Approve	Indifferent	Disapprove	Other
Recommendations within the scope of the WUP process				
1. Provide appropriate transitions between seasonally varying flow regimes to prevent stranding.	13	0	1	0
2. Use recommended minimum flows as targets, but allow some operational flexibility.	14	0	0	0
Other Recommendations beyond the scope of the WUP process				
1. Monitor and maintain Farpoint channel flow.	12	1	1	
2. Explore habitat enhancement opportunities on Squamish River.	10	3	0	1
3. Increase co-ordination between interested parties to achieve integrated watershed management.	14	0	0	0
4. Maintain sediment supply.	11	1	0	0
5. Add large woody debris.	10	2	2	0
6. Identify floodplain areas for restoration.	11	2	0	1
7. Move bridge above NVOS to promote lateral movement of mainstem.	10	3	0	1
8. Improve communication between recreationalists and Squamish Nation.	12	1	0	1

Summary:

Despite making considerable progress in filtering alternatives, the Cheakamus Consultative Committee (CC) was ultimately unable to reach consensus on a single operating alternative for the Water Use Plan. At their final evaluation meeting on January 11th 2002, the CC examined the two most preferred alternatives from the previous meeting, plus two intermediate alternatives designed to meet various concerns. At the meeting, the CC was generally split into two groups (Figure ES.2). One group accepted the FTC models and PMs as a basis for decision making, and found 2 to 4 of the final four alternatives to be acceptable. The other group ultimately did not accept the FTC models and PMs as a basis for decision making, primarily because of the exclusion of engineered side channels from fish habitat PMs. This group rejected 3 to 4 of the final four alternatives, and recommended continuing with the current Interim Flow Agreement (IFA) for another 3-5 years before deciding if different operations were warranted. They felt that there were too many remaining uncertainties to justify changing operations now. Despite considerable effort, the CC could not find common agreement on operating alternatives among these two groups.

The FTC developed a comprehensive monitoring plan to address the critical points of scientific uncertainty and disagreement within the CC and to better inform the next WUP; the CC members strongly supported its main components. The CC recognised that it is essential to address critical scientific uncertainties that can affect future decision making, and to comprehensively assess the response

of the system to whichever operating alternative is implemented. It is very important to refine the statistical and sampling methods to be used.

Monitored ecological indicators should include (in general order of priority): salmonid spawning and juvenile production; groundwater levels and fish production in groundwater-fed side channels in the Cheakamus River; rainbow trout habitat utilisation; stranding of juvenile fish in the Squamish River; riparian vegetation and channel morphology; and benthos, periphyton and nutrients. The plan should also monitor indicators related to Squamish Nation Heritage and Cultural values, and the influence of flow and other factors on recreational usage of the river.

The CC also strongly supported several other recommendations. In particular, one non-WUP recommendation recognised the need for a more integrated watershed approach that better co-ordinates activities in the region among all the various groups involved in the Cheakamus process.

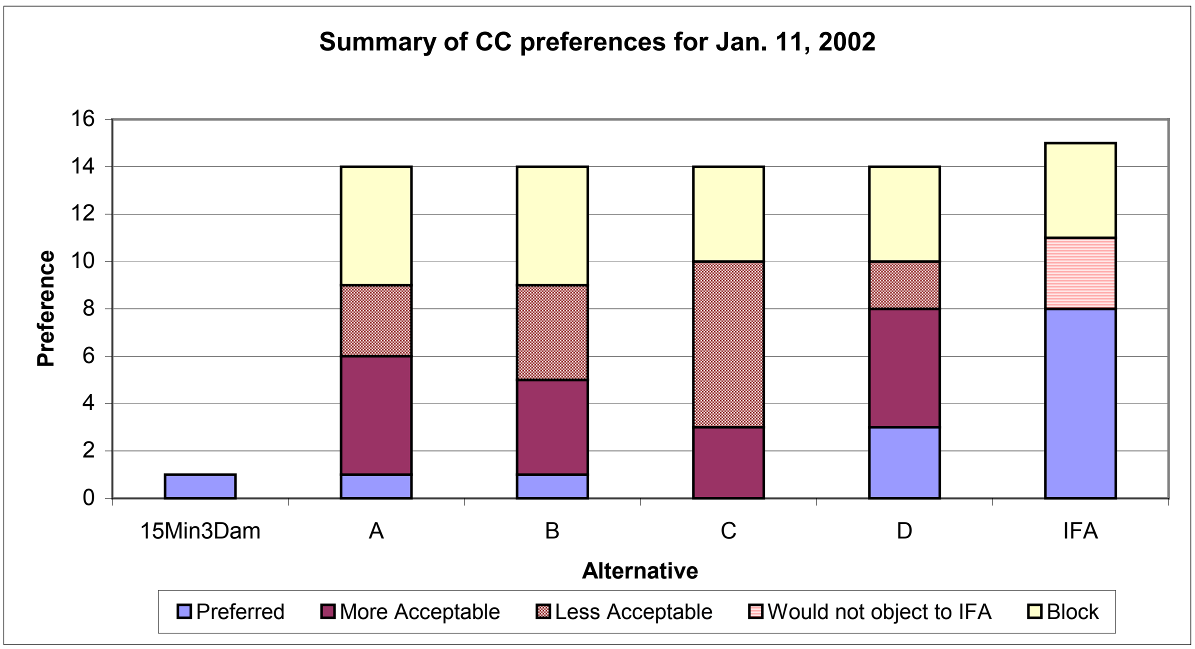

Figure ES.2: Cheakamus Consultative Committee preferences for operating alternatives at the final evaluation meeting, January 11th, 2002. Note that no "Blocks" were expressed for the 15Min3Dam alternative because although one Consultative Committee member expressed a preference for it, the entire Consultative Committee was not asked during the meeting if it would consider putting this alternative back on the table and so no other preferences were recorded for it.

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1.0 Introduction

1.1 Water Use Planning

Water Use Planning was introduced by the Minister of Employment and Investment (MEI)[3] and the Minister of Environment, Lands and Parks (MELP)[4] in 1998 as an approach to ensuring provincial water management decisions reflect changing public values and environmental priorities. A Water Use Plan (WUP) is a technical document which, once reviewed by provincial and federal agencies and approved by the provincial Comptroller of Water Rights, defines how water control facilities will be operated. The purpose of water use planning is to understand public values and develop recommendations defining a preferred operating strategy using a consultative process. This consultative process is outlined in the provincial Water Use Plan Guidelines (Province of British Columbia, 1998).

The Water Use Plan is intended to address issues related to the operations of facilities as they currently exist and incremental operational changes to accommodate other water use interests[5]. Water Use Plans are not intended to be comprehensive watershed management plans or to deal with water management issues associated with other activities in the watershed. Treaty entitlements and historic grievances from facility construction are specifically excluded from Water Use Plans, but can be considered as part of other processes (Province of British Columbia, 2000).

The Cheakamus River consultative process was initiated in May 1999 and completed in January 2002. The purpose of this report is to document the consultative process and present the recommendations of the Cheakamus River WUP Consultative Committee. The interests and values expressed in this report will be used by BC Hydro to prepare a draft Water Use Plan for the Cheakamus River hydroelectric system. This Consultative Report is a record of the water use issues and interests and the analysis of trade-offs associated with operating alternatives. This report ensures the Comptroller of Water Rights has complete information from participants for use in decision making. Both the Cheakamus River WUP Consultative Committee Report and BC Hydro's draft Water Use Plan will be submitted for review and approval.

What's Covered in the Remaining Sections of This Report

The remainder of **Section 1** provides a general description of the Cheakamus system, including geographical, ecological and socioeconomic information.

Section 2 introduces the steps of the Water Use Planning process, and provides details for WUP steps 2-3. It describes the consultative process, including the composition of the Cheakamus Consultative Committee (CC), its mandate and the support provided to it during the decision making process.

Section 3 covers WUP step 4. It describes the objectives the CC developed and the performance measures it used to evaluate how well operating alternatives met these objectives,

Section 4 describes WUP Step 5, the information gathering processes that the CC, FTC and HOPSC used to learn about the Cheakamus system, and to develop performance measures.

---

3 The Ministry of Employment and Investment was renamed in 2001 to the Ministry of Energy and Mines.

4 The Ministry of Environment, Lands and Parks was reorganized in 2001 into the Ministry of Water, Land and Air Protection and the Ministry of Sustainable Resource Management.

5 The focus of a WUP is to determine how water could be allocated to accommodate different uses. However, there may be opportunities to undertake physical works as a substitute for changes in flow.

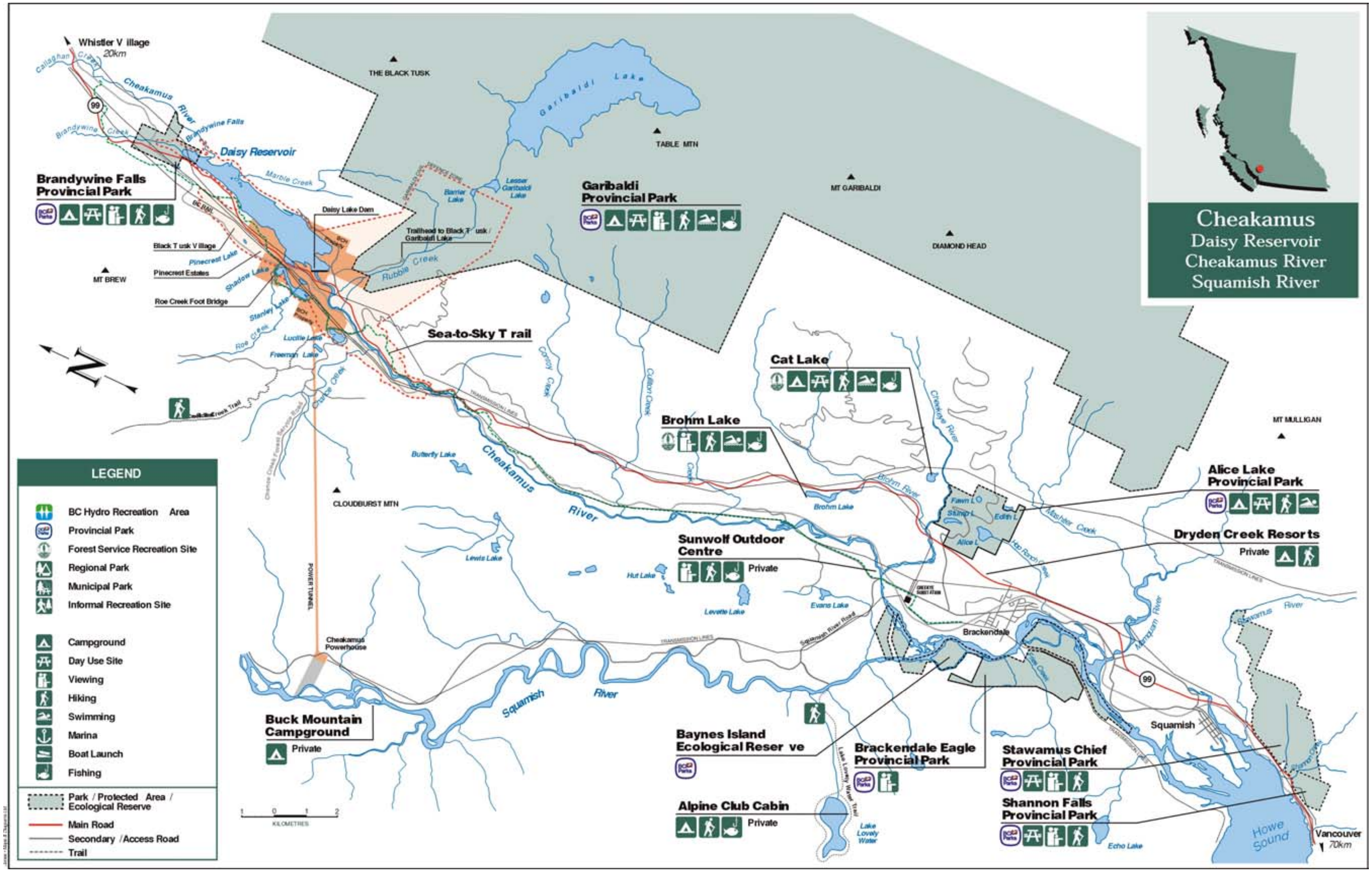

Figure 1.1: Map of the lower Cheakamus and Squamish watershed.

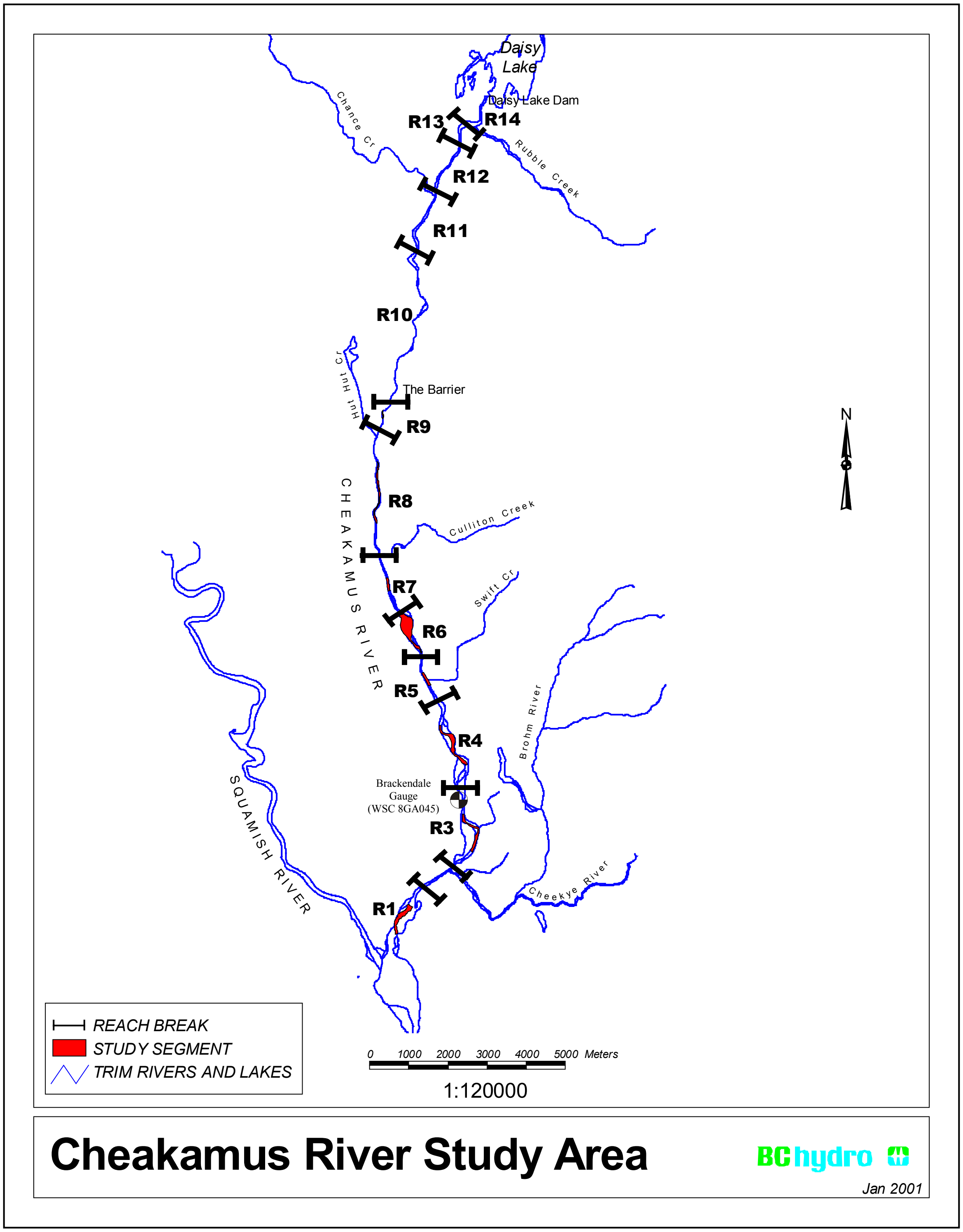

Figure 1.2: Map of lower river reaches defined by the Fisheries Technical Committee (Source: Dave Wilson, BCH).

Section 5 covers WUP Step 6. It describes the suite of operating alternatives the CC considered during the WUP process, and the modeling procedures used to express the consequences of these operating alternatives as performance measures.

Section 6 covers WUP Step 7 (evaluation) and begins Step 8 (documentation). It describes the methods the Consultative Committee used to evaluate operating alternatives and address tradeoffs between objectives, provides an overview of progress across the evaluation meetings, gives details of the shortlisted set of alternatives considered at the penultimate meeting and summarizes the results of the final evaluation meeting. It also documents the reasons for a lack of consensus.

Section 7 describes the comprehensive WUP monitoring plan the FTC developed and summarizes the support within the CC for each of its components.

Section 8 provides a concise summary of the WUP results, and describes other CC recommendations – some within the scope of the WUP process, and others outside of it.

Sections 9 and 10 provide a glossary of terms and the cited references respectively.

The report includes **several appendices** to supplement specific topics. Additionally, the enclosed CD-ROM provides the full documentation from the Consultative Committee meetings, documentation from the Fisheries Technical Committee meetings and analyses over the course of performance measure model development, performance measure calculation tools and data, and some documentation of work by the Hydro Operations and Power Supply Committee. The CC meeting notes are stored on the CD-ROM as Adobe Acrobat™ pdf files. The following examples shows how they are referenced in this report: "25_CC Meeting Notes January 11 2002.pdf".

1.2 The Cheakamus River System

1.2.1 The Cheakamus River and Watershed

The Cheakamus River originates in the Fitzsimmons Range of the Coast Mountains (KWL 1998, NHC 2000a) in Garibaldi Provincial Park, about 25 km southeast of Whistler, BC. Its watershed has an area of 1,070 km^2 and an elevation ranging from 30 metres above sea level at its confluence with the Squamish River to 2300 metres at its headwaters. From its headwaters, it flows through Cheakamus Lake and runs northwest towards Whistler then turns south for 46 km, travelling parallel to the Squamish River, to the Daisy Lake Reservoir. From there, water is released either through the dam, or diverted to the Squamish generating station (Figure 1.1). Water that is released through the Daisy Lake Dam continues south for another 24 km to its confluence with the Squamish River north of Brackendale, which continues to Howe Sound.

Climate

The Cheakamus watershed is transitional between the milder Pacific Coast and colder interior, or cordilleran, climatic regimes (NHC 2000a). The valley is oriented such that it receives the predominant winter southwesterly winds that transport moist air up Howe Sound and far up the valley. A series of fall and winter storms occur from late September until March. Summer storms also occur but are usually small, though intense. Infrequent, large, summer storms can produce extreme flooding (e.g., August of 1991). Annual precipitation tends to decline along the valley bottom moving inland where a greater proportion also falls as snow due to the colder inland climate and higher elevations. At the Garibaldi and Alta Lake climate stations, over half the annual precipitation falls between October and January. Snow accumulates rapidly in the watershed during the fall, especially at the higher elevations.

Hydrology

The natural flow regime of the Cheakamus River follows a cyclical seasonal pattern driven by climatic factors (Figure 1.3). Generally, the flows rise in April as temperatures increase and the snowpack begins to melt. This snowmelt period is referred to as the spring freshet. The freshet peaks in June or July, which are typically the months when the highest sustained flows are recorded. The flows decrease noticeably through August and September and then taper gradually to a minimum in March. Storm events resulting in pronounced short duration increases in flow occur sporadically throughout the year and are superimposed on the snow accumulation, snowmelt trends. The highest daily flows typically occur from September to January due to the combination of intense precipitation and melting snow commonly called a "rain on snow" event.

Approximately three-quarters of the total natural inflow to the Cheakamus River watershed originates upstream of Daisy Lake Dam. The remaining one-quarter of the natural inflow enters the river below the location of the Dam and is thus not affected by the project.

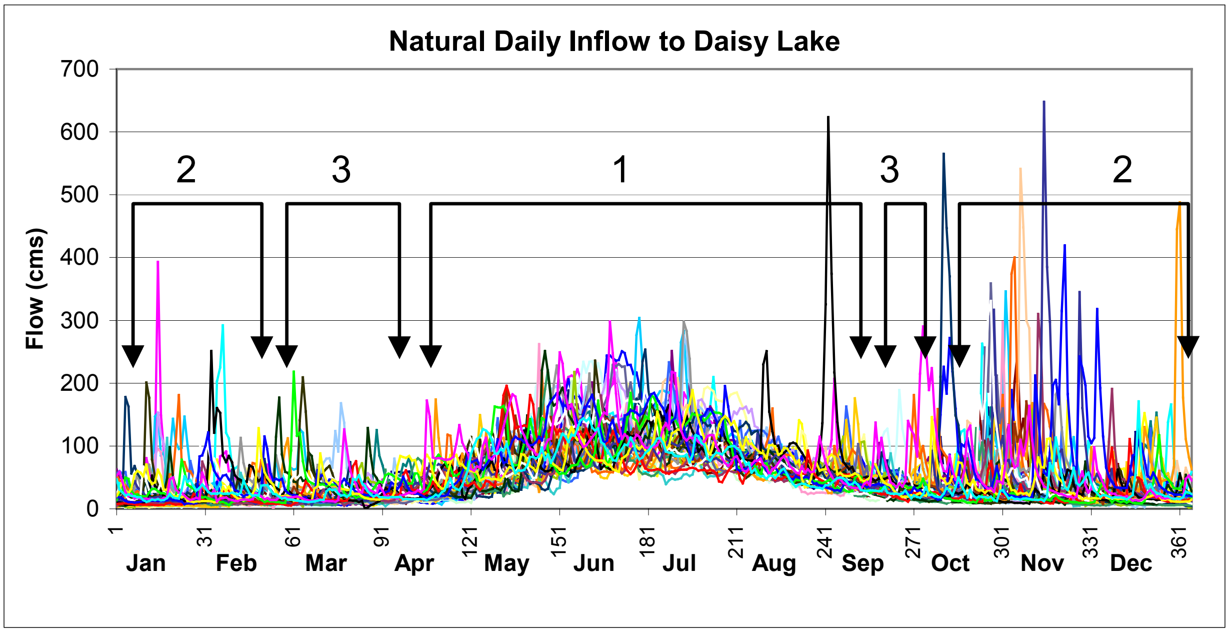

Figure 1.3: Historical natural daily inflow upstream of the location of Daisy Dam over 32 water years (1967 to 1998). Important features marked on graph: 1 = the generally consistent timing and magnitude of the summer freshet; 2 = the highly variable magnitudes of fall and winter storm events; and 3 = the consistently lower flows in the "shoulder seasons" of March-April and September. (Source: Kathy Groves, BC Hydro)

Since construction of the Daisy Dam, the same seasonal patterns of precipitation and snowmelt occur, but less water goes down the Cheakamus River. There have also been changes to the hydrology during particularly wet and dry years. For example, the diversion of water to the powerhouse can significantly reduce the snowmelt freshet during low reservoir inflow years (NHC 2000a). However, reservoir operations have been effective in reducing peak discharges from the dam during small and moderate floods. A revised operating regime (see next paragraph) has been effective in reducing small peak flows.

Since the construction of the Daisy Dam, the combined effects of reservoir operations and tributary inflow have driven the hydrology of the lower Cheakamus River. Precipitation, snowmelt, and glacial melt influence these factors. From 1958 until 1994, the dam was operated primarily to generate maximum power. In 1995, BC Hydro implemented a winter reservoir drawdown program to reduce the risk of uncontrolled spillage during high floods. In 1997, DFO issued a flow order to BC Hydro that specified that the greater of 5 cms, or 45% of the previous day's inflows to the Daisy Dam reservoir be released downstream (the Interim Flow Order, or "45% Rule"). BC Hydro challenged this order and it was overturned in Court. An Interim Flow Agreement (IFA) was negotiated in 1998 that modified the required release to be the greater of 5 cms or 45% of the previous day's average inflows to the reservoir (within a daily range of 37% to 52% and within 45% of the previous 7 days' average inflows). A water licence was issued from the Comptroller of Water Rights that reflected this agreement.

Tributaries

Major tributaries of the Cheakamus include Rubble Creek, Culliton Creek and the Cheekye River. These three tributaries play an important role in maintaining hydrologic conditions in the river below the dam. Rubble Creek enters the Cheakamus just below the dam. During low flow periods it is fed by seepage through the Barrier, a lava dyke that contains Garibaldi and the Barrier Lakes. This seepage helps maintain a relatively stable base flow that augments low releases from the dam during the lower flow winter period. The Garibaldi Névé and several small glaciers feed the Cheekye River. It is the largest single source of gravel and sediment to the Cheakamus because the dam now blocks input from upstream sources, though Rubble Creek torrents also provide periodic sediment inputs.

Ecological

The Cheakamus is a productive river by coastal standards due to the nutrients leached from the volcanic geology of the watershed. In the past, the river has provided spawning and rearing habitat for several salmon species. But, in addition to the disruption of natural flows by the dam, a system of dykes now constrains the river, particularly in the lower reaches. The dykes cut off most natural[6] side channel spawning and rearing habitat from the mainstem and prevent natural erosion and channel movement processes (See Bob Newbury's presentation summarized in the February 7th CC meeting notes ("12_CC Meeting Notes February 7, 2000.pdf"), NHC 2000a and KWL 1998). Of the salmon species, the chum population has remained the most stable and their spawned out carcasses attract large congregations of bald eagles during late fall and winter. A natural river barrier restricts anadromous species to the lower River below reach 10 (Figure 1.2). There are some differing views on the importance of engineered side channels and their sensitivity to mainstem flows (see NVOS comments in Appendix 9).

Socioeconomic

The Cheakamus River is a popular rafting, kayaking, and sportfishing destination. The large fall/winter congregations of bald eagles attract naturalists. Many wilderness recreational areas, including Garibaldi Provincial Park, are nearby (Figure 1.1). The watershed is in the Squamish-Lillooet Regional District and borders the community of Whistler to the north and the communities of Squamish and Brackendale to the South. The watershed is a major transportation corridor, bisected by both the Sea-to-Sky Highway and the BC Rail line to the interior of the province. A large portion of the watershed is within the Barrier Civil Defense Zone and is off-limits for recreational and domestic use (see Figure 1.1.) This zone was created in case of the collapse of the Barrier.

---

[6] Natural side channels receive flow from the mainstem without artificial means (e.g., pipes through dykes).

First Nations

The Cheakamus watershed is entirely within the traditional territory of the Squamish Nation. Two Squamish Nation reserves are located adjacent to the lower Cheakamus River: Cheakamus I.R. No. 11, and Poquiosin and Skamain I.R. No. 13. The Squamish people have traditionally relied on the river and its watershed for food, transportation and cultural practices. The portion of the watershed above the reservoir falls within the traditional territory of the Lil'Wat First Nation, based in Mount Currie.

1.2.2 The Cheakamus Generating System[7]

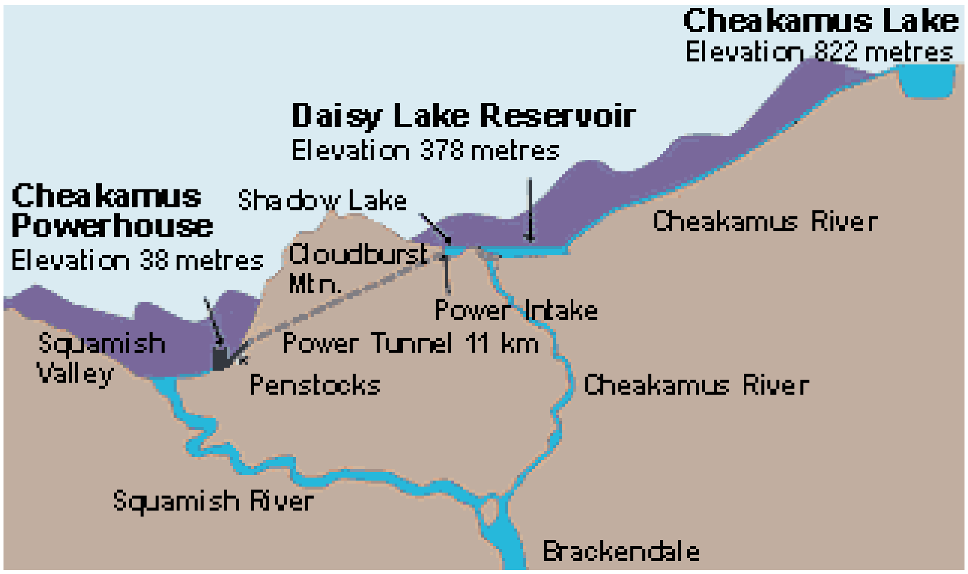

Figure 1.4: Schematic showing reservoir, tunnel and generating station. (Source: BC Hydro WUP Web brochure).

The Cheakamus generating system was completed in 1957 and is comprised of the Daisy Lake Dam and Reservoir, the Cheakamus Powerhouse in the Squamish Valley, and a connecting tunnel through Cloudburst Mountain.

The Daisy Lake Dam and Reservoir are located 24 km up the Cheakamus River from its confluence with the Squamish River and are visible from the Sea-to-Sky highway where it crosses the Cheakamus River about 40 km north of Squamish. The reservoir has a surface area of 430 hectares. During normal operations its surface elevation ranges from 364.9 to 377.3 metres above sea level, a fluctuation of 13.1 metres. The reservoir can store about 55 million cubic metres of water, a volume equivalent to 1 km^2 filled to a depth of 55 metres.

Water for generating power is drawn from Daisy Reservoir via a canal under the Sea-to-Sky highway into Shadow Lake where it enters an 11km tunnel that runs through Cloudburst Mountain to the Squamish Valley. Twin penstocks carry the water from the tunnel exit to the Cheakamus generating station after which it is discharged into the Squamish River. The maximum flow capacity of the tunnel is 60 cms. There is a difference in elevation of approximately 327 metres between the tunnel entrance and the turbines of the generating station.

[7] Cheakamus Generating System, BC Hydro. May 1999.

The generating station is located about 40 km north of Squamish along the upper Squamish River (Figure 1.1). Its twin turbines have a generating capacity of 157 megawatts. Operation of the Cheakamus plant produced approximately 790 GWh per year prior to implementation of the Interim Flow Agreement (IFA) in 1998. After implementation of the IFA, the Cheakamus plant produced approximately 590 GWh per year. The electricity generated at Cheakamus provides about 1.5 percent of BC Hydro's total system production. This electricity is transmitted to Hydro's integrated grid by a 230 kilovolt powerline to the Cheekye substation located 19 kilometres to the south.

The generating station normally operates as a "peaking plant" to meet increased customer demand, typically during the daytime. It is often shut down at night when the amount of water entering the reservoir is insufficient to run the plant continuously, especially during the low flow winter period from January to April.

2.0 The Consultative Process

The Cheakamus consultative process followed the steps and methods described in the Provincial Water Use Planning guidelines for WUP Steps 2-8 (http://srmwww.gov.bc.ca/wat/wup/wup) (Figure 2.1). The focus of this section is WUP Steps 1 (Initiation and Announcement), 2 (Scope water issues and interests) and 3 (Determine consultative process).

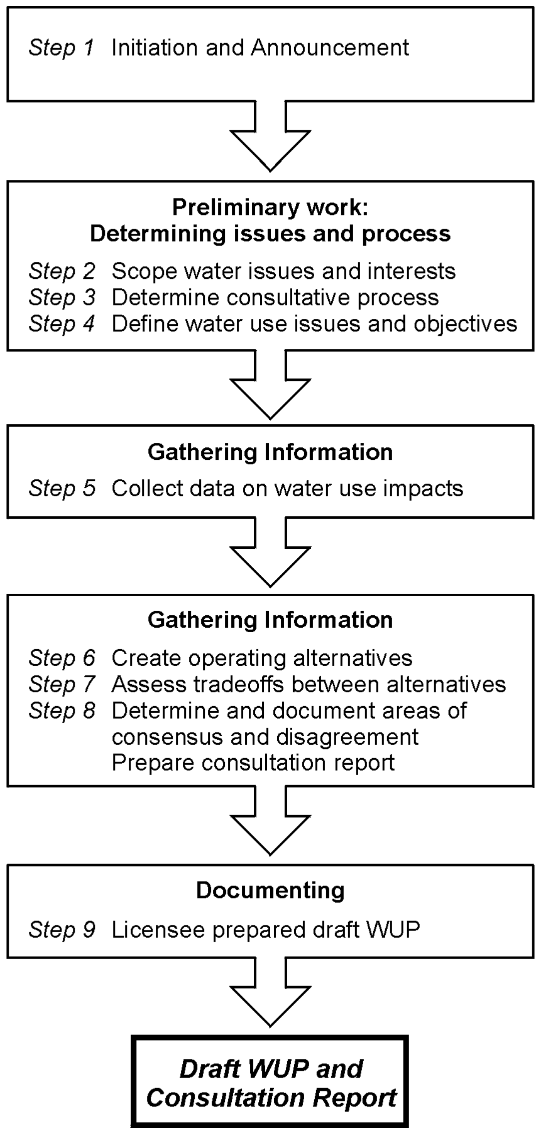

Figure 2.1: Steps in the Provincial Water Use Plan process (Source: Province of British Columbia 1998).

2.1 WUP Initiation and Scoping of Issues (Steps 1 and 2)

Step 1 (Initiation and Announcement) began prior to the public announcement of the Cheakamus WUP process. BC Hydro invited a broad range of stakeholders with potential interest in the Cheakamus River to participate in the Cheakamus WUP process. Two-dozen participants agreed to serve as members of an *ad hoc* 'Cheakamus Steering Committee,' until the announcement of the formal Water Use Planning process and selection of the official 'Consultative Committee'. At meetings held April 15 and May 6 1999, the Steering Committee worked together to define the composition of the Consultative Committee, develop its draft mandate, and scope out a preliminary list of issues. Several members of the Steering Committee joined the Consultative Committee.

Step 2 (Scope water issues and interests) began with the public announcement of the WUP in June 1999. The announcement was followed by open houses held in Squamish and Whistler to introduce the WUP process to the public and elicit further issues for consideration during the consultation process. Table 2.1 summarizes some of the issues raised in the early meetings and the extent to which they were considered in the WUP process.

Table 2.1: Summary table of issues raised at 1999 Steering Committee and Consultative Committee meetings and initial open houses, and if/how these issues were considered in the WUP process. PMs = performance measures.

Issue	Considered in WUP Process?
Impact of WUP on power production, value of energy to province	Yes. PMs created for value of energy, amount of power production and Greenhouse Gas emissions associated with replacement energy sources.
Use of river by Squamish First Nation	Yes. PMs for fish and aquatic ecosystem relevant to SFN traditional use. Protection of sacred sites considered through flooding PMs and other analyses, after appropriate studies concluded.
Downstream consequences of dam operations for water flow, flooding and erosion	Yes. Flooding PMs created which also reflect risk of erosion.
Maintaining recreational opportunities	Yes. PMs created for physical conditions / access to kayaking, rafting and sportfishing opportunities.
Public notification regarding changes in water level / Emergency preparedness	Not part of evaluation of alternatives. CC recommended continuation of existing Cheakamus Emergency Notification System.
Effects of water flow on fish habitat and fish production	Yes. Major research and monitoring effort completed by FTC to assess relationships between flow and fish habitat PMs in mainstem. During trade-off analyses, concerns raised about effects of flow on engineered side channels, leading to monitoring recommendations to address uncertainties.
Effects of water flow on overall aquatic ecosystem integrity.	Partly. PMs developed for benthic biomass. PMs not developed to link riparian vegetation to flow due to presence of dykes (see section 3.3.1)
Opportunities to enhance productive capacity of fish habitat	Partly. Enhancement outside terms of reference of WUP, unless enhancement is a less expensive method of achieving objectives than changes to dam operations. Enhancements considered in this context for engineered side channels. Recommendations made on other enhancement opportunities that could be pursued through other means (e.g. Bridge-Coastal Compensation Fund).

Issue	Considered in WUP Process?
River channelization and effects of fish habitat quality and quantity	Research conducted on effects of dykes as part of Step 5 of WUP. Effects of channelization considered when building tools to predict fish habitat response to flow. Recommendations made concerning need to explore potential changes to dykes, but not as part of Hydro operations or WUP.
Impacts of other land uses (e.g. forestry, roads, rail, floodplain development)	Outside of WUP terms of reference. Influences of existing channel development considered in evaluation of alternatives.
Effects of Whistler, other point sources, and non-point sources	Regulation of nutrient sources outside scope of WUP, but interaction of nutrients and flow considered in field monitoring and models used to predict periphyton and benthic biomass PMs.
Daisy Lake management for fisheries and recreation	Not considered in evaluation of alternatives. Daisy Lake is in the Civil Defense Zone and fishing and recreation are not permitted.
Wildlife	Not directly represented in WUP PMs. Considered indirectly through PMs for benthos and fish (e.g. chum production very important for eagles).

2.2 The Cheakamus Consultative Process (Step 3)

2.2.1 Consultative Committee

In June 1999, Step 3 of the WUP process (Determine consultative process) began with the formation of the Cheakamus Consultative Committee (CC) in conjunction with the announcement of the Cheakamus WUP. Its inaugural meeting was held June 23, 1999 at the Squamish Public Library. The Consultative Committee agreed on its mandate, objectives and responsibilities (Appendix 1) and agreed to a broad consultation process leading to identification of: 1) multiple water uses in the Cheakamus and Squamish River systems[8]; and 2) means for achieving a "balance" between competing interests and needs.

Specifically, the committee agreed to recommend:

1. the most appropriate water flow regime (or range of regimes) for the facilities, considering allocation of water to different water uses (e.g., flood control, fisheries, power generation, First Nations, aquatic ecosystem 'health', recreation, cultural impacts);
2. any conditions, mitigation, or compensation to be associated with the identified regime(s);
3. criteria for a water use monitoring program; and
4. timing for periodic review of the Cheakamus Water Use Plan.

Structure

The CC was structured to represent all interests (Table 2.2). For interests with more than one representative, one member focused on province-wide issues and the other on local issues. The composition of the committee changed over the course of the WUP process as some seats were filled, new seats were added, some members resigned and were replaced, and some members switched to observer status and were not replaced. Table A1.1 in Appendix 1 provides details of consultative committee

[8] The initial focus for the Squamish was potential flooding, erosion and stranding of juvenile fish below the powerhouse. However, the focus shifted to the Cheakamus River because diverted powerhouse flows had little influence on Squamish River flows and the Fisheries Technical Committee found no evidence of stranding for juvenile fish. However, further investigation of juvenile stranding below the powerhouse is a component of the monitoring plan.

turnover and attrition. The committee strove for consensus, with equal weights given to the opinions of each representative. Consultation was supplemented by field trips, expert presentations, a Fisheries Technical Committee and a Power Studies Technical Committee. A Facilitator was hired to assist the Consultative Committee through the consultative process. Details of the structure and responsibilities of each committee are provided in Appendix 1.

Table 2.2: Cheakamus WUP Consultative Committee composition.

Group	**Representatives**
Fisheries and Oceans, Coast Guard (CCG)	1
Fisheries and Oceans, Water Use Section (DFO)	1
Ministry of Water, Land and Air Protection (WLAP)	1
District of Squamish (DoS)	1
BC Hydro (BCH)	2
Ministry of Energy and Mines (MEM)	1
Squamish Lillooet Regional District (SLRD)	1
Squamish Residents (SR)	1
North Vancouver Outdoor School (NVOS)	1
Ministry of Sustainable Resource Management (MSRM)	1
Squamish Nation (SN)	1
Sierra Legal Defense Fund (SLDF)	1
Squamish River Watershed Society (SRWS)	1
Cheakamus Residents (CR)	1
Angling: Whistler Angling Club (WAC), Steelhead Society (SS), Totem Fly Fishers (TFF)	3
Resort Municipality of Whistler (RMW)	1
Outdoor Recreation Council of BC (ORC)	1

2.2.2 Consultative Committee Meetings

The consultation process consisted of a series of 25 facilitated meetings from June 1999 to January 2002. Table 2.3 lists dates of each meeting, the WUP step it addressed, and the topics discussed.

Table 2.3: List of facilitated Consultative Committee meetings. This table indicates the meeting number, date, associated WUP step and purpose. The far right column indicates whether meeting notes are available on the enclosed CD-ROM. List abbreviations: FTC, HOPSC.

#	Date	WUP Step	Purpose	Notes
SC1	April 15, 1999		Pre-announcement meeting of *ad hoc* "steering committee"	✓
SC2	May 6, 1999	2	Pre-announcement meeting of *ad hoc* "steering committee", preliminary definition of issues Draft CC Terms of Reference	✓
1	June 23, 1999	3	Inaugural CC meeting: 1) Design and operation of CC; 2) Review of recent activities; 3) Discuss summer work	✓
2	June 28, 1999		1) Introduction to technical approach (decision analysis, resource valuation, adaptive management); 2) Review of work program	✓
3	September 15, 1999	4	1) Review of summer activities; 2) Draft of CC "Master Plan"; 3) Overview of approach to developing and assessing alternatives (Smart Choices: "PrOACT"); 4) Begin selecting issues and defining objectives.	✓
4	October 4, 1999	4	Issues and objectives.	✓
5	October 18, 1999		Issues and Objectives – focus on fisheries.	✓
6	November 1, 1999		Finalize list of objectives; Develop performance measures.	✓
7	November 15, 1999	5	Expert presentations on geography, hydrology, power studies, geodynamic and hydrodynamic process relevant to fish; FTC work.	✗
8	November 29, 1999		Review fundamental objectives; Define means objectives and performance measures; Define mandate for FTC and HOPSC.	✓
9	December 13, 1999		Establish technical committees; Determine supplemental data and information required; Discuss draft fundamental objectives (7 of them).	✓
10	January 10, 2000		Confirm consensus on the fundamental objectives; Presentation on Cheakamus flooding.	✓
11	January 24, 2000		Flooding presentation; FTC update (Impact Hypothesis (IH) workshops); HOPSC update; Constraints on operations.	✓
12	February 7, 2000		Fluvial geomorphology and fish habitat; Tenderfoot Hatchery; Tour of NVOS hatchery.	✓
13	March 20, 2000		Introduce new CC members; HOPSC report; SFN heritage and cultural values; Fish and aquatic ecosystem presentation.	✓
14	April 3, 2000		Candidate PMs; Subgroup discussions to develop PMs for recreation and flooding.	✓
15	May 1, 2000		BC Hydro Operations and Finances; Review list of PMs; Discuss Draft Fundamental Objectives and PMs.	✓
16	May 29, 2000		Presentation on Cheakamus Hydrology; Draft letter to FTC.	✓
17	June 26, 2000		Presentations by FTC: Impact hypotheses, studies and models; Schedule; Flow diagram of process; Summary of relevance of Cheakamus literature to fisheries.	✓

#	Date	WUP Step	Purpose	Notes
18	October 23, 2000	6	Modelling water management alternatives; Methods for comparing alternatives; Hands-on trade off analysis; Developing alternatives.	✓
19	April 30, 2001		Confirm performance measures for fundamental objectives 1-4 (power, SFN, recreation, flooding); Confirm performance measures for fundamental objectives 5-6 (fish, aquatic ecosystems); Example tradeoffs.	✓
20	May 28th and 29th, 2001		Scope of Consultative Report; Clarification of alternatives; Review of performance measures; Decisions on alternatives (features worth carrying forward, which alternatives should be retained and which should be dropped, new alternatives to be examined); Schedule.	✓
21	July 3rd and 4th, 2001		Review of items from the May28th-29th meeting; Update and review of results for current set of alternatives; Review of performance measures; rating of alternatives; Decisions on alternatives; Other CC decisions; Schedule.	✓
22	September 7, 2001	7	Review of items from the July 3rd and 4th meeting; Update and review of results for current set of alternatives; Review of performance measures; Rating of alternatives; Decisions on alternatives; Other CC decisions; Schedule.	✓
23	October 4th, 2001		Review of items from the September 7th meeting; Update and review of results for current set of alternatives; Review of performance measures; rating of alternatives; Decisions on alternatives; Other CC decisions; Schedule.	✓
24	October 24th, 2001	7	Review: results and final 4 alternatives selected at October 4th meeting; consensus proposal from previous meeting, a table of concerns, and draft CC recommendations; and several hybrid alternatives within the range of the final four selected on October 4th. Rating of alternatives: Consensus not achieved, but CC defined two most preferred alternatives: 15-20Min3-7Dam, 20Min7Dam.	✓
25	January 11 2002	8	Develop final CC recommendations for an operating alternative, a monitoring plan and other activities; Outline areas of agreement and disagreement with respect to these recommendations.	✓

2.2.3 Consultation Support

Facilitation Team

Both the CC and the BC Hydro Project Team collaboratively selected the Facilitators (ESSA Technologies Ltd.). They provided the CC with expertise in facilitation and decision analysis. This included:

- training the CC in decision and trade-off analysis;
- developing and applying models to generate performance measures, based on inputs from the CC, FTC and HOPSC; and
- preparing meeting materials, meeting summaries and this report.

Similar facilitation and technical services were provided to the Fisheries Technical Committee. There was a change in the primary lead in CC facilitation from D. Bernard to D. Marmorek at the May 28th/29th 2001 CC meeting.

Fisheries Technical Committee

At the request of the CC, a multi-stakeholder Fisheries Technical Committee (FTC) was formed to evaluate issues and identify data gaps related to the Fish and Aquatic Ecosystem. The FTC conducted two years of field research to gather data necessary to develop models that calculated fish performance measures as a function of river flow. The committee had representatives of the Provincial and Federal governments, BC Hydro, Squamish Nation, Sierra Legal Defense Fund and the Steelhead Society. The FTC Mandate is in Appendix 1 (Section A1.2). Results of the FTC's work are contained in Appendices 2, 3, and 4, as well as the enclosed CD.

Hydro Operations and Power Studies Committee

The Hydro Operations and Power Studies Committee (HOPSC) developed the input data and models required for simulating alternative operating regimes at the Daisy Dam. Additionally, they provided educational presentations to the Consultative Committee on Cheakamus operations for the generation of power and flood mitigation and had a representative on hand at CC meetings to answer questions and elaborate on the results of hydro modelling. HOPSC was somewhat disbanded after one of its members, Barry Chilibeck, left DFO. The work was carried out by Power Supply Engineering acting on behalf of Resource Management (also Power Supply). An independent reviewer (Peter Ward) initially selected by HOPSC was retained for the duration of the WUP. The HOPSC mandate is in Appendix 1 (Section A1.3). Results of the HOPSC's work are described in the *WUP Hydro Operations Report* (BCH 2002a).

Educational presentations

The Consultative Committee also requested presentations by local experts to learn more about the Cheakamus River system. These presentations helped the CC through Step 5 of the WUP process (Collecting data on water use impacts). Section 4 elaborates on the content and information acquired from these presentations.

2.2.4 Squamish Nation Participation

The Cheakamus hydroelectric generating facilities fall within the northern part of Squamish First Nation traditional territory. They also have two reserves (IR 11 and 13) which front on the Cheakamus River, downstream of the facility. In the months prior to the initiation of the WUP their leadership had communicated to Hydro a strong interest in participating. Squamish had been involved in the process leading to the interim flow agreement and communicated its desire to play a role in the impending WUP.

The other First Nation with a potential interest in the WUP was the Lil'wat First Nation of Mt. Currie. The southern portion of their territory runs to the immediate north of Daisy Reservoir. They were contacted prior to the WUP initiation but declined because operational changes as a result of the WUP cannot impact their territory.

Squamish Nation participated from the outset, taking part in the pre-WUP Steering Committee, touring the facilities and river, and attending the early pre-scoping meetings with other community interests. The current chief was informed of these activities and attended some early meetings. Prior to formal initiation he assigned a staff resource, Randall Lewis, to manage the nation's interests. Randall remained as the representative on the CC throughout its entirety.

Two of the nation's consultants – a fisheries biologist and engineer – played a key role in an advisory capacity. The fisheries consultant, Brent Lister, participated as a full member of the Fish Technical Committee throughout its entirety. This included having input into study selections, terms of reference, interpreting and communicating results. Mr. Lister attended many of the CC meetings; particularly those concerned with fish interests and trading alternatives. The engineering consultant, Mike Currie (Kerr Wood Leidal Associates Ltd.), participated on an "as required" basis. He attended early meetings, for familiarity with the process, and later reviewed the geomorphology information gathered to address Squamish heritage interests. Like Mr. Lister, he also attended subsequent meetings where operating alternatives were considered by the CC.

A cross cultural training session for the CC was held at Totem Hall (Squamish Nation) on October 13, four months after the WUP was initiated. It included a trainer from Hydro, who worked in concert with a councillor from Squamish Nation to develop the material and background for the session. During the session the councillor provided the CC with a component specifically designed to educate the CC around Squamish traditions and interests in the Cheakamus watershed.

Squamish Nation's chief and governing council were kept informed throughout the process. During the initiation phase three members from Hydro's process team (the project manager, aboriginal consultation manager and community relations manager) attended a council meeting to review the WUP process guidelines and present the consultation plan. In November 2001 its representatives and advisors gave the council a full briefing. In addition, numerous meetings throughout the process took place with the chief to update him regarding key milestones such as identifying objectives, performance measures and studies. The CC distribution list for all meeting minutes, notices and information included the Squamish chief and councillor responsible for overseeing their participation in the WUP.

3.0 Issues, Objectives, and Performance Measures

In Step 4 of the water use planning process, the consultative committee (CC) took the issues and interests confirmed by the group and expressed them in terms of specific objectives and performance measures. In defining the objectives, the participants articulated what they were seeking to achieve through a change in operations. The performance measures developed by the CC provide the tools to assess the degree to which alternative operating regimes achieve the objectives.

This section summarizes objectives and corresponding performance measures for the Cheakamus WUP. A more detailed description of the interests, objectives and performance measures, and how they were calculated, is found in the associated appendices.

3.1 Objectives (Step 4)

The CC reviewed the preliminary issues gathered by the steering committee (Table 2.1) and built upon them to create six fundamental objectives that captured the values the issues represent (not listed in order of importance):

1. Power: Maximise economic returns from power generated at Cheakamus Generating System.
2. First Nations: Protect integrity of the Squamish Nation's heritage sites and cultural values.
3. Recreation: Maximise physical conditions for recreation.
4. Flooding: Minimise adverse effects of flood events through operation of the Cheakamus Generating system.
5. Fish: Maximise wild fish populations.
6. Aquatic Ecosystem: Maximise area and integrity of the aquatic and riparian ecosystem.

The FTC expanded objectives 5 and 6 into a set of means objectives (Table 3.1, see also Appendix 4,). The CC asked that 6 be separated into 6a, Aquatic Ecosystem and 6b Riparian Ecosystem because no performance measures were developed for the riparian ecosystem on the advice of the FTC ("CC meeting April 30th, 2001.pdf").

Squamish FN submitted a list of fundamental objectives for the process (January 7, 2000). Later, they endorsed the six fundamental objectives listed above for the consultative committee as a whole. Throughout the process they made it clear that their primary interests were in protecting fish stocks and their cultural heritage. Their interests in fish, on a technical level, were assigned to Brent Lister, who participated on the FTC and in all the subsequent studies. The results of the FTC work were communicated to the SFN representative and leadership periodically outside the CC process.

The Squamish FN's other primary interest was the protection of their culture and heritage. This interest was embodied in the second objective: "Protect the integrity of Squamish First Nation's heritage values and cultural sites". In February 2000 Randall Lewis met with Cam Matheson, their consultant (Mike Currie, Kerr Wood Leidal Associates Ltd.) and the CMS WUP facilitator at that time, David Bernard, to determine how to achieve this objective. All agreed that information gathering should focus only on those interests that could be potentially impacted by changing BC Hydro operations or those currently being impacted.

Performance measures were developed for each of these fundamental objectives (Table 3.1).

Table 3.1: The objectives and performance measures considered by the Cheakamus WUP Consultative Committee. The grey shaded rows (Objectives #6b riparian ecosystem and #7 Learning) were not explicitly addressed by the CC through performance measures.

Objective	Fundamental Objective	Performance Measure (units)
1 Power	Maximise economic returns from power generated at the Cheakamus Generating System	(a) Average annual power revenue over 32 water years ($). (b) Average annual power production (GWh) (c) Average annual greenhouse gas emissions reduction (CO^2 ktonnes/yr)
2 First Nations	Protect integrity of Squamish First Nation's heritage sites and cultural values	Level of protection of ancestral burial grounds and culturally important locations (erosion / flooding index)
3 Recreation	Maximise physical conditions for recreation (rafting, kayaking, sportfishing, general)	(a) Average number of days during the rafting season (June to August, December to February) that the Brackendale gauge reads between 34.9 cms (0.9 m) and 450 cms (2.7 m) (days) (b) Average number of days during the kayaking season (April to September, December to January) that the Brackendale gauge reads between 19.4 cms (0.7 m) and 450 cms (2.7 m) (days) (c) Average number of days in the sport fishing season (mid March to 1 May; August to December) that the Brackendale gauge reads between 19.4 cms (0.7 m) and 68.4 cms (1.2 m) (days) (d) Average number of days year round the Brackendale gauge reading is between 5 cms and 68.4 cms (1.2 m).
4 Flooding	Minimise adverse effects of flood events through operations	# days over 32 water years with Brackendale flows > 450 cms. As modelled, none of the current operating alternatives under consideration have flows that exceed the flood criterion of 450 cms at Brackendale.
5 Fish	Maximise wild fish populations	(a) Area (m^2) of anadromous juvenile rearing habitat in the Cheakamus River below Daisy Dam for chinook, coho, and steelhead (RUA, WUA methods). (b) Area (m^2) of resident rainbow trout juvenile rearing habitat in the Cheakamus River below Daisy Dam (RUA method only). (b) Effective spawning area (m^2) in the Cheakamus River below Daisy Dam for steelhead, chinook, coho, and chum salmon, taking into account egg stranding (m2 that remains wetted from spawning to hatch). (c) Potential adult migration problems, Avg. # days in 32 water years < 10 cms at Brackendale during migration.
6a Aquatic ecosystem	Maximise area and integrity of the aquatic ecosystem	Average spring and summer riffle benthic biomass (g x 10^6). Biomass estimates are for representative anadromous reaches (reaches 1, 7 and 8 in Figure 1.2) and a representative resident reach (reach 11 in Figure 1.2).
6b Riparian ecosystem	Maximise area and integrity of the riparian ecosystem	No PM developed on advice of FTC.
7 Learning	Promote learning about system to improve quality of monitoring and plan review	Reduction in uncertainty associated with long term decisions on operating procedures (low to high)

3.2 Performance Measures

In conjunction with HOPSC and FTC, the CC developed performance measures (PMs) to assess how well different operating alternatives met the objectives (Table 3.1). A short description of each performance measure is presented below. Appendix 2 contains detailed summaries of all performance measure except Value of Energy and GWh, which are described in the *WUP Hydro Operations Report* (BCH 2002a). Appendix 4 also contains details about the development and calculation of the fish and aquatic ecosystem PMs.

Power

The Power objective used three performance measures: annual average Value of Energy ($/year), power production (GWh/year), and Greenhouse Gas Reductions (tonnes/year). These PMs are all derived either directly or indirectly from megawatts (MW) a standard output of the hydro operations model (Section 5). Thus they provide the same information in different units.

First Nations

Squamish Nation developed a PM to address the level of protection provided to ancestral burial grounds and culturally important locations. After identifying the appropriate sites in an archaeological overview (Arcas 2001), this PM was assessed by examining the flood risk to the sites under the two most extreme alternatives (Power Optimal and Pass All Inflows) (NHC 2000b). The results showed that the sites were vulnerable to flows above 450 cms at Brackendale; therefore the flood PM could be used to address this important interest. Section 4.2 describes the information gathering and learning that led to this conclusion.

Recreation

The CC developed PMs for four recreational components: rafting, kayaking, sportfishing and general recreation (e.g., hiking and birdwatching). These were quantified as the average number of "access days" over 32 water years. A limited data set allowed only a subjective rating of rafting quality at different flows, and these data showed substantial variability in the flows associated with a good quality rafting experience. No data were available to develop a relationship between other types of recreational activities and flow, so the CC used their best judgement to define flow ranges at the Brackendale gauge that provided optimal access to or use of the river for each activity. The rafting season was composed of two periods: June to August and December to February. Optimal rafting occurred when the Brackendale gauge read between 34.9 cms (0.9 m) and 450 cms (2.7 m). The kayaking season was also broken into two periods: April to September and December to January. Optimal kayaking was assumed to occur when the Brackendale gauge read between 19.4 cms (0.7 m) and 450 cms (2.7 m). The sportfishing season ran from mid March to 1 May and from August to December. Optimal sportfishing access occurred over flows at the Brackendale gauge between 19.4 cms (0.7 m) and 68.4 cms (1.2 m). Several CC members were concerned with the 'knife-edge' nature of these PMs: flows of 19 cms are not considered suitable for sportfishing or kayaking, while flows of 20 cms are. This can lead to large jumps in the value of these PMs around 20 cms.

Flooding

Flooding occurs when flows carry over the top of natural banks. This occurs for flows greater than ~450 cms at the Brackendale gauge; therefore, the flooding PM is the number of days within the 32 year water record where the flow would exceed 450 cms bankfull capacity. All of the alternatives considered by the CC apply BC Hydro's current precautionary flood management practices: target reservoir elevations are decreased during the months of October to December; and pre-spilling up to the bankfull capacity occurs in response to inflow forecasts. Applying these constraints within the model results in none of the operating alternatives exceeding the flood criterion. This modelling outcome is due to the fact that the Hydro operations model has perfect knowledge of the next 5 days of inflows and pre-spills appropriately in advance of storm events to keep the maximum Brackendale flows from exceeding 450 cms. Such perfect knowledge doesn't exist in the real world. The current flood management practices do mitigate flood impacts for small to moderate sized inflow events, but there are 6 events in the 32 year record where flooding would likely occur ("21_CC Meeting Notes July 3_4, 2001.pdf"). All of the alternatives considered by the CC apply current precautionary management practices during the months of October to December (BCH 2002a and Box 2 in Section 5.2).

Fish

The FTC developed several fish performance measures for different species and lifestages (see FTC performance measures summaries in Appendices 2 and 4):

(a) Usable area (m^2) of *juvenile rearing habitat* in the Cheakamus River below Daisy Dam for the parr stage of *chinook* and *coho* and the fry and parr stages of *steelhead.* This PM includes the mainstem river and naturally connected off channel habitat, but does not consider the engineered side channel habitat behind the dykes that protect the North Vancouver Outdoor School. Changes in usable area under different flow conditions were modelled using data from two independent methods developed by the FTC: 1) rated usable area (RUA) and 2) weighted usable area (WUA). The RUA method relies on measurements of stream habitat at different flows, juvenile fish density measured in different habitats and statistical analyses plus expert judgement of the species specific habitat preferences of juvenile fish. The WUA method relies on channel morphology and its influence on water depth and velocity in relation to habitat suitability indices (developed by expert judgement and data from other rivers) for each species and life stage.

(b) Usable area (m^2) of *resident juvenile rearing habitat* in the upper reaches of the Cheakamus River below Daisy Dam for the fry and parr stages of *resident rainbow trout* for the mainstem river and naturally connected off channel habitat. This PM does not consider engineered side channel habitat. Only the RUA method was used to calculate this performance measure, assuming that rainbow trout fry and parr have the same habitat preferences as steelhead. The majority of the FTC considered the parr stage to be the most important stage because fry rearing habitat is generally not limiting.

(c) *Effective spawning area* (m^2) in the Cheakamus River below Daisy Dam for *steelhead*, *chinook*, *coho*, and *chum* salmon for all potential spawning habitat within the mainstem river (e.g., areas of upwelling, riffles) and connected off channel habitat. This PM did not consider engineered side channel habitat. This PM takes into account both the spawning habitat preferences of each species and the risk of stranding eggs during the sensitive part of the incubation stage (m^2 that remains wetted from spawning to hatch). The FTC considered that the PM probably overestimated the effective spawning habitat for each species.

(d) Risk of potential problems during *adult upstream migration* (Avg. # days in 32 water years): indicated by flow < 10 cms at the Brackendale gauge during each species upstream migration period. This was calculated for *chinook*, *chum*, *coho*, and *steelhead*.

The results obtained using the above fish PMs were generally consisten with those obtained by Ron Ptolomy (WLAP) using empirically derived percentages of mean annual natrualized discharge for rearing, spawning and migration.

Daisy Lake Reservoir Fish PM

The FTC recommended that the CC not include performance measures for fish populations in the Daisy Lake Reservoir because it is the Barrier Civil Defense zone where no fishing or recreation can legally take place. The CC generally agreed, but reserved the right to call upon the FTC for qualitative evaluation of impacts on reservoir fish populations in future. The FTC indicated that no new field data would be required for such an analysis, since the hydro operations model generates values for reservoir levels, and some data already exist on the fish species found in the reservoir. The CC agreed that, if required, such qualitative analyses would be acceptable. ("13_CC Meeting Notes March 20 2000.pdf").

Hatchery Fish PM

The FTC recommended the CC not develop a PM related to hatchery fish as this contradicted the fundamental objective of producing wild fish. The CC accepted this recommendation. ("13_CC Meeting Notes March 20 2000.pdf").

Pink Salmon PM

The FTC recommended that Pink salmon not be directly considered for PM development because their success in the river appears to be related to a lack of suitable small gravel spawning substrate rather than the adequacy of flows. Channel morphology and hydrology studies showed that substrate availability is not likely to improve with flow management practices at the dam, and is therefore not a WUP issue (Appendix 4, Section A4.3.7). Despite the rationale provided by the FTC, some CC members (NVOS, SFN, and SRWS) remained concerned that pink salmon were not considered by the FTC.

Aquatic Ecosystem

Benthic Biomass

The only PM used for the Aquatic Ecosystem objective was the average riffle benthic biomass (g x 10^6) during the spring and summer seasons. Biomass estimates represent total riffle areas in representative anadromous reaches (reaches 1,7 and 8 in Figure 1.2) and a representative resident reach (reach 11). The model used to generate these PMs was developed from Chris Perrin's periphyton and benthos monitoring data (Perrin 2001). This PM serves as a measure of food availability for fish and wildlife populations that rely on stream invertebrates.

Species at Risk

To determine the existence of any species at risk in the Cheakamus watershed, a general survey of species was conducted for the overall WUP Program (Robertson et al, 2001). Robertson et al searched both the federal (Committee for the Status of Endangered Species in Canada (COSEWIC)) and provincial (Conservation Data Centre (CDC)) data bases. Unfortunately, the level of detail in these data bases is sufficient only to provide data for the larger Squamish River watershed. Additionally, only the presence of species at risk is noted; discrete habitat sites are not identified. It is therefore difficult to conclude whether the species are found in the Cheakamus watershed and if so, whether they might be adversely affected by dam operations. Box 1 lists the species categories reported for the Squamish River watershed:

Box 1. Species categories listed for the Squamish River watershed for the Province wide WUP Program

Priority 1 COSEWIC Endangered and Threatened

- Marbled Murrelet *Brachyramphus marmoratus*
- Spotted Owl *Strix occidentalis*

Priority 2 COSEWIC Vulnerable and CDC red listed species

- Cisco (lake herring) *Coregonus artedi*
- Purple Martin *Progne subis*
- Grizzly Bear *Ursus arctos*
- Ken's Long-eared Myotis *Myotis keenii*

Priority 3 COSEWIC species under assessment and CDC blue listed species

- Tailed Frog *Ascaphus truei*
- Double-crested Cormorant *Phalacrorax auritus*
- Great Blue Heron *Ardea herodias fannini*
- Hutton's Vireo *Vireo huttoni*
- Peregrine Falcon anatum subspecies *Falco peregrinus anatum*
- Wolverine luscus subspecies *Gulo gulo luscus*
- Rubber Boa *Charina bottae*

Benthic Aquatic Community PM

The FTC recommended against developing a performance measure specifically for integrity of the benthic aquatic community because integrity is a generic term and difficult to set up as PM to evaluate alternatives. The CC accepted this recommendation. ("13_CC Meeting Notes March 20 2000"). The FTC did however recommend developing a PM for benthic biomass (related to fish food availability), and the CC accepted this recommendation at their April 30th, 2001 meeting.

Riparian Ecosystem PM

The FTC recommended that a riparian PM not be developed due to the presence of dykes. The FTC felt that since higher flows will not improve riparian vegetation in most reaches because this water will not reach the original floodplain. Therefore, the FTC believed that a Riparian Ecosystem PM would be misleading (Summary of PMs, Appendix 4, Section A4.3). Furthermore, the flooding PMs indicate that the frequency of moderately high to high flows seems pretty well unaffected by operating alternatives in the Cheakamus River; they are driven mostly by year to year climatic variability.

3.3 Consideration of Variability and Uncertainty

Variability

Variability in performance measures and hence the year-to-year ability of an alternative to meet its target constraints was assessed by driving the Hydro Operations model (Section 5) with 32 water years of historical reservoir inflow and downstream reach inflow data.

Variability in the year-to-year performance measures was calculated using the output from the Hydro operations model. This output included 32 water years of turbine flows, reservoir elevations, dam releases and flows at the Brackendale gauge, as simulated for the particular alternative.

Most performance measures were summarized using only the average or median annual value over 32 water years. However, for the fish and aquatic ecosystem performance measures, variability in annual estimates was shown using the 10^{th} and 90^{th} percentiles over 32 water years.

Uncertainty and Sensitivity Analyses

The results included uncertainty from several sources: data uncertainty (e.g., historical inflow data); model uncertainty (e.g., response of wetted area to flows above and below air photo flows); and poorly understood relationships (e.g., rafting activity vs. flow). The CC and the FTC identified several important unknowns throughout the WUP process that could influence future decisions, but were unable to resolve these uncertainties due to either the limited scope and time of the WUP process, or the lack of data from which to develop flow-dependent PMs. For example, there are gaps in our understanding of how mainstem flow conditions affect fish production in groundwater fed side channels. With the approval of the CC, the FTC developed a monitoring plan to address these uncertainties (Section 7.1).

Where possible, the impact of uncertainty on performance measures was evaluated through sensitivity analysis. Both the HOPSC Hydro operations model and the FTC Fish PM models were subjected to intensive sensitivity analyses.

HOPSC Hydro Operations Model Sensitivity Analyses

Comparison of historic versus simulated generation indicated a systematic bias attributable to estimates of turbine efficiencies. Sensitivity tests conducted with several years of corrected inflow data indicated that the bias in the data had a negligible impact on the simulation of project operation in terms of satisfying minimum flows and flood operation. However, the systematic bias did affect the calculation of power generation when the biased data was run through a model that is calibrated with a more recent turbine efficiency curves. To compensate, generation and corresponding Value of Energy (VOE) determinations were reduced by 10%. With the 10% reduction applied, the generation values for historical and IFA flow scenarios run through the model compare favourably to actual historical generation data.

FTC Fish PM Model Sensitivity Analyses

The FTC conducted very detailed sensitivity analyses for all PMs. For example, the FTC found the initial Fish RUA rearing PM results counterintuitive because higher flows did not necessarily produce more juvenile rearing habitat. To understand this result, the FTC conducted a series of sensitivity analyses to understand model behaviour:

- RUA wetted area curves: Calculation of the rated useable area (RUA) fish habitat PM required estimating RUA wetted area for flows beyond the range of field measurements. The FTC examined several methods and found that the PM results were especially sensitive to the method used to estimate RUA at flows associated with a dam release of less than 5 cms. The FTC eventually decided to use the River2D model to predict wetted area for flows less then 5 cms since River2D predicted wetted area based on detailed field measurements of channel morphology.
- Influence of tributary inflows: To further explore the influence of tributary inflows, the FTC calculated juvenile rearing PM results without adding the cumulative reach inflows to the modeled dam release. Although unrealistic (i.e. this scenario assumes all tributary inflows are eliminated), this caused the RUA PM to be more sensitive to flow. That is, higher flow alternatives had significantly higher rearing areas than lower flow alternatives. These results clarified the important role that tributary inflows have in mitigating the impact of low dam releases on salmonid rearing habitat.

- Tributary inflow data set: Flows below the dam are modelled as the sum of the dam release and tributary inflows. The FTC found the Fish PMs to be most sensitive to the range of flows below those with a 5 cms dam release. However, flows were generally greater than this due to the influence of tributary inflows. Therefore the HOPSC and FTC scrutinised the assumptions used to prepare the cumulative reach inflow data set. The primary cumulative reach inflow data set prepared by HOPSC required many assumptions to fill gaps in sub-basin runoff data (BCH 2002b). Therefore, the HOPSC prepared a second inflow data set using alternative assumptions to estimate flows in the upper reaches of the river (BCH 2002b). The FTC found little difference between the results calculated using the two inflow data sets. In general, the new inflow data were slightly higher than the primary inflow data and therefore moved river flows further into the non-sensitive area of the wetted area curves. The PM results were virtually identical. The FTC concluded that the original inflow data set was adequate for assessing the performance of the Fish PMs across alternatives.

- Relative performance of RUA vs. WUA: The FTC used two independent methods for estimating the response of fish rearing habitat to flow. The rated usable area (RUA) method used air-photo measures of wetted area at different flows. The total wetted area was then divided into habitat-types using air photo interpretation and each habitat type was rated according to fish preference using expert judgement. The FTC supplemented these preference ratings by sampling different habitat-types during the summer rearing period to determine usage by species and lifestage. The weighted usable area (WUA) method used two-dimensional modeling of the river channel to produce estimates of wetted area at flow and estimates of depth and velocity. Fish preferences for these combinations of depth and velocity were described by species and lifestage Habitat Suitability Index curves developed by the FTC from the literature and data from other systems. The RUA and WUA methods produced PMs that responded similarly across flow alternatives. Additionally, the results of these two methods were consistent with a previous methodology developed by Ron Ptolemy (WLAP), as noted above in Section 3.2.

4.0 Information Gathering

During the process of identifying issues and structuring objectives, the CC, HOPSC and FTC identified knowledge gaps that impaired the development of performance measures upon which to base operational decisions. A number of studies were undertaken to fill these gaps and improve the knowledge base of the Cheakamus River system and allow development of performance measures (WUP Step 5). The following sections provide a brief summary of this process:

- **Section 4.1** describes the information gathering required to develop the Hydro Operations model used to produce the Value of Energy, Power performance measures.
- **Section 4.2** describes the information gathering conducted by the Squamish Nation to develop a PM that could be used to assess the risk to heritage sites and cultural values.
- **Section 4.3** describes the information gathering process for preparing the Flood PM.
- **Section 4.4** describes the work the FTC did to develop the Fish PMs. This includes the process they used to identify key uncertainties and prioritise studies, the sensitivity analyses used to test and understand the Fish PM models and the key learning that came out of their research that was important for evaluation operating alternatives. The FTC work was the most time consuming component of the information gathering process, requiring two field seasons and several months of analyses and model development.
- **Section 4.5** describes the work the FTC did to address the Aquatic and Riparian Ecosystem PMs.
- **Section 4.6** describes what and why certain information was not pursued. Section 4.7 summarises educational presentation topics for the CC and summarises key learning points from those presentations that influenced evaluation of operating alternatives.

4.1 Power

The following information was required for configuring the Hydro Operations Model:

Historic Daily Natural Inflows Upstream of Daisy Dam

This data was extracted from BC Hydro's Plant Data Storage System (PDSS) and quality controlled prior to input to the model as described in the WUP Hydrology and Inflows report (BCH 2002b).

Historic Cumulative Daily Natural Inflow Between Daisy Dam and the Brackendale Gauge

This data set was calculated using historical PDSS Daisy Lake Spill data and Water Survey of Canada (WSC) Gauge No. 08GA043 at Brackendale data as described in the WUP Hydrology and Inflows report (BCH 2002b).

System configuration and component characteristics

This information includes Daisy Lake storage relationships, Daisy Dam discharge facility rating curves, average tailwater elevation and characteristics of the Cheakamus Generating station. This information was available within BC Hydro's data storage systems.

Operating Constraints

HOPSC reviewed the existing System Operating Order (SOO 4P-25, 06/1999) to identify physical operating constraints that needed to be incorporated into the model.

Value of Energy determinations followed standardized procedures developed for the Water Use Planning Program and as previously agreed to with the BC Provincial Government. No project specific information gathering was required.

4.2 First Nations

A primary interest of the Squamish FN was the protection of their culture and heritage. This interest was embodied in the second objective: “Protect the integrity of Squamish First Nation’s heritage values and cultural sites”. In February 2000 Randall Lewis met with Cam Matheson, the Squamish Nation geomorpological consultant (Mike Currie, Kerr Wood Leidal Associates Ltd.) and the CMS WUP facilitator at that time, David Bernard, to determine how to achieve this objective. All agreed that information gathering should focus only on those interests that could be potentially impacted by changing operations or those currently being impacted. The following process was agreed to:

1. Identify relevant sites on the lower Cheakamus River.
2. Assess those sites in terms of geomorphology to determine their vulnerability to a change in operations.
3. Using this information, create performance measures so the interests can be factored into the selection of alternatives by the Squamish Nation and other members of the CC.

It was agreed that an archaeology overview should be conducted for the lower Cheakamus River to identify sites in need of protection. It was also agreed that such information should be confidential, unless otherwise released by the nation. Squamish requested Arcas Consulting be used to conduct the overview and they were subsequently hired. The overview was completed in the summer of 2000, and included interviews with Mr. Lewis and other members familiar with cultural practices on the lower Cheakamus.

The overview identified seven sites with the potential to be impacted (Arcas 2001). Of these, four were either clearly above the high water mark, or impacted by the Squamish River’s mainstem. Squamish First Nation thus narrowed this list to three. A geomorphologist (Northwest Hydraulics) was hired to assess these sites in terms of their vulnerability to flooding and erosion. On November 1, 2000 the consultant visited these sites with Randall Lewis and Cam Matheson. On December 6 2000 the report was submitted for review (NHC 2000b). Mike Currie reviewed the report and subsequently agreed with its conclusions.

The report and its conclusions were shared with Mr. Lewis. It became clear that a set of performance measures to protect these sites could not be distinguished from the flood PMs. In other words, they were not sensitive to river flow alternatives below flooding events and would therefore not be of assistance to the CC in selecting alternatives. It was decided that the flood PMs would best address this important Squamish Nation interest.

4.3 Flood

A considerable amount of information pertaining to floods existed for the Cheakamus project prior to the initiation of the WUP. No further information gathering was required specifically for the WUP. “Flooding” was defined as flows that exceed the bankfull capacity of the lower Cheakamus River which equates to flows greater than 450 cms at the Brackendale gauge (BCH SOO 4P-25, 06/1999).

4.4 Fish

The FTC used a two-stage process to identify information needs and prioritize studies. First, preliminary studies were conducted to identify where the fish were in the system. Second, the FTC used an impact hypothesis (IH) approach to identify key uncertainties and data gaps associated with the fish objectives described in Table 3.1 (Appendix 4, Marmorek and Parnell 2000). The FTC used the results of the IH exercise to prioritize further fisheries studies to gather information for the development of fish performance measures. Prioritization considerations included the ability to complete a study within the available timeframe and budget. The FTC then recommended the prioritized studies to the Consultative Committee who accepted the FTC's recommendations. Table 4.1 summarizes the impact hypotheses, the conclusions drawn by the FTC for these hypotheses, the rationale for these conclusions, remaining uncertainties, the associated studies and recommendations. Appendix 3 contains summaries for each study The FTC impact hypothesis summaries that were prepared for the Consultative Committee are shown in Appendix 4 (Section A4.2).

Key learning from FTC studies and modeling:

- Dam operations do not affect mainstem juvenile rearing area. Two independent methods for calculating juvenile rearing area in relation to flow gave similar results; the cumulative weighted usable rearing area was relatively insensitive to flows greater than those associated with a 5 cms release from the Dam. This finding agrees with previous work by WLAP prior to the Cheakamus WUP process and is due mainly to two factors:
    1. Tributary inflows augment low releases from the Dam. Particularly flow from Rubble Creek, which is fed by groundwater from Garibaldi Lake and thus maintains a relatively constant base flow throughout the winter low flow periods (5-8 cms).
    2. The confined nature of the river channel below Daisy Dam due to canyons, historical dyking and other works for flood and erosion protection built subsequent to the Dam means increased flows cannot spread out over the flood plain to create more juvenile rearing habitat.
- Dam operations may affect the amount of chum spawning habitat. Using historical chum escapement records, the FTC found chum to be the only salmon species limited by spawning area. The chum effective spawning area performance measure was highest for lower flow operating alternatives.
- Dam operations may affect the benthic community, but fish are not currently food limited in the main rearing areas. Field studies found that the Cheakamus benthic community was depressed immediately below the dam because it prevents the downstream movement of benthos, but that the community recovered quickly moving downstream. These studies also found a relationship between benthic biomass and two variables: flow and flow variability. However, the Cheakamus River is rich in nutrients relative to most coastal rivers due to the volcanic geology of its watershed with most nutrients below the Dam introduced through brought tributary inflow rather than from above the Dam. Additionally, fish stomach content analyses showed that the fish ate the same organisms sampled in the benthic studies. For these reasons, the FTC concluded that while flow may affect the benthic community, the fish rearing in the Cheakamus River are not food limited.

Table 4.1: Summary of FTC impact hypotheses, evaluations and recommendations. All hypotheses lead to impacts on wild fish production. The FTC "suspended" hypotheses that were important but for which there was currently not enough information for their evaluation, or for which information could not be gathered within the WUP timeframe. IF summaries in Appendix 4 (Section A4.2 list the full impact hypothesis, its status, rationale for the FTC evaluation, any key uncertainties, and FTC recommendations for each impact hypothesis.

Impact Hypothesis	FTC Conclusion	Rationale	Key Uncertainties	Studies	Recommendations
1. Dam Operations at the Cheakamus Facility affect the mainstem river geomorphology.	rejected	• minimal ability to manipulate high flows • inability to use dam operations to change sediment regime	• episodic nature of coarse sediment supply • pre-dam sediment contribution of watershed above Daisy Dam	**Northwest Hydraulic Consultants.** 2001. Analysis of Channel Morphology and Sediment Transport Characteristics of the Cheakamus River. Prepared for BC Hydro & Power Authority. 40 p. + App. *(completed)*	• augment sediment recruitment (e.g. ,move Rubble Ck. sediments • identify and prioritize existing floodplain areas for potential restoration • move or modify the Bailey bridge • promote side-channel development , remove dykes
2. Dam Operations affect the quantity and quality of the mainstem river spawning and rearing habitat.	accepted	• flows affect wetted area, depth, and velocity; in turn, habitat quantity and quality	• effect of daily flow variability on fish • effect of spawning flows on egg distribution • flow influences on overwintering survival • groundwater channel flow levels and fish production	**James Bruce RUA description** *(study completed)* **Barry Chilibeck R2D WUA description** *(study completed)* **Latitude Geographics Group Ltd.** 2001. Cheakamus river Water Use Plan: GIS Development and 2D Fish habitat Analysis. Prepared for BC Hydro. 57 p + app. *(completed)* **Melville, C.** 2001. Water Quality Monitoring on the Cheakamus River 2000. Final Report. 26 p. *(completed)* **Sneep, J.** 2001. Cheakamus River Juvenile Salmonid Distribution Assessment September 1999 to July 2000. 32 p. + app. *(completed)*	
3. Dam operations affect fish food supply.	accepted	• field study found relationship between benthic biomass and variables (flow and flow variability)	• extrapolation of study results to the entire stream cross section and to the flow levels above those studied	**Perrin, C.J.** 2001. Trophic structure and function in the Cheakamus River for water use planning. Report prepared by Limnotek Research and Development Inc. for BC Hydro and Resort Municipality of Whistler. 67p. *(completed)* **McIntosh, K.A. and I. Robertson.** 2001. Cheakamus Floodplain Ecosystem and Wildlife Overview. 26 p. + maps.	• none

Impact Hypothesis	FTC Conclusion	Rationale	Key Uncertainties	Studies	Recommendations
4. Dam Operations affect upstream migration and spawning distribution of adult salmonids and the outmigration timing of smolts.	rejected	• low flow threshold of 10 cms at Brackendale appears to be adequate during late fall and winter migration periods	• side channel accessibility at very low flows	**McCubbing, D. and C. Melville**. 2000. Chinook Spawning Migration in the Cheakamus river, Based on Radio Tracking in the summer of 1999. Prepared for BC Hydro by Instream Fisheries Consultants. 35 p. *(completed)* **McCubbing, D. and C. Melville.** 2000. Steelhead trout escapement monitoring on the Cheakamus River- an evaluation of the potential application of automated counter technologies utilizing radio tracking data from 2000. 31 p. *(completed)* **Golder Associates Ltd.** 2000. Salmon distribution in the Lower Cheakamus River, B.C.: BC Hydro Water Use Plan. Report 002-1742. 7 p. + app. **Korman, J. and R. Ahrens.** 2001. Escapement Estimation of Winter-Run Steelhead on the Cheakamus River: Stock Assessment and Monitoring Implications. Prepared for CMS WUP FTC. 37 p. *(completed)* **Melville, C. and D. McCubbing.** 2000. Assessment of the 2000 Juvenile Salmon Migration from the Cheakamus river, Using Rotary Traps. Prepared for BC Hydro by Instream fisheries Consultants. 42p. *(completed)*	• field observations during chum spawning and low flows
5. Dam operations affect water temperatures and hence, growth and survival of juvenile salmonids.	rejected	• climate is primary determinant of Cheakamus River thermal regime • tributaries act to moderate temperature changes	• none	**McAdam, S.** 2001. Water Temperature Measurements on the Cheakamus River- Data Report June, 1999 to December, 2000. *(completed)*	• continue temperature monitoring
6. Dam operations affect the vulnerability of juvenile fish to predators.	suspended	• migrant fry timing coincides with rising tributary flows and with low risk of increased predation	• magnitude of predation risk and effect on fry to smolt survival	No further study planned at this time.	• none

Impact Hypothesis	FTC Conclusion	Rationale	Key Uncertainties	Studies	Recommendations
7. Dam operations affect groundwater characteristics of mainstem river side-channels and hence, salmonid spawning and rearing habitat.	suspended	• groundwater upwelling important for chum and coho spawning with less variable temperatures	• relationship between groundwater flows and dam releases • role of hyporheic zone, thermodynamics, and river sinuosity in riverine ecosystems	To be addressed through WUP monitoring (See Monitoring Plan)	• literature review of hyporheic zones • monitoring program
8. Powerhouse operations cause stranding of juvenile fish.	suspended	• field study in fall 95/winter 96 and day visit in fall/00 found no stranding • daily peaking discourages spawning in areas susceptible to stranding	• stranding risk magnitude, areal extent and timing • impact of continuous peaking	• To be addressed through WUP monitoring (See Monitoring Plan)	• relate key life history timing to Squamish hydrology • monitor river levels in Squamish mainstem • monitor stranding risk; design monitoring program • consider physical works in Squamish channel

4.5 Aquatic and Riparian Ecosystem Studies

Three studies addressed aspects of the aquatic and riparian ecosystem:

- Limnotek report on Trophic Structure and Function in the Cheakamus River (Perrin 2001). Used to assess fish food supply IH; led to development of benthic biomass PM.
- Robertson Environmental Services report on Floodplain Ecosystem and Wildlife Overview (RES 2001). Used to assess need for Riparian ecosystem PM.
- Northwest Hydraulics Report on Channel Morphology and Sediment Transport Characteristics. Used to assess gravel/spawning habitat IH; need for riparian ecosystem PM; led to FTC recommendations for gravel management (NHC 2000a).

4.6 Information Not Pursued

This section highlights what was not studied because it was not deemed helpful in choosing between alternatives.

4.6.1 What was not Pursued at the Advice of the CC

The CC did not recommend dropping any research topics.

4.6.2 What was not Pursued by CC at the Advice of the FTC

Tenderfoot Hatchery Smolt Production

The CC was concerned about budget cutbacks at Tenderfoot hatchery and the consequent impact of reduced hatchery smolt output on FTC studies. The CC contemplated writing a letter to the Federal Minister's Office. However, the FTC determined that these changes would not adversely affect ongoing FTC scientific studies. They therefore recommended that there was no need for the CC to send a letter to the Minister's office. The CC accepted their recommendation. (See meeting notes for Nov. 29 and Dec. 13 1999 for more detail.)

As discussed previously in Section 3.2, the FTC also recommended that the CC not pursue development of PMs for the riparian ecosystem hatcheries fish, or pink salmon.

4.7 Education

Part of the information gathering process included a series of presentations to inform the CC about different components of the evaluation process and the Cheakamus River system. The presentation topics included:

- field trips to the Cheakamus River (rafting), Daisy Dam and Cheakamus generating station;
- decision analysis and resource valuation (Kristy McLeod, David Marmorek);
- fluvial geomorphology and fish habitat in the Cheakamus River (Bob Newbury);
- modelling hydro operations (Eric Weiss, BCH);
- hydrology of the Cheakamus and Squamish River Hydrology (Robert Bland);
- geology of the Cheakamus and Squamish Basins (Bob Turner, Geological Survey of Canada);

- nutrients, algal growth and benthic production in the Cheakamus River (Chris Perrin, Limnotek);
- operation of the Tenderfoot Fish Hatchery (David Celli);
- flooding (Gordon Boyd, BCH);
- cross-cultural training – Squamish Nation;
- BC Hydro Operations and Finances, including limitations on flexibility of Cheakamus to shift operations in time (Ken Spafford, BCH); and
- Value of energy (Doug Robinson, BCH).

Information from Educational Presentations that Potentially Affect Choice of Operating Alternatives:

- *Bob Newberry*: The Cheakamus River's natural meanders should move downstream at a rate of about 4.5 m per year. However dykes or riprap (e.g., railway embankment, transmission line, North Vancouver Outdoor School) stop this movement, which causes increased velocities and down-cutting, lowering the water table and possibly isolating tributaries. Dam operations and consequent flows therefore need to consider the increased channel confinement.

  Some further points from Bob Newbury's presentation to the CC, February 7, 2000:

  "Normal" river behaviour is to travel in a 3-D sine wave with a "flip" from one side to the other every six river widths. Moreover, "normal" river behaviour also includes "translation" – the gradual downstream movement of the sine wave, with the downstream movement being faster in systems with narrow meanders. The presence of dykes in the Cheakamus has broken the natural progression of river processes. Thus, energy dissipation is currently resulting in formation of new side channels and altered deposition patterns.

  The main factor currently affecting gravel flow patterns is not water flow, but human interventions that interfere with natural hydrologic processes (e.g., diking, embankment armouring). As long as these human interventions exist, no amount of flow will result in re-establishment of the "old" distribution and quality of salmon spawning beds.

  Historically, the "natural" form of the Cheakamus River was determined primarily by the median flood-peak flow. Currently, 60% of the lower Cheakamus River system is channelized.

  In his comments on the Draft CC Report the NVOS representative disputed the extent of channel confinement and supplied additional information on this issue (see Appendix 9).

- *Eric Weiss*: Rubble Creek is fed by sub-surface seepage from Garibaldi Lake, which results in a very even base flow throughout the year of 5-8 cms (2.5-5.5 cms during the winter months), unlike the other tributaries (Chance, Culliton, Cheekeye) which fluctuate with storm and snowmelt events. Rubble Creek is therefore very important for maintaining flows in the Cheakamus River during dry winter periods between January to March.
- *Robert Bland*: The creation of Daisy Dam cut off the supply of gravel and large woody debris from the Upper Cheakamus. However, gravel movement has not been significantly affected by the dam because the frequency and magnitude of high flow events that move gravel (> 150 cms) have not changed that much. Dam operations are unlikely to affect gravel movement. This conclusion is consistent with the findings of NHC (2000a), which is summarized in the FTC's Impact Hypothesis Report (Appendix 4).

- *Bob Turner / Chris Perrin*: Volcanic rock west of the Cheakamus River is more easily weathered and eroded than the granitic rock in other parts of the watershed. This supplies the Cheakamus River with natural sources of phosphorus, the nutrient that most limits aquatic ecosystem productivity. (Work by Chris Perrin confirmed that most of the nutrients reaching the lower Cheakamus come from natural tributaries, and that the Whistler treatment plant contributes only 0.02% of the biologically available phosphorus (Perrin 2001)). This means that the effects of Whistler sewage on the lower Cheakamus, one of the issues of concern in Table 2.1, are currently relatively minor, and should not affect decisions on operations at Daisy Dam.
- *Gordon Boyd*: Without the dam in place, there would have been 41 all day flooding events during the last 38 years (450 cms at Brackendale gauge). With the dam in place and present operations (extra 3m flood storage buffer in reservoir during September – December), there would be 14 all day flooding events. Statistically, 5 of these floods would have been of such daily flow magnitude that flooding could not be stopped with any operating procedure at Daisy Dam. Hence, flood risk is not likely to vary much over most conceivable operating alternatives.

5.0 Alternatives and Modeling

As required under Step 6 of the WUP Guidelines, the consultative committee created a meaningful set of alternative operating regimes. These alternatives were evaluated to compare the degree to which they met different water user's interests and objectives. Operating alternatives are the allocation of water through water control structures to satisfy stated objectives within given operating constraints, subject to natural variability. Where and when water is released from Daisy reservoir directly affects many of the stated objectives. Alternatives are forward looking, recognizing that facilities are in place and that the focus of WUPs is on improvements to operations to reflect different uses.

Flow alternatives selected by the CC were run through BC Hydro's operations model, AMPL, to determine how the system responds to a given set of constraints (see Figure 5.1). Output from the Hydro operations model (e.g., reservoir levels, river flows) were used to calculate previously determined performance measures. Performance measures were then used to determine the degree to which objectives were met.

The following sections describe the operating alternatives, the Hydro operations model and the performance measures modeling process.

5.1 Operating Alternatives

An operating alternative is a combination of hard and soft constraints submitted to the Hydro Operations model. A hard constraint is a physical limitation that **cannot** be exceeded (e.g., you can't store more water than the total volume of the reservoir, or exceed the 60 cms capacity of the powerhouse turbines). A soft constraint is a desired outcome which the Operations model **attempts** to achieve (e.g., minimum releases from Daisy Dam, minimum or maximum flows at the Brackendale gauge) whenever possible. Hard and soft constraints can be specified for the daily reservoir elevation, daily turbine discharge, daily spill released from the Dam, and daily discharge as measured at the Brackendale gauge location. These constraints can be formulated to optimize results for a particular objective (e.g., maximise power production, minimize flooding, maximise effective spawning area for chum), to better meet multiple objectives (Figure 5.1).

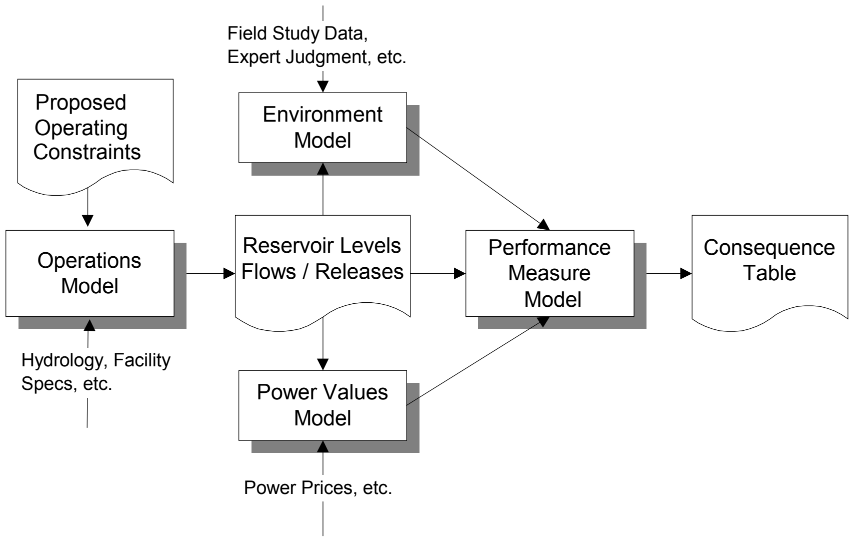

Figure 5.1: General process to convert operational alternatives to performance measures. Each operating alternative the Consultative Committee defined was run through the BC Hydro operations model. Secondary models calculate performance measures from its output. A consequence table summarizes PM results across alternatives for each objective (e.g., Table 6.3). (Source: Michael Harstone, BCH)

The Consultative Committee experimented with hard and soft constraints at the beginning of the evaluation process in April 2001. The first two alternatives were the most extreme possible. One passed all reservoir inflows downstream to produce flows as close to a pre-dam flow regime as possible (Pass All Inflows, or PI). The other passed as much water as possible for power production with no specified minimum dam release (Power Optimal, or PO). Although unrealistic, these alternatives demonstrated the range of response of performance measures under zero and maximum Value of Energy (VOE). Then within this range, the CC specified several alternatives that minimised flooding or maximised recreation and sportfishing opportunities. The recreation and sportfishing alternatives were based on some CC members' subjective judgements of a 'good flow', as the FTC had not yet completed development of fish habitat PMs.

Flooding was the only issue reviewed by the CC that required the application of constraints to the daily reservoir elevation. The standardized features (described in Box 2) were proposed to the CC and then applied to all alternatives. This was done to ensure that variations to the model foresight, reservoir and turbine constraints did not confound the comparison of specified daily spill and Brackendale flow scenarios constraints. These constraints included modelling the current flood control constraints for all alternatives, which meant that the modelled flows never exceeded the flooding criterion of 450 cms at the Brackendale gauge. None of the alternatives reviewed by the CC required the application of specific constraints to the daily turbine discharge, provided that other constraints specified by the CC were satisfied before turbine operation. Thus the operating alternatives of interest to the CC began to focus on specifying various constraints to be applied to the daily spill from the Dam, and the daily discharge at the Brackendale location. With the knowledge that the other features of the modelled alternatives were identical, the CC specified new alternatives only in terms of minimum dam spill and/or minimum flow at the Brackendale gauge.

Initially, the CC specified alternatives only as a single combination of minimum Dam release and Brackendale gauge flow over the year. As it increased its understanding of how alternatives affected different performance measures, the CC developed hybrid alternatives with multiple spill and gauge flows designed to address specific concerns at particular times of the year.

Table 5.1 shows all of the operating alternatives considered by CC during the WUP process. They fall into four general categories:

1. alternatives that specify that a certain percentage of inflows be released at Daisy Dam [e.g., Int22.5% and Int45% (current operations under the Interim Flow Agreement)];
2. alternatives that specify a minimum release at Daisy Dam in cms (e.g., 5Dam, 10Dam);
3. alternatives that specify a minimum flow at the Brackendale gauge (e.g., 10Min, 15Min, and 20Min); and
4. alternatives that specify both a minimum release at Daisy Dam and a minimum flow at the Brackendale gauge (sometimes these alternatives varied by season).

Table 5.1: Summary of operating alternatives. Abbreviations and symbols: "Min" = target minimum flow at Brackendale Gauge; "Dam" = target minimum release from Daisy Dam (0.56 cms is the lowest possible release; it is required to operate the on-site generator., *cms = cubic metres per second. ** = An instantaneous flow rate that is maintained at all times (as indicated). Figure 6.1 illustrates the 'lifespan' of each considered alternative over the WUP process.

Alternative	**Minimum Release from Dam (cms*)**	**Minimum flow At Brackendale (cms)**	**Maximum Reservoir Elevation (m) (after which spill occurs)**	**Minimum Reservoir Elevation (m) at which generation occurs)**	**Fall/Winter Flood Control**	**CC Decision**
Preliminary Alternatives discussed at the April 30th 2001 CC meeting						
Pass All Inflows (PI)						Dropped by CC May 28th/29th.
Int45%	The greater of 45% of previous daily inflow to Daisy Dam reservoir or 5 cms**	n/a	*377.25 m* (Jan– Sep) *375 m* (Oct- Dec)	369 m	Current ops	Dropped by CC July 3rd/4th (consensus decision). Preferred by 7 CC members at final Jan. 11, 2002 meeting.
30Min	0.56	30	″	″	″	Dropped July 3rd/4th
20Min	0.56	20	″	″	″	Dropped Oct. 4th, 2001
10Min	0.56	10	″	″	″	Dropped September 7th
Flood Empty Reservoir (FER)	0.56	n/a	″	″	″	Dropped by CC May 28th/29th
Power Optimal (PO)	0.56					Dropped by CC May 28th/29th
Alternatives added at the May 28th/ 29th, 2001 CC meeting						
25Min	0.56	25	″	″	″	Dropped July 3rd/4th
Int22.5%	5	n/a	″	″	″	Dropped July 3rd/4th
5Dam	5	n/a	″	″	″	Dropped Oct. 4th, 2001
15Min	0.56	15	″	″	″	Dropped Sept 7th
10Dam	10	n/a	″	″	″	Less preferred/acceptable Oct 24th
Alternatives added at the July 3-4th, 2001 CC meeting						
20Min7Dam	7	20	″	″	″	One of final 4 evaluated Jan. 11th
7Dam	7	n/a	″	″	″	Dropped Oct. 4th, 2001
15Min3Dam	3	15	″	″	″	Less preferred/Acceptable Oct. 24th
3Dam	3	n/a	″	″	″	Dropped Sept. 7th

Alternative	Minimum Release from Dam (cms*)	Minimum flow At Brackendale (cms)	Maximum Reservoir Elevation (m) (after which spill occurs)	Minimum Reservoir Elevation (m) at which generation occurs)	Fall/Winter Flood Control	CC Decision
Alternatives added at the September 7th, 2001 CC meeting						
15Min5Dam	5	15	″	″	″	Less preferred/acceptable Oct. 24th
20Min3Dam	3	20	″	″	″	Dropped Oct. 4th, 2001
Alternatives added prior to the October 4th, 2001 CC meeting						
15-20Min3-7Dam (Hybrid A)	3 (Nov–Apr) 7 (May- Oct)	15 (Nov–Apr) 20 (May–Oct)	″	″	″	One of final 4 evaluated Jan 11th
Alternatives added during the October 24th, 2001 CC meeting						
15Min3-10Dam	3 or 10	15	″	″	″	Less preferred / acceptable Oct. 24th
15Min5-10Dam	5 or 10	15	″	″	″	
15Min7Dam	7	15	″	″	″	
20Min7-10Dam	7 or 10	20	″	″	″	
Alternatives added prior to the January 11th, 2002 CC meeting to resolve concerns about Hybrid A and 20Min7Dam						
15/20Min3/5/7Dm Hybrid B	3 (Nov-Dec) 5 (Jan-Mar) 7 (Apr-Oct)	15 (Nov-Mar) 20 (Apr-Oct)	″	″	″	One of final 4 evaluated Jan. 11th
15/20Min3/7Dam Hybrid C	3 (Nov-Dec) 7 (Jan-Oct)	15 (Nov-Dec) 20 (Jan-Oct)	″	″	″	One of final 4 evaluated Jan. 11th

5.2 Overview of Modelling

A series of models were used to assess the degree to which objectives were met across the different operating alternatives (Figure 5.2).

The process begins with the Hydro Operations model (BCH 2002a). In order to assess operating alternatives, BC Hydro developed a software toolbox of water resources routines. Development centred on the AMPL (A Mathematical Programming Language) and CPLEX software packages. AMPL is a modeling language that enables conversion of a problem by transforming mathematical formulations to computer code. The transformed problem is solved by CPLEX, a package of mathematical solvers for linear and non-linear programming. The AMPL-CPLEX toolbox constitutes the Hydro Operations Model. The Hydro Operations model must be calibrated prior to the evaluation of each alternative. Calibration was carried out using BC Hydro's most current data and plant characteristics for the Cheakamus project.

Once calibrated, the Hydro Operations model is used to simulate an operating alternative for the entire reservoir inflow record of 32 water years (1967-1998). The model is subject to “hard constraints” corresponding to maximum and minimum physical characteristics of the natural system (e.g., height of free crest spillway). A five-day foresight is used for optimisation. While the assumption of an accurate five-day forecast is generally consistent with normal summer conditions at Cheakamus, there are times – particularly in the winter – when the facility operators must rely on far less accurate five-day forecasts. The model can also ‘distinguish’ between high- and low-load hours, and can allocate generation to high-load hours when water supplies are insufficient to allow a full day of power generation.

The Hydro operations model uses “soft constraints” to represent preferred zones of operation. These constraints can vary daily, weekly, or monthly, as required. These constraints are:

- Daisy Lake elevation (m);
- Daisy dam release into Cheakamus River (cms);
- Cheakamus River flows at the Water Survey of Canada Brackendale gauge (cms); and
- Power plant discharge into the Squamish River (cms).

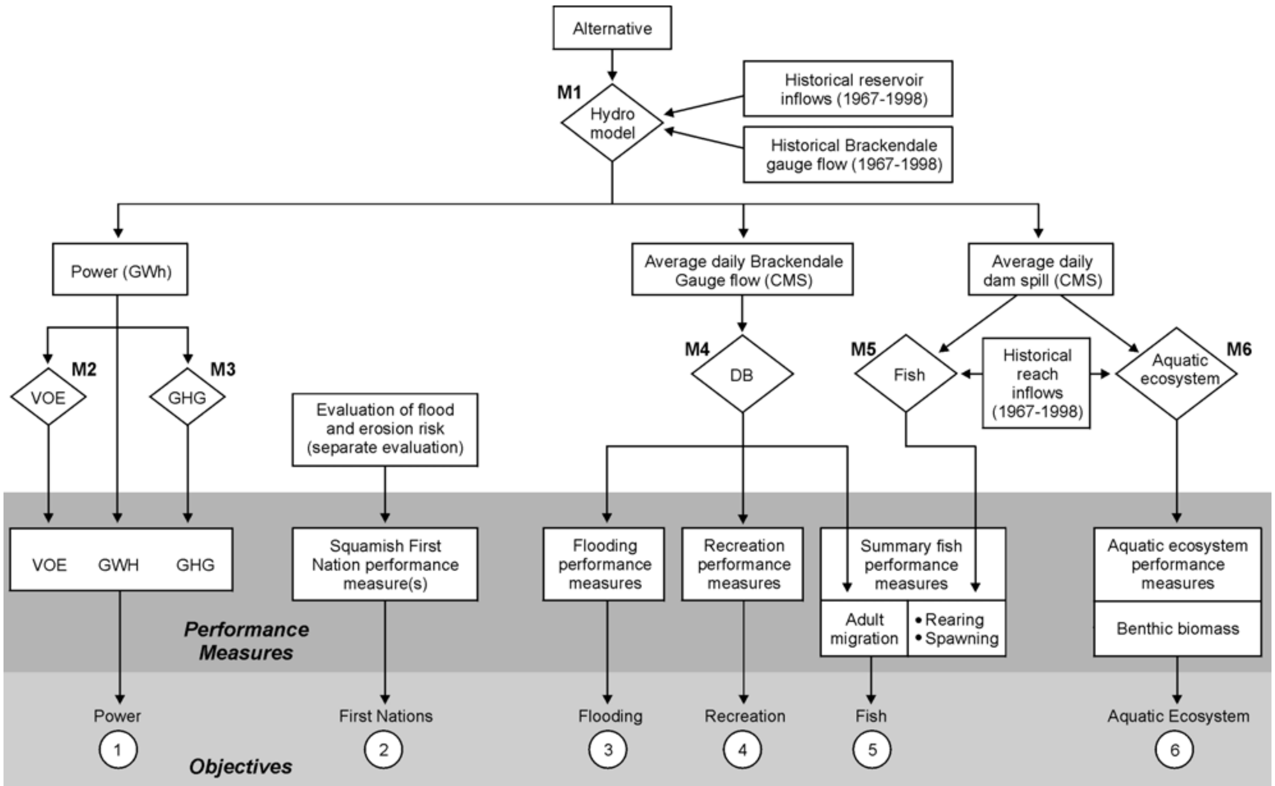

Figure 5.2: The Cheakamus WUP modelling process and set of performance measures. Abbreviations: M1 = AMPL Hydro Operations Model; M2 = model for calculating the value of energy using AMPL MW output; M3 = calculation to convert GWh to Greenhouse gas reductions (tonnes/year); M4 = database calculations that prepare the flood, recreation and fish adult migration PMs; M5 = models for calculating fish juvenile rearing area and effective spawning area PMs; M6 = model for calculating benthic biomass PMs.

With respect to flows at the Brackendale gauge, the Hydro operations model has access to data describing 32 years of tributary inflows below the dam, so these water flows can be factored into any optimisation. The Consultative Committee specified new alternatives in terms of minimum Dam spill and minimum Brackendale gauge discharge constraints. Box 2 summarizes the standardized AMPL parameters common to all alternatives after May 2001.

Box 2: Standardised AMPL Model Parameters

In June 2001 HOPSC standardised some of the AMPL model parameters to be common to all alternatives. These are as follows:

5 day Model Foresight
The model has perfect knowledge of the next 5 days of inflows when determining the optimum operation for any particular day. This is much better information than would be available for routing storm events but otherwise represents the more common, normal weather, operation of the project fairly well.

Maximum normal reservoir elevation
1 Jan - 30 September = 377.25 m
1 October - 31 December = 375 m

When inflows are such that the reservoir rises above these elevations, the model commences spilling to maintain the reservoir at or below the specified elevations. These elevations have been defined in order to model all alternatives with flood protection measures similar to the current BCH operation.

Minimum Reservoir Elevation for Turbine Operation
The power tunnel is not operated when the reservoir elevation drops below 369 m in order to avoid entrainment of sediment into the power tunnel flows.

Brackendale Flood Flows
All alternatives are heavily penalised in the model for Brackendale flows greater than 450 cms. There is also a minor penalty for Brackendale flows of 300 - 450 cms. For Brackendale flows less than 300 cms there is no penalty. This penalty scheme encourages the model to limit Brackendale flows to less than 300 cms and forces the model to avoid Brackendale flows greater than 450 cms whenever possible. Applying these penalties results in zero days of Brackendale flow greater than 450 cms for all scenarios.

Output from the Hydro Operations model consists of:

- Daily reservoir elevation (m);
- Average daily discharge (cms) at three locations – 1) below Cheakamus dam, 2) at Brackendale gauging station, and 3) at the power plant tailrace; and
- Daily power generation (MW).

The AMPL output feeds other models that calculate the remaining performance measures (Figure 5.1). Daily Power Generation (MW) feeds into a separate spreadsheet model to calculate the dollar value of the power ("Value of Energy", or VOE). The VOE calculation includes a dispatchability component (i.e., the powerhouse was able to respond to hourly market opportunities, see BCH 2002a). MW is converted to GWh, which is then converted to greenhouse gas reduction ("GHG", ktonnes/year) using a simple regression equation (Appendix 2-A). The Recreation, Flooding, and Fish "Adult Migration" performance measures are calculated using the Average Daily discharge at the Brackendale gauge. Models that use the Average Daily discharge below the dam and historical reach inflow data calculate the remaining Fish PMs and the Aquatic Ecosystem PMs. The Squamish Nations PM is evaluated through a separate process (see NHC 2000b). Additional information about the calculation of these performance measures is found in the Information Sheets in Appendix 2 and in BC Hydro's CMS WUP Report (BCH 2002a).

6.0 Evaluation of Alternatives and Trade-off Analysis

The CC evaluated and compared the operating alternatives described in Section 5.0 through technical analysis and group discussions, as required under Step 7 of the WUP process. The CC participated in six evaluation meetings where they examined and discussed trade-offs. During this period, the CC considered twenty-five alternatives using several techniques to assess technical and value tradeoffs, primarily ranking and pair-wise comparison exercises.

Technical trade-off analysis consists of analysis of technical and scientific information presented as performance measures. Throughout the WUP process this information was evaluated in the form of graphs, descriptions and matrices. Alternatives were compared and those that were clearly "dominated", or performed worse across performance measures either by direct comparison or agreement by the CC, were dropped from further analysis. Those that required value trade-off analysis were then further analyzed and discussed by the CC. Value-based trade-offs and committee member preference analyses helped answer the question of how important the impacts were as indicated by the technical performance measures.

- **Section 6.1** describes the evaluation process
- **Section 6.2** provides an overview of progress over the six evaluation meetings
- **Section 6.3** describes the alternatives and performance measures that were dropped and refined over the evaluation process
- **Section 6.4** provides a detailed summary of the penultimate evaluation meeting held October 24th, 2001. This section is included to provide important background for the discussion of the final meeting.
- **Section 6.5** provides a detailed summary of the final evaluation meeting held January 11th, 2002. It begins by summarizing the pre-meeting package sent to the CC. This material summarized the main sources of disagreement from the October 24th meeting, the main difference in values and sources of scientific uncertainty that contributed to this disagreement and proposed strategies to deal with these issues. These topics were discussed by the CC at the beginning of the final meeting to try and find a path to consensus. The second part of Section 6.5 summarises the results of the CC preference ratings for the final set of operating alternatives evaluated at the meeting.

6.1 The CC Evaluation Process

This section describes the CC's evaluation process. At their meeting on April 30, 2001, the CC agreed on the set of performance measures to be used to evaluate alternatives. The evaluation of alternatives then proceeded as an iterative screening process over a series of six meetings held from May 2001 to January 2002. Prior to each meeting, the facilitation team summarized the Hydro operations model results in terms of the agreed to performance measures, plus additional descriptive information to help clarify the differences between alternatives. They then distributed this information to the CC as an "Update Memo" that summarized the key attributes of each alternative. These attributes included:

- graphs of the median daily flow at Daisy Dam, in Reach 10 (resident fish), and at the Brackendale gauge;
- the timing of spawning and incubation for chinook, coho, chum and steelhead relative to the average daily flow pattern in Reach 3;

- performance measure results by objective;
- a table that summarized the relative “pros” and “cons” of each alternative (given the set of alternatives being compared);
- the detailed PM results; and
- graphs/discussions of emerging tradeoffs.

The CC used this information to understand the implications of the alternatives, considering both the specific performance measures and other factors.

The evaluation meeting followed a general format. At the beginning the CC was asked for comments on the minutes of the previous meeting. The CC then reviewed and discussed the latest modelling results using the Update Memo, and the Facilitator recorded their comments, concerns, and requests. At earlier meetings there were significant differences in how alternatives performed across objectives, so the CC was able to easily agree on what alternatives to drop using the performance measures. As the flow differences between alternatives narrowed, differences based on performance measures became less distinct in some cases. To aid decisions, the CC used a series of exercises designed to clarify tradeoffs and elicit preferences. In these exercises, CC members rated alternatives as preferred, acceptable, or unacceptable and discussed the rationale for their preferences with the group. The group discussions brought forth the values and information used by individual CC members to make their choices, informed other CC members of specific concerns, and showed the challenges to be overcome for consensus to be obtained. For example, most CC members stressed that fish abundance was more important than sportfishing access. As the evaluation process continued, new insight was gained about how operations affected the performance measures. This learning along with the technical presentations and studies assisted in the development of new alternatives that better addressed CC members’ values and objectives. The CC specified new alternatives at the end of the each meeting (Table 5.1). Section 6.2 summarizes the progress made at each evaluation meeting.

Representatives of the FTC and HOPSC attended each meeting. The CC asked them questions to clarify the meaning and importance of particular results. The facilitators also brought all the data, models and analytical results to the meetings so that additional information could be provided at the request of the CC.

Over the duration of the WUP process, the Consultative Committee used the performance measures, supplementary information on flows, and advice from the HOPSC and FTC to considerably narrow the set of alternatives under consideration. Figure 6.1 shows median flows during the non-freshet period for the set of alternatives considered at each CC meeting. Non-freshet flows generally differed between operating alternatives, whereas median freshet flows were much more similar. The “shoulders” of the freshet were narrower for some types of alternatives (i.e., later start to freshet flows and an earlier end).

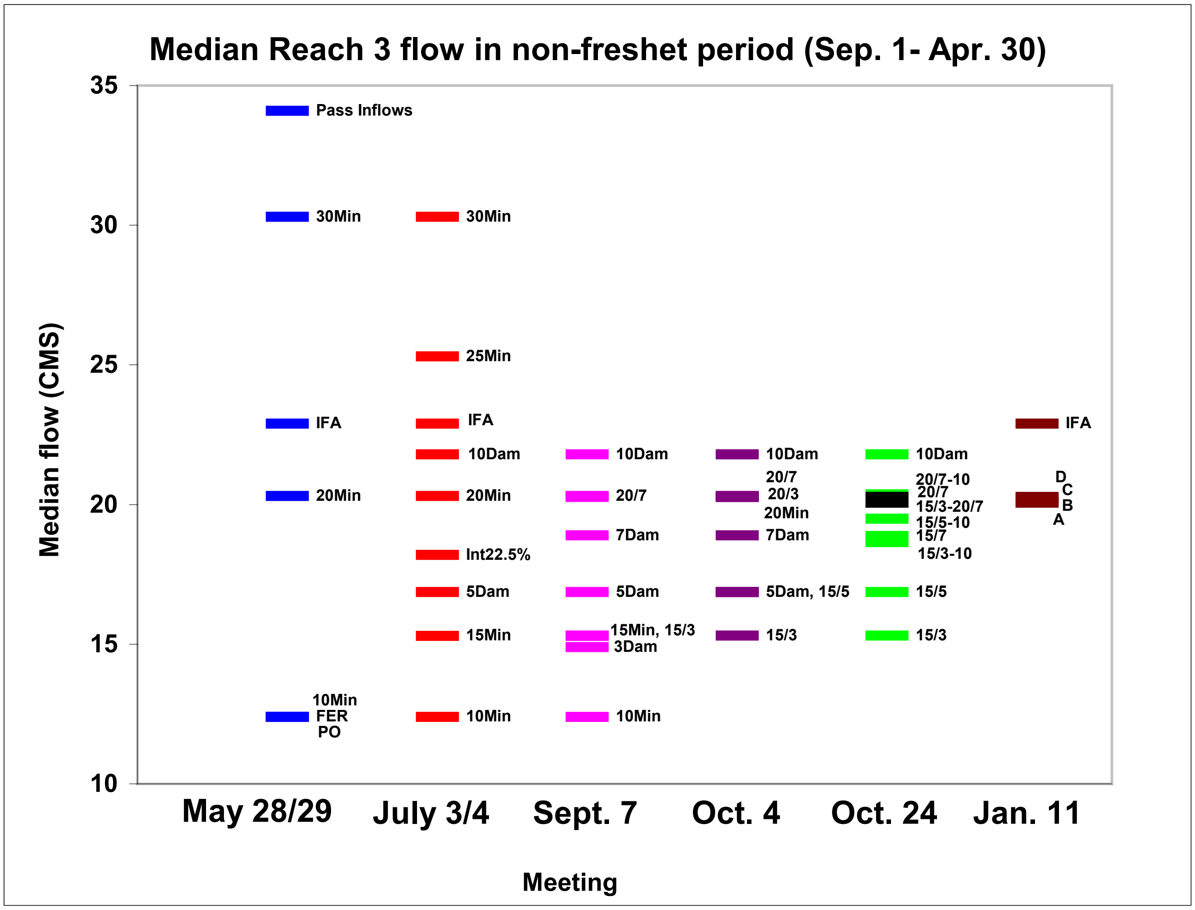

Figure 6.1: This figure shows the narrowing of the range of flows within the alternatives over the evaluation process. The bars represent the median Reach 3 flow during the non-freshet period (September 1 to April 31) over 32 water years. The dates along the bottom axis are the CC meeting dates. October 24th shows the full range of consider alternatives in green and the two most preferred alternatives (20Min7Dam and 15-20Min3-7Dam) in black. The median values for these two alternatives are almost identical. These were carried over to January 11th as alternatives “A” and “D”. The “B” and “C” alternatives are described in Table 5.1, but are essentially variations on A and D.

6.2 Overview of Evaluation Meetings

This section of the report provides an overview of the progress made in evaluating the alternatives summarized in Table 5.1 and Figure 6.1. The last two CC meetings (Oct. 24th 2001; Jan. 11th 2002) are described in more detail in Sections 6.4 and 6.5.

May 28/29, 2001:

At this meeting the CC had its first opportunity to review a full set of performance measures for seven alternatives (PO, FER, 10Min, 20Min, 30Min, Int45%, PI). The entire CC agreed to drop the Power Optimal, Flood Empty Reservoir, and Pass All Inflows alternatives. Most CC members were also willing to drop the Interim Flow Agreement alternative (Int45%) because the performance measures indicated it was not as good for fish, particularly chum effective spawning area. However, the WLAP CC member felt it should be retained for the next round of analyses. The CC also requested five new alternatives:

25Min, 10Dam, Int22.5%, 5Dam, and 15Min. [CC_Prereading_May 28_29_2001_Final.pdf, 20_CC Meeting Notes may 28_29, 2001.pdf].

July 3&4, 2001:

The CC reviewed performance measure results and supporting information for nine alternatives: 10Min, 15Min, 5Dam, Int22.5%, 20Min, 10Dam, Int45%, 25Min and 30Min. The CC used an anonymous rating exercise to collectively eliminate alternatives that were less preferred based on performance measures and also to highlight member's values. Nine CC Members rated alternatives on a scale from 1 to 10, 1 being the least preferred and 10 the most. Figure 6.2 summarizes the results. After this exercise, CC members discussed their preferences with the group and explained what attributes they felt were important for new alternatives. The CC agreed to eliminate four alternatives (30Min, 25Min, Int45%, Int22.5%) because they were the least preferred (Figure 6.2, Table 6.2), retain five alternatives (10Min, 15Min, 5Dam, 20Min and 10Dam) and define four new alternatives (3Dam, 15Min3Dam, 7Dam, 20Min7Dam). The two new minimum dam release alternatives (3Dam, 7Dam) would illustrate the effects of different constant minimum releases from Daisy Dam, a strategy seen as having the benefits of maintaining flows in the upper reaches, maintaining a more natural flow variability and being simpler to implement / monitor. The two new 'hybrid' alternatives (15Min3Dam, 20Min7Dam) maintained both a minimum dam release and a minimum flow at the Brackendale gauge. They had the potential to partially overcome some of the perceived weaknesses of the lower flow alternatives (e.g. less than optimal flows for resident fish, chinook, recreation and groundwater; 'unnaturally' even flows) while maintaining their benefits (e.g. power production; higher effective spawning habitat for chum, coho steelhead; higher benthic biomass). [CC_Prereading July 3-4_2001_Final.pdf, 21_Meeting Notes July 3-4, 2001.pdf].

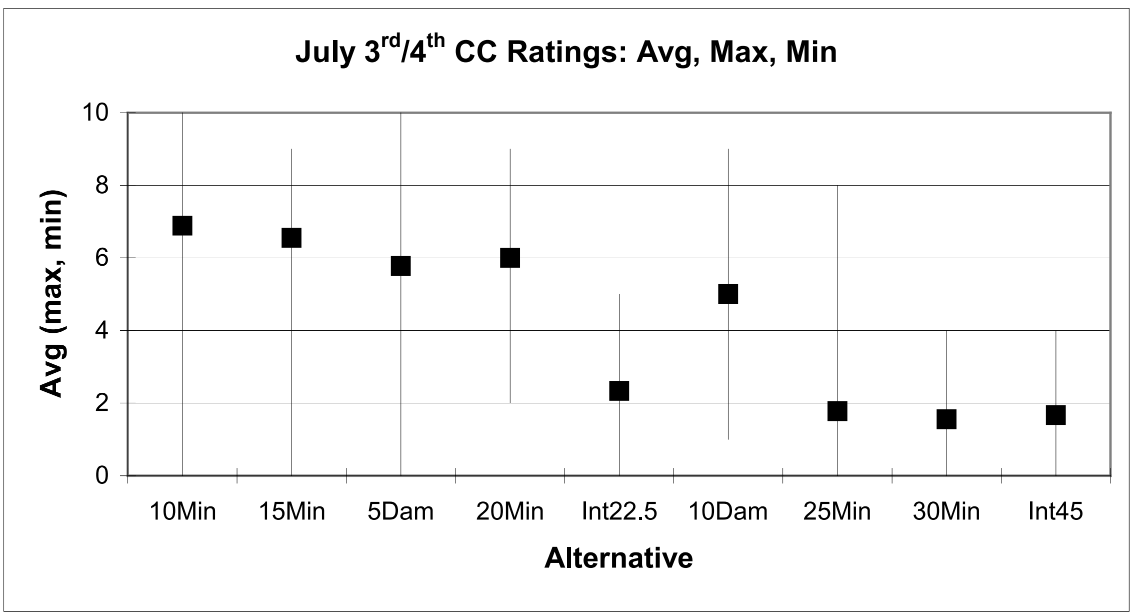

Figure 6.2: CC rating of alternatives at the July 3rd and 4th meeting. The squares indicate the average rating; the lines indicate the range of responses. Higher numbers indicate higher preference; a "0" indicates that a CC member could not be part of a consensus decision if this alternative were selected. Specifically: 0-1 = "Block", 2-3 = "Less Acceptable", 4-5 = "Neutral", 6-8 = "More Acceptable", 9-10 = Fully endorse". Nine CC members participated in this exercise.

September 7, 2001:

The CC reviewed the results for nine alternatives: 10Min, 3Dam, 5Dam, 15Min, 15Min3Dam, 7Dam, 20Min, 20Min7Dam, and 10Dam. Following their review, the CC used another preference rating exercise, filtering alternatives based on the performance measures. Figure 6.3 shows the results. The two most preferred / acceptable alternatives were 15Min3Dam and 5Dam. After completing this exercise, CC members shared the reasons for their choices and expressed their concerns in a group discussion. The CC dropped three alternatives (10Min, 3Dam, 15Min) based primarily on the preference ratings (Figure 6.3, Table 6.2), retained five (15Min3Dam, 5Dam, 7Dam, 20Min7Dam, and 10Dam) and defined three new ones (15Min5Dam, and either 20Min3Dam or 20Min5Dam, whichever was closest to 20Min in terms of VOE). Other meeting topics included a review of the draft monitoring plan prepared and distributed by the FTC at the CC's request, and a discussion of options for moving forward with the evaluation process. [CC_Prereading_September 7_2001_Final.pdf, 22_CC Meeting Notes September 7, 2002.pdf]

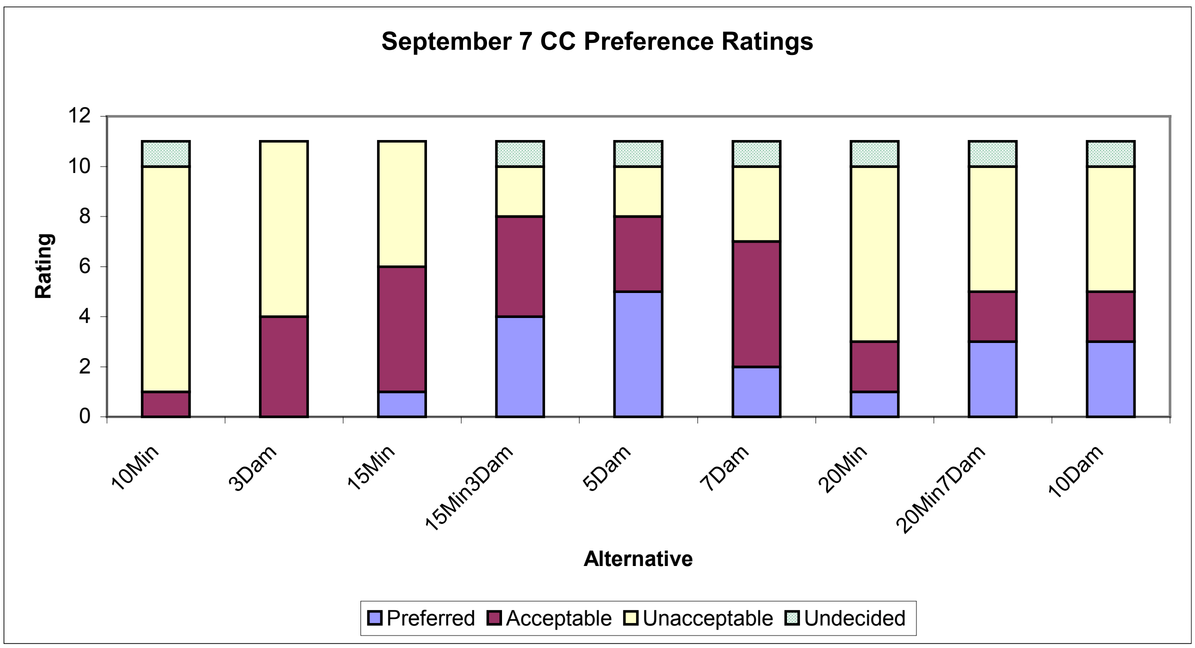

Figure 6.3: CC preferences from the September 7th CC meeting. The CC rated alternatives as preferred, acceptable, or unacceptable. Some CC members were undecided about some alternatives.

October 4th, 2001:

The CC reviewed the PM results and supporting information for eight alternatives: 15Min3Dam, 5Dam, 15Min5Dam, 7Dam, 20Min, 20Min3Dam, 20Min7Dam, and 10Dam. They then reviewed trade-offs amongst those alternatives (e.g., VOE vs., RB Parr and RB Parr vs. chum, see Figures 2.9a and Figures 2.9c in "CC_Prereading_October_4_2001_Final.pdf"). The CC used a two-stage process to reduce the number of alternatives. In the first stage, the CC went through a pair-wise comparison of alternatives based on the agreed upon performance measures. For each comparison, the alternatives that dominated or were at least as good on all PMs were retained. The pair-wise comparison identified four alternatives that were better based on the PMs (15Min3Dam, 15Min5Dam, 20Min7Dam and 10Dam) and the CC agreed to retain only these alternatives for further consideration. In the second-stage, the CC used a preference rating exercise similar to that of the September 7th meeting to narrow the set of remaining alternatives further. Figure 6.4 shows the results of this rating exercise. In a group discussion, CC members explained their preferences, stating if they preferred a single "best" alternative, or wished to pursue an adaptive management approach that compared two or more alternatives. Most CC members (10 out of 12) either preferred 15Min5Dam or found it acceptable with monitoring; two CC members preferred 20Min7Dam. At the end of this discussion session some CC members felt that it was unacceptable to continue the meeting because several CC members known to prefer higher flows had been unable to attend. As the meeting concluded, one CC member made a consensus proposal for CC consideration prior to the next meeting: "1) continue and monitor the Interim Flow Agreement (IFA) for two more years; 2) implement and monitor the 15Min5Dam alternative; and 3) upon review at the end of the WUP period (e.g., 5 years), evaluate the results and decide whether or not to implement a higher flow alternative (e.g., either 20Min7Dam or 10Dam)." The key trade-off that emerged at this meeting was between the PMs for rainbow parr rearing habitat, chum effective spawning area, and Value of Energy. [CC_Prereading_October_4_2001_Final.pdf, 23_CC meeting Notes October 4, 2001.pdf.]

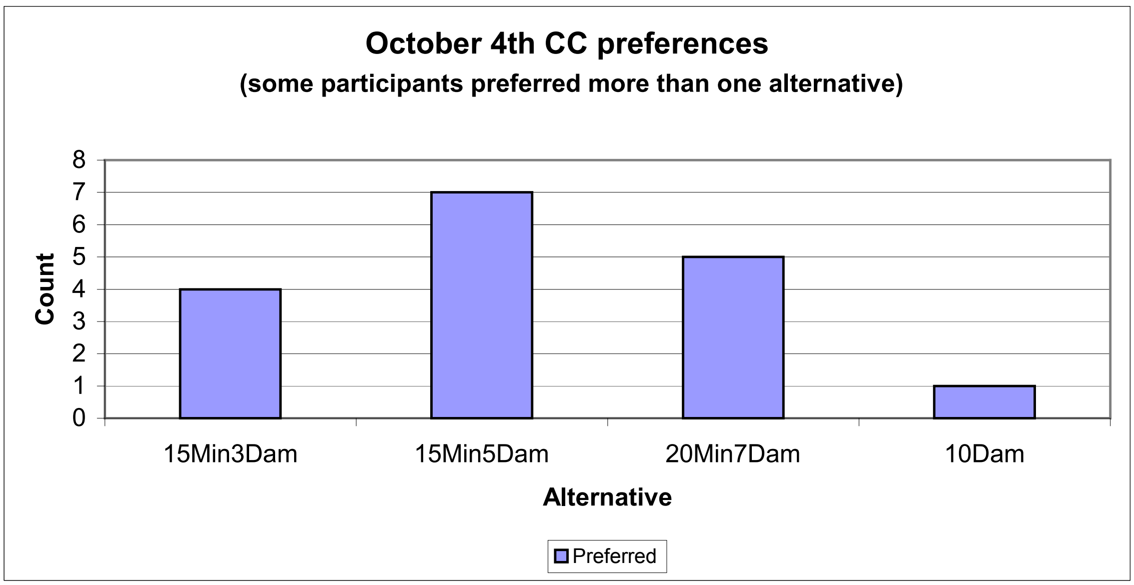

Figure 6.4: CC preferences from October 4th evaluation of four alternatives: 15Min3Dam, 15Min5Dam, 20Min7Dam and 10Dam.

October 24th, 2001 [summarized in detail in Section 6.4]:

The CC reviewed the results of the October 4th meeting, particularly for those CC members who had been unable to attend. Additionally, the CC reviewed the draft consensus proposal from the October 4th meeting, a draft table of CC concerns (with proposed mechanisms for addressing these concerns), and a draft set of CC recommendations. The Facilitation team prepared the latter two items drawing on CC meeting notes. After these reviews, the Facilitator presented a new hybrid alternative (15-20Min3-7Dam) prepared by the WUP Project Team to meet the concerns of some CC members about lower rainbow trout parr rearing habitat under 15Min3Dam. One CC member objected to a new alternative being prepared without direct CC input and requested four additional hybrid alternatives (15Min3-10Dam, 15Min5-10Dam, 15Min7Dam, and 20Min7-10Dam). The WUP Project Team estimated the PMs for these new hybrids at the meeting (the exact results were calculated later) so that the CC could review them. The 15-20Min3-7Dam hybrid and 20Min7Dam alternatives emerged as most the most preferred and acceptable (Figure 6.5). Both of these alternatives implement 20Min7Dam for April through October, but they differ in the November to March flows. However, various CC members had concerns about both of these alternatives that prevented consensus (described in Section 6.4). The CC agreed to consider the implications of a non-consensus WUP, and to explore further opportunities for dealing with the remaining concerns. The key trade-off that emerged at this meeting was the potential impacts on side channels during the low winter flow period, versus chum effective spawning area and Value of Energy. [24_CC Meeting Notes October 24, 2001.pdf]

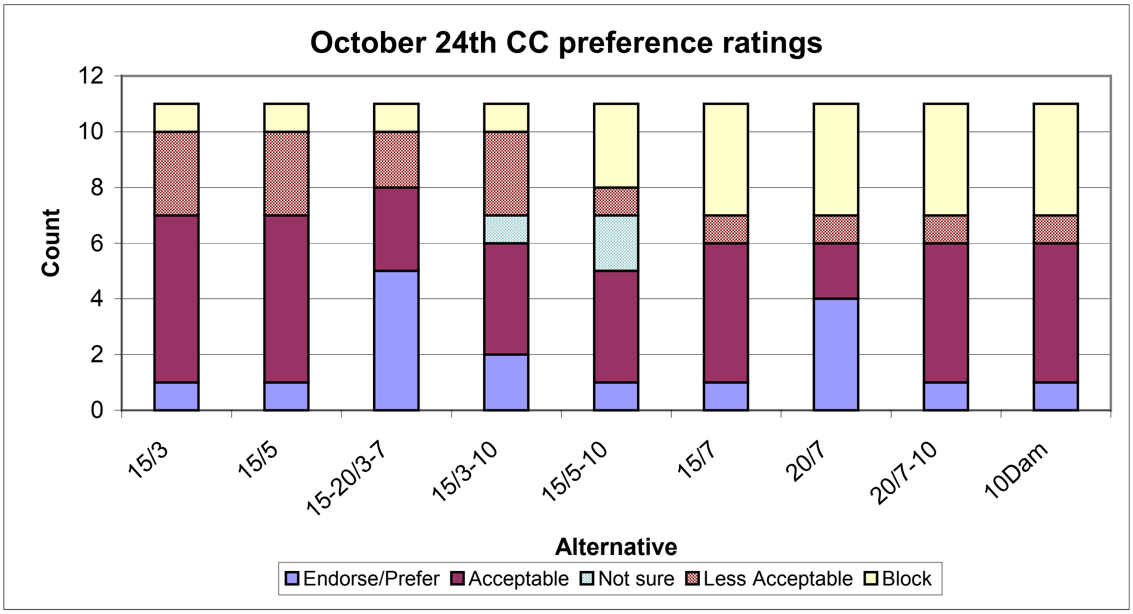

Figure 6.5: CC preferences from the October 24th meeting. Five new alternatives were considered at this meeting. For each alternative, CC members indicated whether they preferred or endorsed it, whether they found it acceptable, whether they found it less acceptable (i.e., could live with it to get consensus), or whether they found it unacceptable and therefore blocked it. Blocking means that they would not participate in a consensus recommendation if the majority of CC members selected that alternative.

January 11th, 2002 [summarised in detail in Section 6.5]:

The CC met for a final attempt at consensus. They reviewed and considered four alternatives (Table 6.1). Alternatives "A" (15-20Min3-7DamA) and "D" (20Min7Dam) were the most preferred alternatives from the October 24th meeting. The WUP Project Team developed alternatives "B" (15-20Min3-5-7Dam) and "C" (15-20Min3-7DamB) to address CC concerns about the potential impacts of Alternative A's lower winter flows on groundwater-dependent side channels. Prior to rating the alternatives, the CC reviewed a proposed one-year monitoring study that would intensively assess potential impacts of flow on groundwater side channels and, if necessary and appropriate, consider options to address this issue. The CC then evaluated the four final alternatives (described below). Afterwards, the CC reviewed the revised draft monitoring plan and rated each of its components in terms of: a) the likelihood that its monitoring data would change their future decisions on operations; and b) its relative importance for the monitoring plan. Finally, the CC reviewed and rated a set of other recommendations to include in this report.

The CC did not achieve consensus on an operating alternative. At least four CC members blocked consensus on each of the four proposed final alternatives (5 to 6 for alternatives A and B) (Table 6.1). The CC agreed that participants could express preferences for alternatives other than the four proposed final alternatives. Eight of the 16 CC members present at the meeting preferred continuing the Int45%

alternative (IFA, status quo) for approximately another 3-5 years to provide enough monitoring information to thoroughly assess its effects. Some CC members were concerned that the Int45% was being proposed when the CC had rejected it at their July 3-4th meeting based on the PMs; others felt it legitimate to "re-instate" this alternative. The WLAP representative favoured an adaptive management program that monitored the IFA for about 5 years before switching to the 15Min3Dam alternative. One BC Hydro CC member expressed a preference for the 15Min3Dam alternative. Table 6.1 summarises the distribution of rating across alternatives. Section 6.5 provides much more detail on the perspectives of each CC member. [25_ CCC Meeting Notes January 11, 2002.pdf]

Table 6.1: Summary of the Cheakamus Consultative Committee preferences at the final evaluation meeting (January 11th 2002). Cell contents show how many CC members assigned the indicated rating to each alternative. The acronyms in the cells below alternatives A, B, C and D indicate which CC representatives gave that rating. Table 2.2 provides a key to these acronyms.

	Alternative				
	A. Hybrid	**B. Revised Hybrid 'B'**	**C. Revised Hybrid 'C'**	**D. 20Min7Dam**	**Other Preferences**
Period: Nov. – Dec	15Min3Dam	15Min3Dam	15Min3Dam	20Min7Dam	
Jan. – Mar.	15Min3Dam	15Min5Dam	20Min7Dam	20Min7Dam	
Apr. – Oct.	20Min7Dam	20Min7Dam	20Min7Dam	20Min7Dam	
Preferred	**1** (BCH)	**1** (DFO)		**3** (SR, SLRD, SLDF)	1 (or 2*) 15Min3Dam 8 (or 7*) IFA
More Acceptable	**5** (or **4***) (BCH, DFO, DoS, MEM, WLAP*)	**4** (or **3***) (BCH, DoS, MEM, WLAP*)	**3** (or **2***) (SLRD, DoS, WLAP*)	**5** (or **4***) (DOS, WLAP*, CCG, SWRS, ORC)	3 did not prefer IFA, but did not block it
Less Acceptable	**3** (SR, SLRD, CCG)	**4** (SR, SLRD, CCG, BCH)	**7** (BCH, SR, DFO, MEM, CCG, ORC, SLDF)	**2** (WAC, NVOS)	
Not Part of Consensus if Selected (Block)	**5** (or **6***) (CR, NVOS, WLAP*, SWRS, ORC, SLDF)	**5** (or **6***) (CR, NVOS, WLAP*, SWRS, ORC, SLDF)	**4** (or **5***) (CR, NVOS, WLAP*, BCH, SWRS)	**4** (or **5***) (2xBCH, DFO, MEM, WLAP*)	4 blocked IFA
Total ratings possible for A, B, C, and D based on submitted rating forms. Not all ratings at the meeting were submitted by rating sheet.	**14**	**14**	**14**	**14**	

* Indicates that the WLAP rating is contingent on whether or not an adaptive management approach is used where the IFA is implemented first and then switched to 15Min3Dam. If this were to take place the WLAP member gave a rating of 2 to alternatives A, B, C, and D. If the IFA were not implemented first then the WLAP member gave a rating of 4 to alternatives A, B, C and D.

6.3 Alternatives and Performance Measures Dropped and Refined during the Evaluation Process

6.3.1 Alternatives Dropped

Over the course of the evaluation process, the CC dropped several alternatives from further consideration. Table 6.2 lists these alternatives and the reasons why they were rejected. No alternatives were formally dropped at the October 24th meeting.

Table 6.2: Alternatives dropped from consideration by the Consultative Committee during the WUP process. Abbreviations: "Min" = target minimum flow (cms) at Brackendale Gauge; "Dam" = target minimum release (cms) from Daisy dam; * = "reinstated" at the final CC meeting (January 11th, 2002), by 8 CC members (other CC members felt that it was important to respect earlier CC decisions made on the basis of the PMs). **Note**: the CC did not agree to drop any alternatives subsequent to the October 4th meeting.

Alternative	**Why Dropped? (only major reasons listed)**	**Date dropped**
Pass All Inflows	Example used to bound range of PMs. Unrealistic to have zero power production. Also has greater flood risk.	May 28/29
Power Optimal	Example used to bound range of PMs.	May 28/29
Flood Empty Res.	• potential migration problems for all species, especially coho and steelhead. • low effective spawning area for chinook. • low rainbow trout rearing area.	
Int45%	• increasing flow reduces power production and has relatively little benefit to fish PMs. • effective spawning area for chum, coho and steelhead lower with Int45%, 30Min, 25Min than with lower flow alternatives. • least preferred by CC (Fig 6.2). • lower benthic biomass with Int22.5% and Int45% due to flow variability	July 3rd/4th *
30Min		July 3rd/4th
25Min		July 3rd/4th
Int22.5%		July 3rd/4th
10Min	• does not maintain a minimum release from dam • not enough natural flow variation • flow too low in Reach 10, a concern for resident rainbow trout. • <20% Mean Annual Discharge (MAD) • less preferred for chinook spawning and rainbow rearing • less preferred for recreation; hard to sell to local residents, fishermen • operationally difficult	Sept. 7th
15Min	• same concerns as 10Min (listed above) • fish PMs are similar to 10Min but ~$2 million less power revenue per year: is it worth it?	Sept. 7th
3Dam	• flows too low in Reach 10, a concern for resident fish. • <20% of Mean Annual Discharge (MAD) most of time • potential concern for adult migration	Sept. 7th
5Dam	not preferred by any CC members	Oct. 4th
7Dam	not preferred by any CC members	Oct. 4th
20Min	not preferred by any CC members	Oct. 4th
20Min3Dam	not preferred by any CC members	Oct. 4th

6.3.2 Narrowing of Performance Measures

As the CC went through the evaluation process some objective and performance measures were dropped from consideration when they became unhelpful for decision making. The reasons for this were:

1. The PMs were always insensitive to alternatives;
2. The PMs become insensitive as the range of flow within alternatives narrowed;
3. Multiple PMs under an objective provided the same information;
4. Differences between PMs were indistinguishable given the range of uncertainty in PM estimates; and
5. Differences in PMs were not important under current river conditions.

The ***first*** reason (PMs always insensitive to alternatives) applies to the Flooding PM and the Squamish First Nations PM. The Hydro Operations model maximised flood control for all alternatives and no modeled flows exceeded 450 cms at the Brackendale gauge, the accepted flooding criterion. Thus the Flood PM was insensitive (equal to zero) over all alternatives and not helpful for decision making. This also affected the Squamish First Nation PM because the Flood PM was a proxy measure of the risk of flood and erosion for selected heritage sites. With an insensitive Flood PM, there was no longer a quantitative means by which to evaluate this risk. Although the CC did not replace the flood and erosion risk PM, they retained the First Nations objective to ensure consideration of issues that could affect Squamish Nation heritage sites and cultural values during the evaluation process.

The ***second*** reason (PMs became insensitive as range of flows within alternatives narrowed) applies to some of the Recreation and Fish PMs. As the range of flows within alternatives narrowed, the recreation rafting PM became insensitive and was dropped from consideration. This insensitivity was also evident when a higher rafting flow threshold was applied (e.g., "23_CC Meeting Notes October 4th, 2001"). *Adult migration*: This PM was dropped from consideration as the range of flows narrowed, and all alternatives showed minimal risks to upstream migration.

The ***third*** reason (multiple PMs under an objective provided the same information) applies to the Power PMs. The three power performance measures (VOE, GWh and GHG) are directly related; both VOE and GHG are calculated from GWh. Therefore they all show the same pattern of response across different alternatives, and merely provide the same information in different units. For the purposes of evaluation, VOE was retained as the power performance measure of interest.

The ***fourth*** reason (PM difference indistinguishable within the range of uncertainty) applies to the fish *Anadromous Rearing* PMs. The FTC used a 20% rule to evaluate the importance of the fish PM results. They felt that PM results within 20% of one another were essentially indistinguishable given the inherent uncertainties of their models and the data on which these models were based ("CC_Prereading_July_4_5_ 2001_Final.pdf"). Using this rule, the anadromous rearing PM became effectively insensitive over the range of flows considered. This was because the flows under all alternatives never dropped low enough to cause significant decreases in RUA and WUA ("CC_Prereading_July_4_5_ 2001_Final.pdf"). Higher flows did not result in increased RUA and WUA, due to the confined nature of the channel over most of the river's length (Appendix 4, Section A4.3.6).

This same situation occurred for the Recreation kayaking and sportfishing PMs and the Aquatic Ecosystem anadromous and resident benthos PMs. As the range of flow within alternatives narrowed, differences in these PMs across alternatives became less important to CC members.

The ***fifth*** reason (PM differences not important under current river conditions) applies to the fish spawning PM. The FTC compared modelled estimates of effective spawning area to estimates of species-specific spawning area (m^2) derived from historic spawning escapement estimates and the area required per spawner ("CC_Prereading_July_4_5_ 2001_Final.pdf"). This analysis suggested that only chum salmon were limited in the amount of mainstem spawning habitat available to them, a result consistent with the FTC's expectations for the four salmonid species the PMs address.

As a result of this narrowing of performance measures, the CC used a smaller set of performance measures for decision making at the end of the evaluation process than at the beginning (e.g., compare Table 3.1 to Table 6.3). Appendix 6 (Section A6.1) shows the full set of PMs results over all alternatives considered by the CC during the evaluation process.

6.4 Detailed Summary of the Penultimate CC Evaluation Meeting (Oct. 24th, 2001)

At the Oct. 24th meeting the CC evaluated nine alternatives that represented a relatively narrow range of flows (15Min3Dam to 10Dam). Though the CC did not formally reject any alternatives, the 15Min3Dam-20Min7Dam hybrid ('hybrid') and the 20Min7Dam alternatives emerged as the most preferred or most acceptable (Figure 6.5).

As Figure 6.5 shows, CC preferences were generally bimodal; some CC members preferred lower flows due to higher power and chum PMs while other CC members preferred higher flows to ensure groundwater-dependent side channels had enough water. The WUP project team had developed the 15-20Min3-7Dam 'hybrid' alternative to simultaneously meet two CC concerns: maintaining chum effective spawning and egg incubation in late fall and winter; and maintaining Srainbow trout parr rearing habitat and recreational access in summer and early fall. In this alternative, the 20Min7Dam component operates from April 1st to October 31st and the 15Min3Dam component from Nov. 1st to March 31st.

6.4.1 Comparison of Flows

Figures 6.6 to 6.8 show the median flow patterns for the 15Min3Dam, 15-20Min3-7Dam and 20Min7Dam alternatives for Daisy Dam spill, Reach 10 (resident fish) and Reach 3 (Brackendale gauge). The Int45% alternative (current operations, IFA) is also shown for comparison. Note the abrupt transition from 15Min3Dam up to 20Min7Dam at the beginning of April and from 20Min7Dam down to 15Min3Dam at the end of October for the hybrid. The CC noted that if this alternative were implemented it would require fine tuning (i.e., ramping flows gradually between the two operating rules, particularly at the end of September).

6.4.2 Trade-offs

Table 6.3 shows a simplified set of performance measures. PM's are not shown if they differed little across alternatives are not shown. Comparing 20Min7Dam with the 15-20Min3-7Dam hybrid, it is clear that rainbow trout parr rearing habitat is identical, and the kayaking PM is similar. The sport-fishing access PM is more than twice as high with 20Min7Dam than with the 15-20Min3-7Dam hybrid, with Brackendale flows greater than 19.5 cms included as sport-fishing access days. The hybrid alternative has $2 million more VOE and 25% more mainstem effective spawning area for chum than does 20Min7Dam. Comparing 15Min3Dam with the 15-20Min3-7 Dam hybrid, it is apparent that the hybrid's improvement in rainbow trout habitat and kayaking PMs comes at a cost of $1.3 million/year in VOE, and a lower benthic biomass.

The side channel issues focussed on the relationship between flow in the mainstem river and flow in the engineered side channels of the North Vancouver Outdoor School. These issues arose and persisted due to the lack of knowledge about mainstem/side channel flow interactions, and the fact that without data, no PMs could be introduced to address the side channel issues. Table 6.4 summarises the CC's bimodal preferences between lower and higher flow alternatives (15-20Min3-7Dam hybrid and 20Min7Dam alternatives).

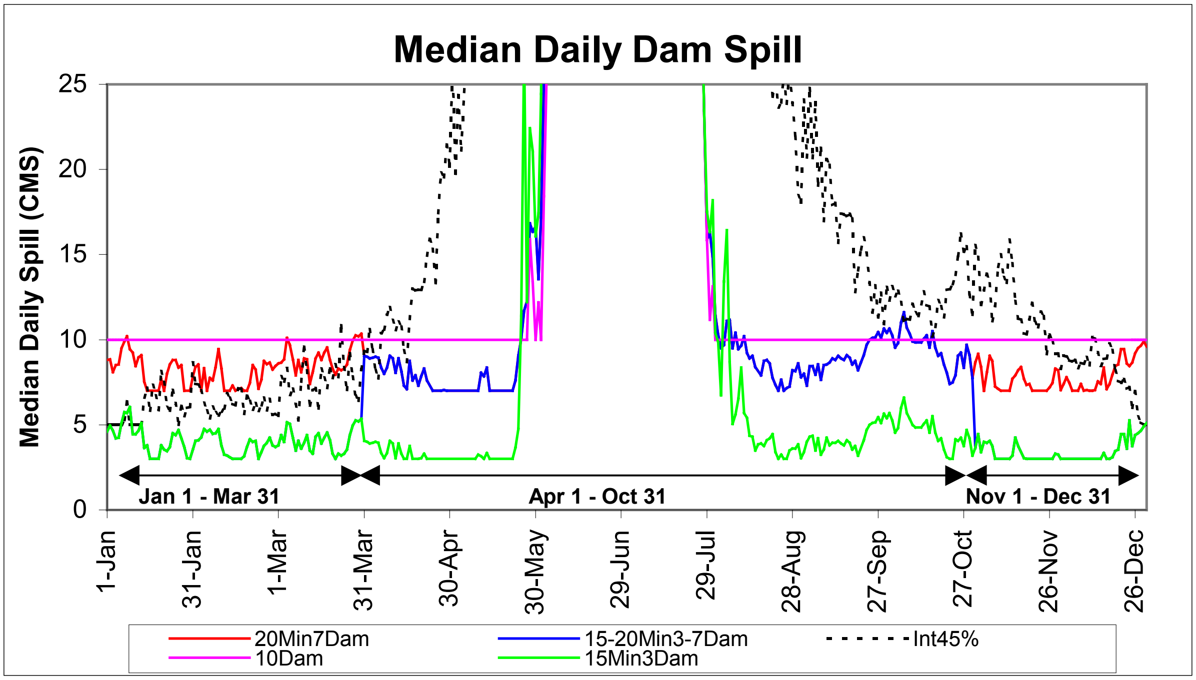

Figure 6.6: Median daily Daisy Dam spill for 15-20Min3-7Dam and 20Min7Dam. 10Dam and 15Min3Dam are shown because they were the highest and lowest flow alternatives under consideration on October 24th, 2001. The IFA (Int45%) is shown for comparison (dashed line).

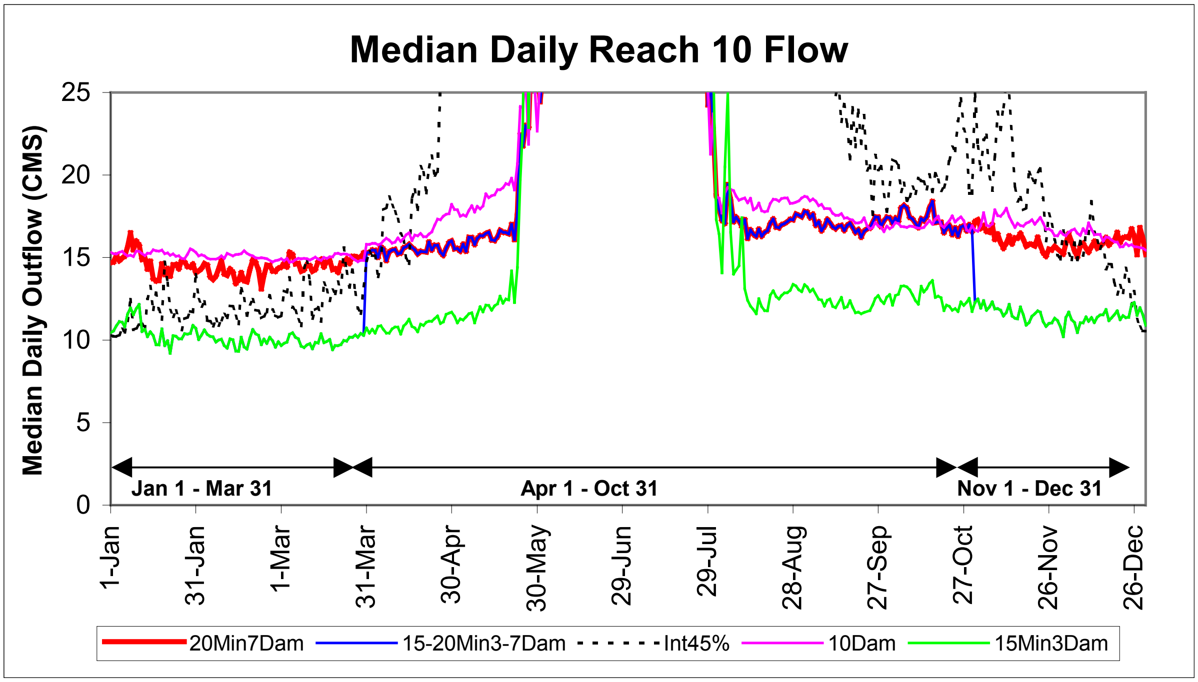

Figure 6.7: Median daily Reach 10 (resident fish) flow for 15-20Min3-7Dam and 20Min7Dam. 10Dam and 15Min3Dam are shown because they were the highest and lowest flow alternatives under consideration on October 24th, 2001. IFA (Int45%) is shown for comparison (dashed line).

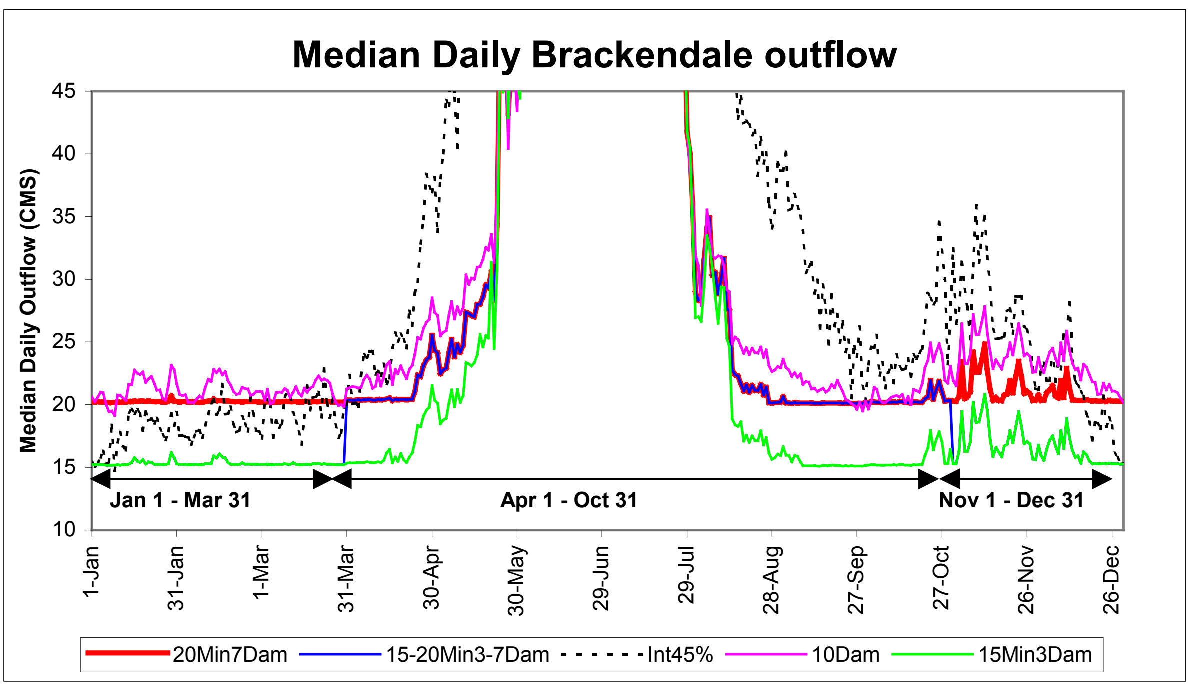

Figure 6.8: Median daily Reach 3 (Brackendale gauge) flow for 15-20Min3-7Dam and 20Min7Dam. 10Dam and 15Min3Dam are shown because they were the highest and lowest flow alternatives under consideration on October 24th, 2001. IFA (Int45%) is shown for comparison (dashed line). Note that y-axis scale starts at 10 cms, instead of zero as in Figures 4.6 and 4.7.

Table 6.3: Consequence table for alternatives at the October 24th CC meeting. The highlighted 15-20Min3-7Dam and 20Min7Dam alternatives were the most preferred options at this meeting. The results for the IFA (Int45%) alternative are shown for comparison.

Fundamental Objectives	Performance Measures	Alternatives					
		15Min3Dam	15Min5Dam	15-20Min3-7Dam	20Min7Dam	10Dam	IFA
1. Maximize economic returns from power generation.	Average power revenue ($M/yr)	35.6	34.8	34.3	32.3	31.8	26.9
2. Protect integrity of SFN heritage sites and cultural values.		Addressed by flood PMs and other studies					
3. Maximize physical conditions / access for recreation (kayaking, rafting, sportfishing).	Kayaking (Avg. #days/yr)	124	138	200	242	204	199
	Sportfishing (Avg. #days/yr)	58	72	83	193	122	107
5. Maximize wild fish populations	**($\times 10^3$ m^2)**						
RUA Resident Habitat	Rainbow Parr	35.8	37.7	42.5	42.5	45.2	40
Effective Spawning Area	Chum	9.8	9.2	9.7	7.3	6.5	6
6a. Maximize area and integrity of aquatic ecosystem	Resident Riffle Benthic Biomass (g $\times 10^6$)	3.4	3.5	2.9	2.9	3.0	2.2

Table 6.4: Primary concerns of CC members with the two most preferred / acceptable alternatives at the Oct. 24th meeting.

CC Concerns with 15-20Min3-7Dam Hybrid	CC Concerns with 20Min7Dam
Side channels: Winter flows may be too low to maintain groundwater-dependent side channels, particularly Kisutch, potentially causing reduced fish production in side channels. (See Appendix 7-C for side channel maps) Water intake to surface water fed side channels (e.g., Far Point) may not function well at flows less than 20 cms.	**Side channels:** The side channels were originally designed to operate at lower flows than 15 cms, so 20 cms flows should not be necessary for these channels to function well. Engineering improvements should be possible to deal with concerns about operation at lower flows (e.g., mechanical improvements to Kisutch; improvements to water intake of Far Point). The IFA had flows of 10 cms at Brackendale during the winter of 2000-2001, lower than 15 cms.
Fish production: Chum are abundant in side channels, and therefore it's less critical to maintain a lower flow (i.e., 15 cms instead of 20 cms) for mainstem chum production. The mainstem should be optimized for species like chinook. The hybrid has less wetted area in winter in resident reach than 20Min7Dam alternative. Minimum dam release is less than current level.	**Fish production:** Chum have 25% less effective spawning area in the mainstem with 20Min7Dam than with the 15-20Min3-7Dam Hybrid. Chum is the salmonid most limited by spawning habitat. Side channel chum production is less valuable ecologically than mainstem production. Wetted area in resident reach more important in summer than winter, since rainbow trout eggs incubate in summer.
Recreation: 15-20Min3-7Dam Hybrid has only half as many sportfishing access days as 20Min7Dam due to higher flows in Nov. - Dec.	**VOE:** 20Min7Dam has 6 % less VOE than the 15-20Min3-7Dam Hybrid ($2 million/year).

6.5 Detailed Summary of Final CC Evaluation Meeting (January 11th, 2002)

6.5.1 Pre-reading Package and Proposed Strategies for Reaching Consensus Considered at the Final Evaluation Meeting (January 11th, 2002)

This section summarizes the pre-reading package sent to the CC prior to the final meeting.

Although the October 24th meeting ended without consensus on a single operating alternative, many CC members felt another meeting would be fruitful and could perhaps lead to consensus. The WUP Project Team supported this idea and co-ordinated a final CC meeting for January 11th. Consensus was believed to be a possibility because despite the split in preferences between higher and lower flow alternatives on October 24th, the difference in flows and performance measures between the two most preferred and acceptable alternatives were narrow and the issues of concern clear. The key issues blocking consensus were that winter flows under the 15-20Min3-7Dam hybrid might not be sufficient to maintain the quality of spawning and rearing habitat in groundwater fed side channels and that winter flows with the 20Min7Dam alternative would reduce chum effective spawning area in the mainstem. In addition, there was large scientific uncertainty about the relationship between mainstem flow, groundwater flow in side channels, and side channel fish production.

Prior to the January 11th meeting, the Facilitation Team provided an agenda document to summarize the status of the WUP process. This document clearly articulated the factors contributing to non-consensus on October 24th and proposed potential methods for addressing the issues of contention so the CC could move towards consensus. The following sections outline the main topics discussed at the January 11th meeting prior to the CC's rating of operating alternatives.

6.5.1.1 Challenges in Reaching Consensus and Proposed Approaches for Resolving Disagreements

Points of Agreement

As of the Oct. 24th meeting, the CC had agreed on several general points.

- CC members had agreed on six fundamental objectives (key objectives being debated are "Maximizing wild fish populations" and "Maximizing economic returns from power").
- CC had accepted the proposed set of PMs presented at their April 30th meeting, though since September other factors not in the original set of PMs (e.g., fish production from engineered side channels, value of natural hydrograph) were raised as concerns.
- CC members preferred alternatives that had 20Min7Dam from April 1st to October 30th.
- CC members had agreed on the general thrust of the monitoring plan developed by the FTC regardless of which alternative is implemented (reviewed at September 7th meeting).
- CC members agreed on the importance of a coordinated approach for future habitat improvements with water use planning and taking an integrated watershed approach (though the best forum for doing this still needs to be determined).
- Most CC members favoured a passive Adaptive Management approach over an active Adaptive Management approach because they thought it would be better to assess the 'best' alternative first before switching to something else.

Points of Disagreement

<u>Disagreements on Values</u>

As of the October 24th meeting, there were also some differences in values which needed to be considered if the CC would reach consensus, in particular the relative importance of mainstem fish production vs. production from engineered side channels; and the relative importance of chum versus other species. This in turn led to disagreements about the value of the FTC's performance measures, analyses and studies.

With respect to the first issue, some CC members saw engineered side channels as restoring the original river as close to what it was before the dam as possible given existing flood control dykes (see comment by NVOS representative in Appendix 9). They felt that side channels should be watered for optimum fish production and wetland ecosystem health, not just kept from drying out. Some of these CC members wanted to see more engineered side channel projects, and to this end wanted higher flows in the river to supply these projects. Though these CC members had agreed to a final set of performance measures in the April 30, 2001 meeting (and had agreed to future groundwater monitoring post-WUP) they were frustrated at the absemce of performance measures for engineered side channels (e.g., NVOS comments in Appendix 9). Other CC members considered fish production from engineered side channels as less important than mainstem production. They felt that since these side channels were engineered to function under the flows that existed prior to the Interim Flow Agreement (i.e., less than the flows currently being considered), they should be able to function under any of the current alternatives. They did not want to see more emphasis placed on engineered side channels if they would directly or indirectly harm mainstem production.

With respect to the second issue, some CC members were less concerned about mainstem chum production, and felt that chum had lots of spawning habitat available to them in side channels. Other CC members felt that chum were he salmonid most limited by mainstem spawning habitat area (which was reflected in the FTC's work) and therefore very important for deciding on operating alternatives.

Ideally, the selected operating alternative would maintain both mainstem chum production and side channel conditions.

Disagreements on Technical Information

Scientific Uncertainties

The FTC used an impact hypothesis process to clarify scientific uncertainties, many of which were reduced by FTC studies (Appendix 4). The same approach was proposed to address CC concerns about remaining scientific uncertainties. Figure 6.9 shows a simple conceptual diagram (or impact hypothesis) of how dam operations might affect fish production in both the mainstem and engineered side channels.

Effects of Dam Operations on Side Channe lFish Production

One of the key uncertainties discussed by the CC is the extent to which dam operations can affect side channel fish production via changes in the groundwater flow and wetted area of side channels, as a result of changed groundwater seepage from the river (i.e., links 5-2-3 in Figure 6.9). These potential impacts also depend on the relative importance of river flow and direct precipitation / regional groundwater in maintaining the wetted area of side channels (i.e., link 1 vs. link 2). Data to better understand links # 1 and 2 in Figure 6.9 (i.e., hydrology) could be collected fairly quickly (lots of contrasts in flows and weather are possible over a single year). Data to assess link 3 (effects of wetted area on fish production) will require 1 year for each data point. Due to this slower accumulation of information, it is generally felt that 5 to 10 years of data are required to assess impacts, but a detailed analysis must be done to be more specific about the length of time.

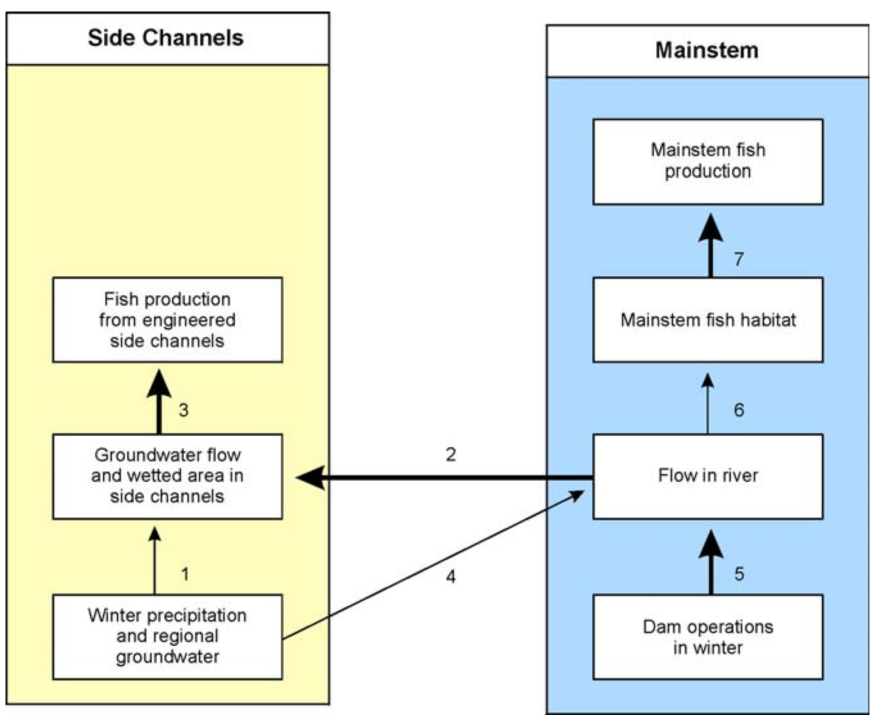

Figure 6.9: Impact hypothesis illustrating some key scientific uncertainties. Critical uncertainties pertaining to hydro operations are shown with thicker arrows.

Proposed Short-term Monitoring to Reduce Scientific Uncertainties Related to Groundwater in Side Channels

As a point of discussion, the WUP Project Team proposed to the CC a possible strategy for dealing with this uncertainty (Figure 6.10). First, choose an alternative that is believed to sustain fish production from engineered side channels. Second, conduct quick short-term monitoring to better understand the hydrologic uncertainties (links 1 and 2 in Figure 6.9). Third, if problems are apparent at the recommended WUP flows, modify the engineering of these side channels and/or flows as appropriate to deal with these problems. Fourth, learn more over time about the linkages between wetted area and fish production (link 3 in Figure 6.9). Finally, once enough data have accumulated to evaluate the impacts of the operating alternative on fish production (e.g., 5 to 10 years of data), then either continue operations (if fish production is satisfactory), or re-initiate the WUP process to revise operations.

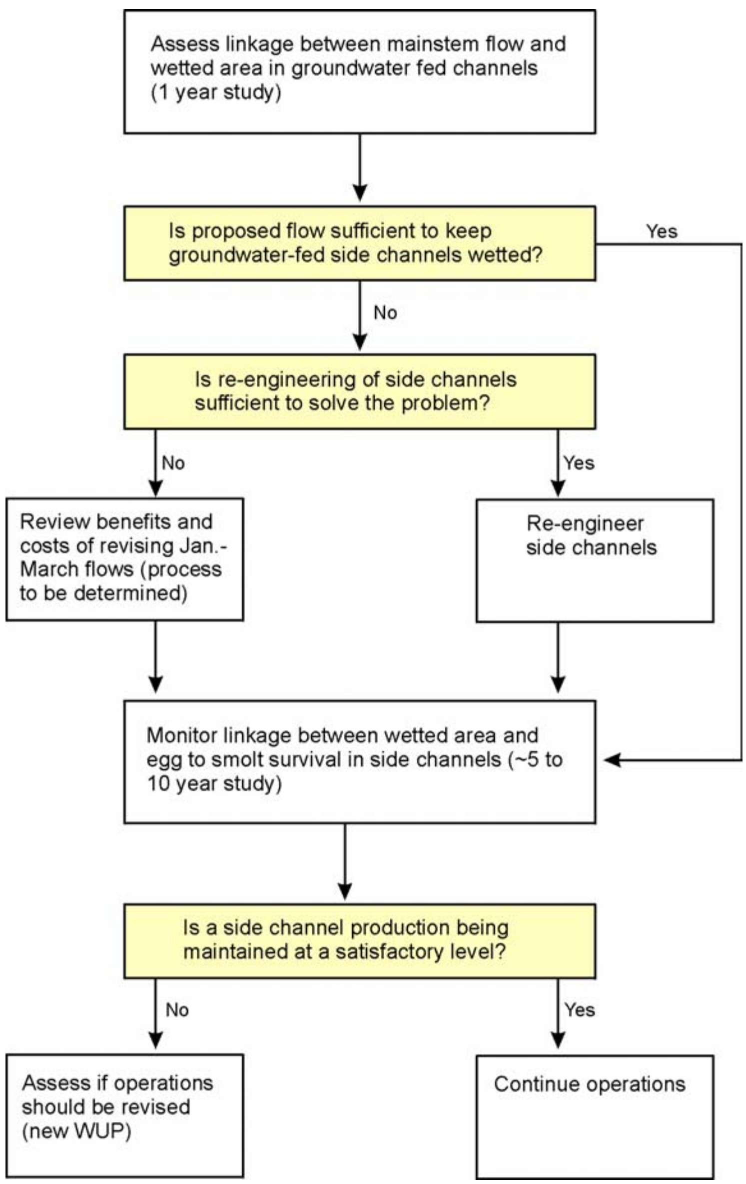

Figure 6.10: Proposed decision process for monitoring side channels and, if necessary, re-engineering them, or revising winter flows. Decision points are shown with shaded boxes.

Effects of Dam Operations on Mainstem Fish Production

Another uncertainty is the strength of the link between the fish abundance and fish habitat PMs developed by the FTC for choosing between alternatives. The FTC has always maintained that their PMs are not meant as absolute predictions, but are useful for the relative evaluation of operating alternatives. However, habitat is only a proxy for fish production and it is uncertain whether changes in fish habitat PMs in response to flow (e.g., area of preferred habitat) accurately reflect the true population responses to particular flows (e.g., smolts per spawner). While the FTC work determined the effects of flow on habitat (link 6 in Figure 6.9), there remains uncertainty about the population responses (link 7).

The WUP Project Team proposed to the CC a possible strategy to deal with uncertainties in mainstem fish production. First, choose an alternative that is expected to generate suitable fish habitat conditions in the mainstem, based on the FTC work. Monitor fish production (particularly smolts/spawner) in both the Cheakamus River and the Mamquam River (the selected control river) over time, and other ecological indicators to understand how the system is changing (i.e., riparian vegetation, nutrients, periphyton, benthos). Re-evaluate operations in a new WUP process once enough data have been accumulated (about 10 years). Evaluating fish population responses in the mainstem will require more effort and time than in side channels due to the fact that populations are more dispersed and population estimates less precise. More details about the methods that would be used for this approach are provided in the monitoring plan (Section 7.1).

Proposed Intermediate Operating Alternatives for Dealing with Remaining Concerns and Disagreement in Values

In an effort to find consensus, the WUP Project Team sought to find operating alternatives which would both maintain chum production in the mainstem and provide more winter flows for side channels. Chum spawn from November through December. The FTC model for chum effective spawning area suggested that one doesn't want to increase flows during November-December or else there will be less suitable mainstem spawning habitat, and also more stranding (see Attachment 8 in notes from October 24th meeting, "23_CC Meeting Notes October 4, 2001.pdf"). However, increasing flows during the January-March period (when eggs are incubating) has no detrimental effect on mainstem chum. It *could* have benefits for side channel production, though there are no data to evaluate this at river flows less than 40 cms.

To assist the CC with their final decision on January 11th, the WUP Project Team developed two new hybrid alternatives to explore the consequences of maintaining the 15Min3Dam alternative in November and December, but increasing flows by various amounts during January to March. Table 6.5 shows the main results and the bullets below summarize the key points:

- the two most preferred / acceptable alternatives from October 24th CC meeting differ by $2 million / year in VOE and by 2,369 m^2 in median chum effective spawning area (alternatives A and D in Table 6.5);
- maintaining 15Min3Dam for November and December, but increasing Jan-Mar winter flows to **15Min5Dam** (Hybrid B) has a VOE cost of $0.3 million / year, and produces identical median chum effective spawning area to maintaining 15Min3Dam throughout Nov-March (alternatives A and B in Table 6.5); and
- increasing Jan-Mar winter flows from 15Min3Dam to **20Min7Dam** (Hybrid C) has a VOE cost of $1.3 million / year, and produces similar chum effective spawning area as maintaining 15Min3Dam from Nov-March (alternatives A and C in Table 6.5; median 200m^2 higher with alternative A, and 10th percentile 200m^2 higher with alternative C).

Table 6.5: Consequence table for the proposed final operating packages. Alternatives A and D are the two most preferred options from the October 24th CC meeting. The two operating packages in the middle columns: (B and C) are example intermediate alternatives that attempt to deal with CC concerns about alternatives A and D. They serve to demonstrate the costs and potential benefits of maintaining different winter flows. Time periods for each alternative that differ from the other alternatives are bolded. "Other information" provides supplemental (non-PM) information about the effects of these alternatives during low flow periods and for side channels.

	Alternative			
	A. Hybrid	**B. Revised Hybrid 'B'**	**C. Revised Hybrid 'C'**	**D. 20Min7Dam**
Period: Nov. – Dec	15Min3Dam	15Min3Dam	15Min3Dam	20Min7Dam
Jan. – Mar.	15Min3Dam	15Min5Dam	20Min7Dam	20Min7Dam
Apr. – Oct.	20Min7Dam	20Min7Dam	20Min7Dam	20Min7Dam
Rationale for Alternative	preferred at Oct. 24 mtg.	maintain chum PM and current minimum dam release for resident reach	maintain chum PM; higher winter flow for resident reach, side channels	preferred at Oct. 24 mtg.
Key PMs that differ among alternatives:				
Median Chum effective spawning area (50th percentile) (10th percentile-90th percentile)	**9,672** (6,220 – 10,651)	**9,672** (6,220 – 10,651)	**9,471** (6,423 – 10,568)	**7,303** (5,781- 8,817)
VOE ($ * 10^6)	**34.3**	**34.0**	**33.0**	**32.3**
Other information (not PMs):				
Median Jan.-Mar flow (10th –90th percentile) at Brackendale	15 cms (15 – 27.1)	16 cms (15 – 29.1)	20 cms (20 – 31.1)	20 cms (20 – 31.1)
# years in which Jan-Mar flow drops below target flow*	1/32	1/32	8/32	10/32
Side channel fish production	unknown	unknown	unknown	unknown
Implementation of alternatives:				
	• implement now • monitor flow - groundwater link in side channels (1 year study); • if necessary, recommend re-engineering side channels • if necessary, modify winter flow (move up or down within agreed range, e.g., 15-20 cms) to provide appropriate groundwater flow to side channels • implement other elements of monitoring plan • re-initiate WUP process when sufficient data collected on link between flow and fish production (at least 10 years)			

* This refers to flows being below the target for one or more days. This information is important to understand how this alternative may be implemented in a regulatory case: i.e., it would be a "target minimum" not an "absolute minimum", otherwise compliance would not be possible.

6.5.2 Values and Preferences expressed at the Final Evaluation Meeting

The January 11th meeting began with a review of the agenda and the opportunity for CC members to comment on the October 24th meeting notes (there were no comments). The Facilitator then reviewed the material presented in Section 6.5.1. The CC members rated the final alternatives providing written confirmation of the rationale for their preferences. The CC then reviewed the revised draft monitoring plan and rated its components. Finally, the CC reviewed and rated other recommendations developed over the course of the WUP process. The results for these topics are in Sections 7.1 and 7.2. The following sections summarize the results of the January 11th meeting. The full meeting notes are in "25_CC Meeting Notes January 11th, 2002.pdf".

6.5.2.1 Preliminary Discussions

Preliminary CC discussions focused on the topics outlined in Section 6.4. The bullets below summarize the main points that were raised during these discussions. Their main focus was side channels, groundwater upwelling and chum salmon.

- *Required flows for side channels:* Carl Halvorson (NVOS) noted that Farpoint channel was designed for flows of 0.8 cms (minimum design flow); however if the network of engineered side channels eventually reaches the Squamish River, they will need 2.5 cms. Steve Macfarlane noted that the Power Optimal alternative (dropped May 28/29 2001) represented the conditions under which the side channels at NVOS were constructed (median flows of about 12 cms at Brackendale). Now, the alternatives under consideration produce flows of about 15-20 cms, so there will actually be flows added to the side channels. Carl Halvorson noted that the amount of side channel habitat at NVOS does not change with flow, but its quality does. (Additional NVOS comments on side channels are in Appendix 9)
- *Effects of flows on groundwater levels:* Doug McDonald (SLRD) asked Carl Halvorson if the dyking and rip rap reinforcement work by the CMS Task Team (1995/96) to control the river had led to a reduction of groundwater upwelling in the NVOS side channels. He felt that this could occur if more downcutting through increased scour changed how the river fed the floodplain aquifer. If so, he felt that raising the riverbed could be a solution. Carl Halvorson noted that the work of the CMS Task Team did not change the flood plain, They only went as far as building berms for protection from flows. They did not build dykes. Conditions on the flood plain have changed, but not because of the Cheakamus Task Team's works.
- *Knowledge of groundwater-side channel linkages:* Lyle Fenton (Cheakamus resident) asked if the FTC fish habitat models still did not consider engineered side channel habitat. The Facilitator replied that the models could not link changes in side channel habitat to flow because there are very few data points on groundwater at river flows below 40 cms. He explained that side channels were considered qualitatively by developing hybrid alternatives that vary flows by time of year to meet different requirements (i.e., lower flows in Nov/Dec for chum spawning; higher flows in Jan-Mar for side channels) and also through the monitoring plan, specifically the 1-year program looking at groundwater in side channels.
- *Relative importance of mainstem and side channels:* James Bruce noted that with respect to the issue of side channels vs. the mainstem habitat, chum in the mainstem provide a number of ecosystem values such as gravel mining, food for eagles and other animals. The FTC wanted to consider a functioning ecosystem. Lyle Fenton noted that he disagreed that side channel habitat was less valuable than mainstem habitat. He felt that chum seem to be the least threatened species and that DFO is merely looking for the most fish. Lyle Fenton stated that engineered side channels need to be considered in an ecosystem approach. Doug McDonald said that DFO could be using chum as an indicator species. Carl Halvorson noted that spiking mainstem flows in the fall and winter can flush out chum carcasses, and potentially chum redds, and that side channels

served as refuges from such conditions. Brent Lister commented that these were very rare events. James Bruce added they were natural and uncontrollable events. John Werring said the objective of the WUP was not to put chum in side channels – it's not an either/or situation.

- *Uncertainties in habitat-fish production linkage:* Steve Macfarlane noted that uncertainty about the relationship between habitat and fish production happens everywhere and is not particular to the Cheakamus WUP and that the only way to deal with this uncertainty is to collect data. Doug McDonald noted that the CC now knows more about most things in the Cheakamus system than they did when the WUP started.
- *Uncertainties in flow-habitat linkage:* Brent Lister (SN, FTC) spoke to Carl Halvorson's (NVOS) and Matt Foy's (DFO, habitat restoration biologist), concern that the chum spawning Habitat Suitability Index spawning the FTC used to model chum effective spawning area ignored groundwater upwelling (see Appendix 7-B). Brent noted that the FTC used data from Big Qualicum River for depth and velocity information and data from other areas for substrate (see description of Effective Spawning PM in Appendix 2-D.1). Brent added that in the majority of cases, chum are seeking a surface environment, looking for riffles. He noted that historically, side channels in the Cheakamus had higher flows when access to channels now on NVOS property was provided. Now, they are sometimes are cut-off from mainstem during dry winters and chum must then rely on upwelling, but chum are adapted to deal with these conditions. Steve Macfarlane noted that 250,000 chum arrived below Stave Dam to spawn and there is no upwelling there. James Bruce (FTC) noted that the chum effective spawning PM is a weighted area that includes areas of upwelling and that the actual area used by chum would be less than the estimate. Carl Halvorson (NVOS) felt the chum results were counterintuitive and contradictory and if they are so adaptable, then why worry about them? He felt that we don't know what chum want, and that there may be a connection between groundwater in the channels and mainstem flow, we just don't know yet. He felt that groundwater-fed side channels offered some of the best habitat for chum. Subsequent to the January 11th meeting, Carl Halverson sent additional comments on this issue (included as an Attachment to the meeting notes, "25_CC Meeting Notes January 11, 2002.pdf").
- *Proposed short term monitoring proposal (Figure 6.10):* John Werring wondered: 1) if monitoring would even take place; 2) how the proposed monitoring sub-committee would work (i.e., who would be on it and who would make decisions); and 3) if DFO would buy into re-engineering side channels if this were the solution.

6.5.2.2 Preferences for Operating Alternatives

The CC did not reach consensus on an operating alternative. Each of the four alternatives presented to the CC for evaluation was blocked by at least four CC members (5 to 6 for alternatives A and B) (Table 6.1). Participants were permitted to express a preference for alternatives other than the four presented. Eight of the 16 CC members preferred continuing the Interim Flow Agreement (IFA, status quo) for approximately another 3-5 years to provide information to thoroughly assess its effects. One of these 8 CC members favoured an adaptive management program that monitored the IFA for about 5 years before switching to the 15Min3Dam alternative. One CC member expressed a preference for the 15Min3Dam alternative. Table 6.6 summarises the preferences of individual CC members. Table A7.1 (Appendix 7-A) presents their detailed responses. Table 6.7 presents the performance measure results for the final set of preferred alternatives.

The major reasons given by CC members who preferred the IFA were:

- uncertainty about the relationship of fish to flow, specifically for groundwater fed side channels;
- likelihood that flows would not go up in future if a lower flow alternative was implemented; it was easier to see flow being reduced from higher flow alternatives; and / or
- uncertainty about the effects of the IFA; the IFA has not been in place long enough to measure these and it is important to have good baseline information against which future changes can be assessed.

The major reasons given by CC members who preferred the Hybrid alternatives (and 15Min3Dam) were:

- higher performance for chum effective spawning area PM;
- improved performance for rainbow trout parr habitat;
- higher performance for Value of Energy (VOE) PM; and
- higher flow alternatives reduce VOE with no apparent benefit in other PMs (and detrimental effects on PMs with IFA).

After each member had presented their preferences to the group, the Facilitator asked the eight CC members who had not preferred the IFA if they would object to bringing the IFA back onto the table for consideration. Four said they would not be part of a consensus that included the IFA while three said they would not object to the IFA. The member for the District of Squamish noted that the District's concerns regarding flooding were met in all alternatives. He was, therefore, comfortable supporting any of the proposed alternatives, though in particular he supported the results of the FTC work (i.e., Alternative "A") with a caution that monitoring is critical to the long-term success and acceptance of any WUP for the Cheakamus River.

Several CC Members submitted written statements in support of their preferences:

> Dave Brown (Whistler Angling Club), was unable to attend the meeting due to work commitments and submitted his preferences by email to Lyle Fenton. Lyle filled in and submitted a preference rating form on Dave Brown's behalf based on this email statement. Dave Brown's email statement has been transcribed and is found in Table A7.1 (Appendix 7-A). Mr. Brown did not provide preferences for alternatives A, B, or C, so these cells are blank in Tables 6.7 and Table A7.1.
>
> Randall Lewis (Squamish Nation) read aloud and then submitted for the record the Squamish Nation's position with respect to the WUP process and their preferred operating alternative. The statement noted that the WUP process alienated SN aboriginal rights. It also raised a concern about the unfortunate choice of wording associated with the SN objective in the consequence tables used for summarising performance measures. The wording implied that SN issues would be re-examined " . . . if necessary". The phrase meant that the original concerns about the impact of flooding and erosion on SN cultural and heritage sites were already considered by the flooding PM. Since flooding risks were low, and equal across all alternatives, there was low risk to Squamish Nation Cultural and Heritage sites, as determined in an independent study conducted for the Squamish Nation (see Section 4.2.2). Cam Matheson (BC Hydro) suggested that a better way to phrase this would be "Squamish Nation objectives were considered inherently in the existing PM set". The Statement also questioned the wisdom of changing from the IFA, especially when there seems to be so much uncertainty about the Cheakamus system and after the strong salmon returns, especially pinks, this year. The full statement has been transcribed and is in Table A7.1 (Appendix 7-A). Randall did not provide preferences for alternatives A, B, C and D so these cells are left blank in Tables 6.7 and Table A7.1.
>
> Carl Halvorson (NVOS) also submitted a written position in support of his preferences. Carl's main concerns were the large uncertainty documented in the monitoring plan that the FTC developed for the CC,

> the fact that under the IFA the Cheakamus had just had one of its finest salmon returns in a long time, and that flows needed to be increased in the upper reaches of the river for resident fish populations. Carl proposed that the IFA might be tweaked to squeeze out more VOE. For example, flows in excess of those required to produce 60 cms at Brackendale could be diverted to the powerhouse. He also suggested that the minimum release from the dam needed to be increased to 7 cms. Carl's statement has been transcribed and is in Table A7.1 (Appendix 7-A). An earlier statement that Carl sent to the CC just prior to the meeting (sent January 9th, 2002) further elaborates his rationale for not preferring lower flow alternatives (Appendix 7-B).

Doug McDonald (SLRD) asked that his suggestions expressed during the discussion of preferences, and noted on Appendix 7, Table A7.1 be brought forward:

> Doug Mcdonald (SLRD) suggested that higher initial flows should be put in place with a mechanism in place that would allow for future reduction of flows if Hydro does certain works to enhance fish production (e.g., put gravel from Roe Creek back to mainstem, put reservoir debris back into mainstem, building civil works to improve or increase lower river salmon habitat, artificial feeding, etc.). Monitoring results should determine what eventual minimum flow should be.

Table 6.6: Summary of Preferences for Operating Alternatives from the January 11th meeting. Alternative: A. Hybrid, B. Revised Hybrid "B", C. Revised Hybrid "C", D. 20Min7Dam (see Table 6.5). Preference: 1. "Preferred"; 2. "More Acceptable"; 3. "Less Acceptable"; 4. "Not Part of Consensus if selected" *(i.e. Blocked)*. The information in this table comes from preferences, written statements and submissions. Table A7.1 of Appendix 7-A has the detailed comments of each CC member.

	A	**B**	**C**	**D**	
CC Member	Hybrid	Hybrid "B"	Hybrid "C"	20Min7 Dam	**Other Comments**
Dave Brown Whistler Angling Club (by proxy)				3	IFA preferred
Dave Cattanach BC Hydro	1	2	3	4	**Would not be part of consensus with IFA
W.R. Dickinson Squamish Residents	3	3	3	1	IFA preferred (another 3-4 years), but if not possible, then prefers 20Min7Dam.
Lyle Fenton Cheakamus Residents	4	4	4	No rating	IFA preferred
Carl Halvorson NVOS	4	4	4	3	IFA preferred
Randall W. Lewis Squamish Nation					IFA preferred
Steve Macfarlane DFO	2	1	3	4	**Would not be part of consensus with IFA
Doug McDonald SLRD	3	3	2	1	**No objection to IFA
Jas Michalski District of Squamish	2	2	2	2	All alternatives meet concerns about flooding.
Denise Mullen-Dalmer MEM	2	2	3	4	**Would not be part of consensus with IFA
Ross Neuman WLAP	*2/4	*2/4	*2/4	*2/4	*rating of 2 is conditional on keeping IFA for 5 more years. Preferred 15min3Dam after this period, but any of ABCD is acceptable. But without IFA, none of A, B, C, D acceptable (rating of 4).
Jim Schellenberg Coast Guard	3	3	3	2	**No objection to IFA
Ken Spafford, BC Hydro	2	3	4	4	15Min3Dam preferred **Would not be part of consensus with IFA
Edith Tobe SWRS	4	4	4	2	IFA preferred (5-10 years)
Rob Way ORC	4	4	3	2	IFA preferred (3-5 years)
John Werring SLDF	4	4	3	1	**No objection to IFA (should keep for approx. 3 years, review monitoring, then possibly 20Min7Dam for 5 years)
**In response to question: "Would you object to bringing the IFA back for consideration?" Asked by Facilitator of those CC members who had not stated a preference for the IFA during the initial rating discussions.					

Table 6.7: Consequence table for the final preferred alternatives. This table compares the performance measure results by objective across the final preferred alternatives at the final CC evaluation meeting, January 11th, 2002. Alternatives "A", "B", "C", and "D" were proposed to the CC prior to the meeting. Some CC members also preferred the 15Min3Dam and IFA alternatives at the meeting.

Fundamental Objectives	Performance Measures	Alternatives					
		15Min3Dam	15-20Min3-7Dam "A"	15-20Min3-5-7Dam "B"	15-20Min3-7Dam "C"	20Min7Dam "D"	IFA
1. Maximize economic returns from power generation.	Average power revenue ($M/yr)	35.6	34.3	34.0	33.0	32.3	26.9
2. Protect integrity of SFN heritage sites and cultural values.		Addressed by flood PMs and other studies					
3. Maximize physical conditions / access for recreation (kayaking, rafting, sportfishing).	Kayaking (Avg. #days/yr)	124	200	202	222	242	199
	Sportfishing (Avg. #days/yr)	58	83	142	125	193	107
5. Maximize wild fish populations	($m^2 \times 10^3$)						
RUA Resident Habitat	Rainbow Parr	35.8	42.5	42.5	42.5	42.5	40
Effective Spawning Area	Chum	9.8	9.7	9.7	9.5	7.3	6
6a. Maximize area and integrity of aquatic ecosystem	Resident Riffle Benthic Biomass ($g \times 10^6$)	3.4	2.9	2.9	3.0	2.9	2.2

Comparison of Final Alternatives to the Interim Flow Agreement (IFA) and Illustration of Trade-offs

Figure 6.11 further illustrates the trade-offs between the performance measures shown in Table 6.7 that were of most interest during evaluation discussions (VOE, chum effective spawning area, and resident rainbow rearing area). The figure provides two types of information. First it shows how the performance measures behave relative to the IFA. Second, it shows how the alternatives behave relative to one another for a particular performance measure (i.e. trade-offs).

With respect to the IFA, the VOE PM shows a steady decline as flows increase (moving from left to right), but the PM is still are higher than the IFA, ranging from 32% better for 15Min3Dam to 20% for 20Min7Dam. The chum effective spawning PM stays at a relatively constant at approximately 60% better than IFA until 20Min7Dam where is drops sharply, but is still 20% better than the IFA. The resident rainbow parr PM is closest to the IFA being 10% worse than IFA at 15Min3Dam and a constant 6% better than the IFA for the remaining alternatives. The latter result occurs because alternatives A, B, and C were developed to address CC concerns about poor resident rainbow rearing area at lower flows (e.g., 15Min3Dam). Each alternative maintains a 20Min7Dam component over the rearing period for resident rainbow, so the results are identical to those for the 20Min7Dam alone alternative.

With respect to trade-offs between performance measures, Figure 6.11 shows that the trade-off between chum effective spawning area and rainbow parr rearing area was virtually eliminated under the three hybrid alternatives (A, B, and C). Both PMs are better than for the IFA and remain constant (resident rainbow) or relatively constant (chum) across increasing flows (moving left to right). There is still something of a trade-off between resident rainbow and VOE. Though the resident rainbow PM remains constant across A, B and C, VOE shows a decline. However, as noted above, VOE is still 32% to 20% better than for the IFA.

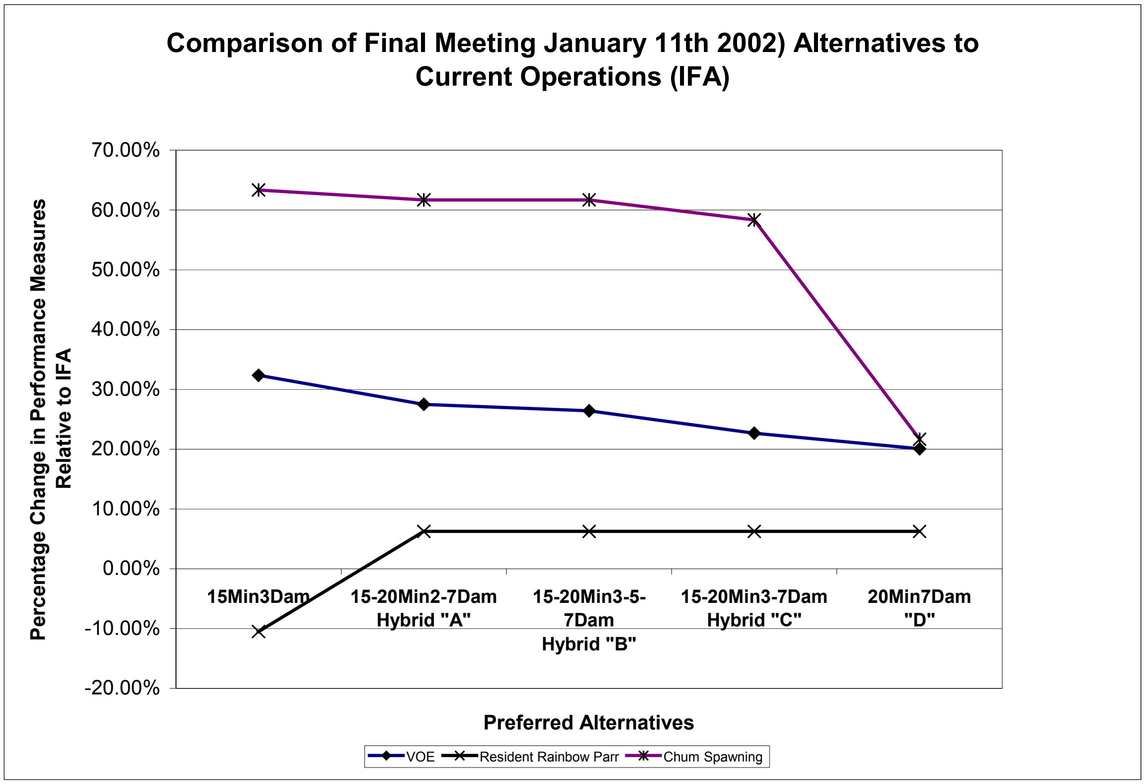

Figure 6.11: Trade-offs between alternatives at final evaluation meeting (January 11th, 2002) relative to the IFA. This figure illustrates the trade-offs between alternatives in Table 6.7 for the performance measures of most interest (VOE, Resident rainbow parr, and chum spawning). The results are expressed as the percent change in a performance measure relative to the IFA. A positive value means the PM is better than for the IFA; a negative value means the PM is worse than for the IFA.

Issues Raised during Discussions of Ratings for Operating Alternatives

Two process issues arose during discussion around CC preferences for the operating alternatives. The first issue was CC members submitting preferences although they previously had attended few CC meetings, and had not actively participated in the evaluation process (Dave Brown, Whistler Angling Club and Jim Schellenberg, Coast Guard). The second issue was the move towards putting the IFA (Interim Flow Agreement, Int45%) alternative back on the table. With respect to the issue of participation, Dave Brown (Whistler Angling Club) passed his preference by email to Lyle Fenton who submitted a copy of the email at the meeting and filled out a rating sheet on Dave Brown's behalf. Neither Dave Brown nor his alternate attended any of the six evaluation meetings (May 28/29 2001 to January 11 2002), or provided verbal or written feedback based on the summary packages or meeting notes (except for Jan. 11th)[9]. Some CC members protested against accepting preferences submitted by a member who had not been actively

[9] The last CC meeting that Dave Brown attended was November 1st, 1999.

engaged in the evaluation of alternatives. However, other CC members felt that his opinion was valid because he was a CC member and pointed out that he had been receiving meeting material by e-mail; therefore, he was part of the process. Doug McDonald suggested that the CC accept Dave Brown's preferences, but not let them throw any alternative off the table. Jim Schellenberg, the member for the Coast Guard felt he should abstain from stating preferences having missed most evaluation meetings[10]. However, John Werring, the CC member for the Sierra Legal Defense Fund requested that Coast Guard go on record.

With respect to the issue of re-instating the IFA, a number of CC members preferred the IFA alternative although the CC had agreed to drop it from consideration at the July 3rd/4th CC meeting. Some CC members felt that this showed a lack of respect for the agreed upon process and a return to positions (rather than using performance measures) because the PM results did not turn out as originally expected. These CC members felt that the FTC fish PMs were sufficiently reliable for decision making and that no new evidence had been presented to reject them. Other CC members felt that the re-evaluation of past alternatives was reasonable and that all alternatives were on the table until the final decision. They also felt that the FTC fish PMs were too uncertain, and that there was too much uncertainty overall, to make a decision on operations until the IFA had been thoroughly evaluated.

Process for a Non-consensus WUP

Michael Harstone (BC Hydro) reviewed the next steps for a non-consensus WUP (an email describing the process was sent out to CC members after the October 24th, 2001 CC meeting). He noted that the WUP Guidelines describe the steps in a non-consensus WUP. The facilitators would now draft the Consultative Committee Report (CCR) to accurately reflect the process and the CC would review it for accuracy. Then BC Hydro would use the information in the CCR to prepare an operations document (referred to as a Water Use Plan) to submit to the Provincial Comptroller of Water Rights along with the CCR. The Comptroller then decides on an operating alternative and sends the plan out according to the referral process within the Water Act to the licensee (BC Hydro), responsible agencies (e.g., DFO), Squamish Nation, and affected stakeholders for their review and to gather additional feedback.

John Werring asked if BC Hydro could draft their Water Use Plan without further discussion, noting that he would feel more comfortable if the CCR report was sent to the Water Comptroller before it was sent to Hydro. Denise Mullen-Dalmer noted that the WUP consultation process was voluntary on Hydro's part and the Comptroller could not direct them about how to do it. The Facilitator said it was unlikely that the WUP operations document would be written until after completion of the CCR. Ken Spafford confirmed this, adding that the WUP would not be written until Hydro receives the CCR to make sure that they capture concerns accurately.

Monitoring and Other Recommendations

Also discussed at the final meeting were the monitoring plan and other recommendations. The monitoring plan is summarized in Section 7. Other recommendations are summarized in Section 8.

[10] The Coast Guard had only attended one other evaluation meeting (May 28th/29th, attended by John Mackie).

7.0 Monitoring Plan and Review Period

Section 7.1 describes the monitoring plan that the FTC developed with the approval of the CC. Section 7.2 describes the status of the WUP review period.

7.1 Monitoring Plan

The FTC developed a comprehensive monitoring plan with the approval of the CC. In part, the monitoring plan addresses the primary issues of concern that led to some CC members not using the previously agreed upon performance measures for selecting alternatives. These issues include the scientific uncertainty about the relationship between mainstem flows and flow in groundwater-fed side channels, and its ultimate effects on side channel fish production. Another critical uncertainty is the relative importance of fish production from side channels and the mainstem. The Consultative Committee asked that the Fisheries Technical Committee prepare a monitoring plan to reduce these and other uncertainties and to better inform future WUP decisions. At the final evaluation meeting, the CC strongly recommended many components of the proposed comprehensive monitoring plan.

Section 7.1.1 summarizes the rationale for the monitoring plan. Section 7.1.2 summarizes the monitoring plan components. Section 7.1.3 summarizes consultative committee support for these components. The full monitoring plan is on the accompanying CD-ROM (Table of Contents in Appendix 8).

7.1.1 Rationale for Monitoring

The state of Cheakamus River fish populations and associated ecosystem components should be monitored to address two fundamental questions:

1. *Are the WUP hydro operations helping to achieve the fundamental objectives for the fish and aquatic ecosystem?; and*
2. *Should there be further revisions to hydro operations in the future?*

To answer the first question we need to ***determine the status and trends*** of Cheakamus fish populations and selected ecosystem components. There are considerable uncertainties regarding the actual population responses to hydro operations. We need to confirm that selected operating alternative actually has beneficial, or neutral, effects, and has no unexpected negative effects.

To answer the second question, we need to be able to clearly ***diagnose the reasons for changes*** to fish populations and selected ecosystem components to determine if hydro operations require future changes, or if changes to hydro operations are unlikely to mitigate observed problems. Figure 7.1 is a flowchart that illustrates how future operational decisions link to monitoring. The numbered boxes in this figure summarize the key steps in the monitoring process and are summarized below.

Step 1: Implement WUP alternative(s) and other recommendations.

Step 2: Monitor status and trends of fish populations and selected ecosystem components in both the Cheakamus and a 'control' river.

Why should we "monitor the status and trends of fish populations"? The fish PMs the CC used to narrow the range of WUP alternatives were based largely on measures of habitat response. We don't know if these *habitat* responses PMs correctly anticipate the response of fish *population* in the future to flow implied in the implemented alternative. The only way to know is to carefully monitor the status and trends of fish populations. There are many uncertainties that could cause future fish population responses to be different from those anticipated by the fish habitat PMs. First, some PMs were developed without field calibration (e.g., rainbow trout RUA, effective spawning PM). Second, many PMs involved extrapolations to flows, time periods and/or spatial units beyond those sampled. Third, habitat area only limits populations at higher abundance. At lower abundance, survival rates control population abundance.

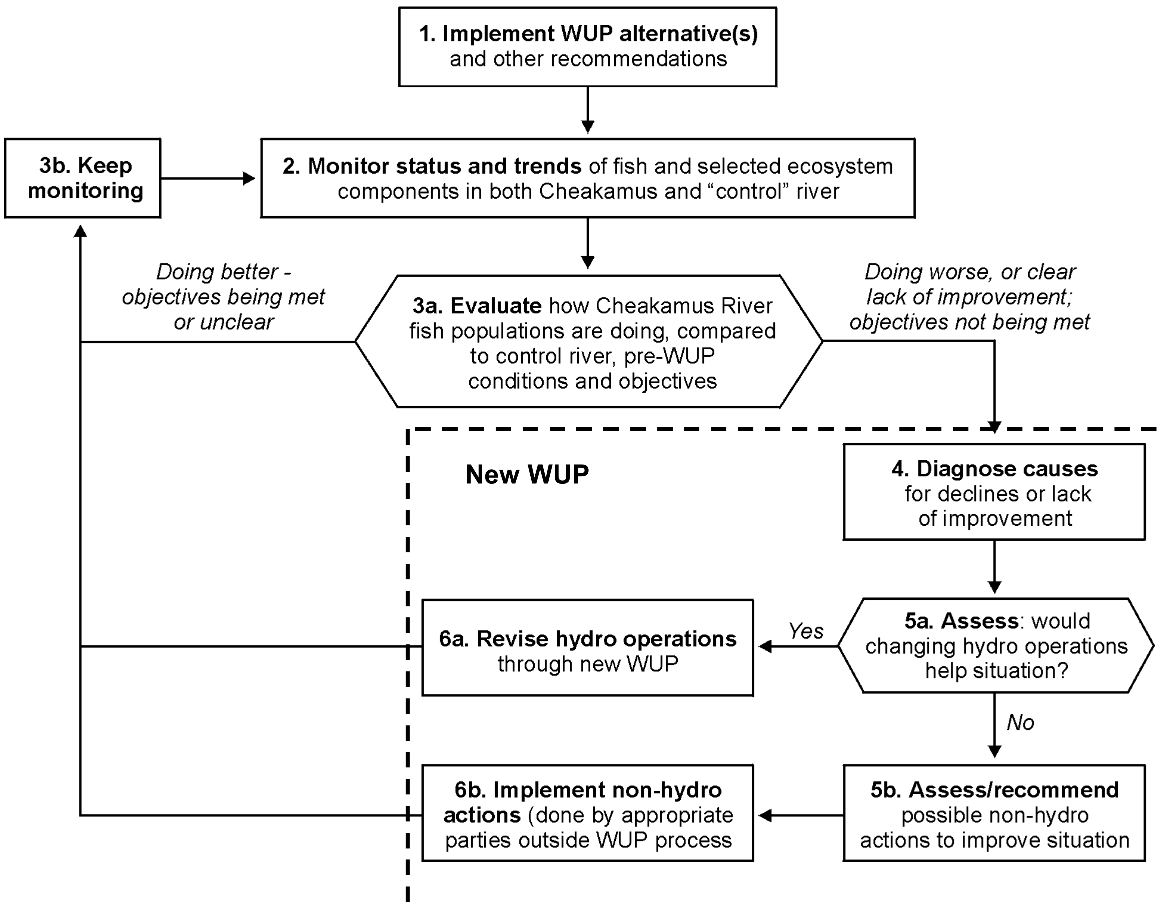

Figure 7.1: Conceptual framework for Cheakamus WUP monitoring program. Steps within the dashed box entail the re-opening of a WUP.

Why should we "monitor selected ecosystem components"? The CC selected operating alternatives based on the best information available during the WUP process. This information is based on the current condition of the Cheakamus channel and ecosystem. Hydro operations, other natural events (e.g., floods, droughts) or human factors (e.g., forestry, dykes) could change future channel and ecosystem conditions. Without proper monitoring of channel conditions and selected ecosystem components it will be difficult to correctly diagnose the reasons for future changes in fish populations, and to make the right decisions about future changes to hydro operations.

Why should we monitor both the Cheakamus and a 'control' river? Monitoring a control river is essential to distinguish among competing hypotheses of change, and for deciding whether or not to change hydro operations in the future. To illustrate this, imagine that a decade from now Cheakamus fish populations and/or selected ecosystem components have shown an unexpected decline. We would want to know why this occurred, and if hydro operations contributed to the decline. If we were monitoring only in the Cheakamus River, we would not be able to say whether the changes were due to operations alone or to some other factor. For example, regional climatic factors could be affecting all streams draining into Howe Sound similarly. Without the additional information provided by monitoring control systems we might wrongly conclude that the WUP operating alternative had caused the declines.

Step 3: Evaluate how Cheakamus River fish populations are doing, compared to control river, pre-WUP conditions and objectives.

Trends will not be immediately apparent. Hence, it may be necessary to keep monitoring for a while until trends are clear (**Step 3b Keep monitoring**). The amount of time required to detect changes will depend on the responsiveness of the monitored indicators, how variable these indicators are naturally, how precisely they can be measured, and whether or not a control system is monitored (including a control can shorten the time required to detect meaningful trends).

Step 4: Diagnose causes for declines or lack of improvement.

Diagnosis involves testing alternative hypotheses, as discussed above. Example hypotheses could include:

- H1: decline in quality of channel or substrate;
- H2: decline in abundance of fish food;
- H3: decline in egg to fry survival due to stranding of eggs;
- H4: decline in fry to smolt survival due to reductions in quantity and quality of off-channel rearing habitat;
- H5: non-hydro changes in Cheakamus watershed (e.g. dyking, natural floods); and
- H6: regional climate factors affecting both Cheakamus River and other nearby rivers.

Hypotheses H1 to H4 could be related to hydro operations, *or the result of other factors*. The ability to test these hypotheses and make the right decisions (i.e., **Steps 5a** and **5b** in Figure 7.1) will depend on the quality of monitoring data available, and the amount of contrast in conditions (i.e., variations in flows due to either natural fluctuations or deliberate manipulations).

Step 5a: Assess if changes in hydro operations would help situation
Step 5b: Assess / recommend possible non-hydro actions to improve situation

Even though the WUP process is dealing only with hydro operations, these operations must be viewed in the context of the whole system. It is only in this context that one can diagnose what restorative actions are required, and whether they include changes to hydro operations.

Step 6a: Revise hydro operations through new WUP
Step 6b. Implement non-hydro actions (done by appropriate parties outside WUP process)

While only hydro operations fall under the domain of the WUP, the process of monitoring and diagnosing problems has benefits for other entities responsible for watershed and fisheries management. After implementing remedial actions, one must continue to monitor (i.e., **Step 3b**) to ensure these actions were effective.

7.1.2 Details of Monitoring Plan

Table 7.1 summarizes the components of the monitoring program.

Table 7.1: Summary of proposed Cheakamus monitoring plan. CC evaluations of monitoring plan components are shown in Table 7.2.

I. Study (WUP, Title of Study, Interest Area) **II. Description**	**III. Data Gap Addressed (list the issue, the competing hypotheses, and the estimates of the probability of these competing hypotheses being true.)**	**IV. Amount of Learning Expected Through Monitoring**	**V. Estimated Duration of Study Program**	**VI. Timeframe in Which This Information Will Be Used**	**VII. Estimated Cost**
1. Refine statistical methodology Precisely determine sampling methods and data analyses that will yield best learning benefits (i.e., statistical power) for costs.	Use literature to fill gaps in historical data on natural variability and measurement error of some indicators in the Cheakamus (e.g., smolts per spawner). Refine methods and statistical power expected over different time frames.	n.a.	2 months	At start of monitoring program for this WUP	$25,000
2. Fish Populations Assess salmonid spawner abundance and smolt output in both the Cheakamus and Mamquam (control) rivers. Include both mainstem and side channel populations. Assess abundance of juvenile and adult rainbow, and relationship to physical habitat features. Assess risk of stranding on Squamish River below powerhouse.	*Lack of knowledge on fish population responses to flow.* H_0: Fish population responses to operations are consistent with habitat PMs and CC / FTC assumptions used to select recommended alternative. H_1: Population responses (in mainstem and/or side channels) are significantly worse than that expected from habitat PMs, and can be attributed to negative impact of hydro operations. H_2: Regional scale climate effects, not hydro operations, are the dominant factor causing trends in fish populations. H_3: Flow- fish habitat relationships are significantly different in future years from models used to select recommended alternative, and suggest different flow.	**High** if control population is monitored as recommended **Low** if control population not monitored	~10 to 20 years (study #1 needed to precisely define relationship between study duration and statistical power)[11]	Before the next WUP, to decide if / when conditions warrant initiating next WUP During next WUP After next WUP	$457,000 in year 1 $10,000 for stranding study in year 1 $326,300 in subsequent years

[11] Monitoring of Cheakamus mainstem fish populations partly implemented as part of Interim Flow Agreement. Monitoring of control populations should begin ASAP to increase statistical power.

I. Study (WUP, Title of Study, Interest Area) **II. Description**	**III. Data Gap Addressed (list the issue, the competing hypotheses, and the estimates of the probability of these competing hypotheses being true.)**	**IV. Amount of Learning Expected Through Monitoring**	**V. Estimated Duration of Study Program**	**VI. Timeframe in Which This Information Will Be Used**	**VII. Estimated Cost**
3. Groundwater in side channels Monitor groundwater in side channels and to characterize the linkage between mainstem low flows, floodplain groundwater systems, and side channel upwelling	*Lack of knowledge on link between hydro operations and groundwater flow in side channels affects recommended Jan-Mar flows.* H_0: Recommended operating alternative maintains sufficient groundwater in side channels. H_1: Recommended operating alternative insufficient to maintain groundwater in side channels, but side channels can be re-engineered to provide enough water. H_2: Recommended operating alternative insufficient to maintain groundwater in side channels, and only higher flows can solve problem.	High	1 year intensive subsequent years synoptic	Immediately after start of WUP to determine if adjustments to winter flows (Jan. to March) are required, within a 'pre-approved' range by the CC (e.g. between 15 cms and 20 cms)*	$41,000 in year 1 $3,200 in subsequent years
4. Benthos / Periphyton / Nutrients Monitor nutrients, periphyton (epibenthic algae) and benthos at existing sites in Cheakamus River monitored during 1996 and 2000. Monitor control sites in Mamquam River.	Rapid feedback on impacts of WUP on aquatic ecosystems, providing less noisy data than for fish. Insights on impacts of WUP on other ecosystem components, and causes of changes to fish populations. H_0: Recommended operating alternative maintains sufficient benthic biomass for fish and wildlife populations, as expected from benthic PMs. H_1: Periphyton / Benthos responses are significantly worse than that expected from modelled PMs, and can be attributed to negative impact of hydro operations. H_2: Regional scale climate effects, not hydro operations, are the dominant factor causing trends in benthos. H_3: Unexpected releases of sewage from Whistler (or other sources) are responsible for declining condition of periphyton and/or benthos.	**High** if control population is monitored as recommended **Low** if control population not monitored	5 years, then reassess	Before the next WUP, to decide if / when conditions warrant initiating next WUP During next WUP After next WUP	$48,170

I. Study (WUP, Title of Study, Interest Area) II. Description	III. Data Gap Addressed (list the issue, the competing hypotheses, and the estimates of the probability of these competing hypotheses being true.)	IV. Amount of Learning Expected Through Monitoring	V. Estimated Duration of Study Program	VI. Timeframe in Which This Information Will Be Used	VII. Estimated Cost
5. Channel morphology Monitor changes in channel form, gravel quantity and quality, vegetation distribution	*Insights on impacts of WUP on other ecosystem components, and causes of changes to fish populations.* H_0: Recommended operating alternative maintains does not negatively affect channel morphology. H_1: Channel morphology trends significantly worse than that expected from FTC studies, and can be attributed to negative impact of hydro operations. H_2: Regional scale climate effects (e.g. debris torrents associated with major storms), and not hydro operations, are the dominant factor causing trends in channel morphology.	Medium	10-20 years	Before the next WUP, to decide if / when conditions warrant initiating next WUP During next WUP After next WUP	$70,000 in first year $10,000 in subsequent years

Learning Scales Explained (Column IV)

High – monitoring study will definitely lead to quantitative discrimination among all of the competing hypotheses.
Medium – monitoring study will likely lead to the ability to discriminate quantitatively among some of the competing hypotheses.
Low – likely to allow only qualitative comparisons among a few competing hypotheses.

7.1.3 Consultative Committee Support for Monitoring Plan Components

The CC reviewed the purpose and cost of each component in the revised draft Monitoring Plan (Table 7.2). The monitoring components were the same as those discussed and approved by the CC at their September 7th, 2001 meeting, but the revised draft had more detail on monitoring methods and cost estimates.

After the review the CC members individually rated the components based on two criteria: 1) the likelihood that the results of that component would change their future decisions on hydro operations, and 2) the relative importance of that component for the monitoring plan. Only 14 of the 15 CC members at the table took part in this exercise; Jim Schellenberg (Coast Guard) abstained because he did not feel familiar enough with the monitoring information to evaluate the plan. Table 7.2 summarises the CC evaluations by component. Table A7.2 (Appendix 7-A) also shows results by CC member and includes their written comments.

The CC gave the **highest** rating to:

- “Refine Statistical Methodology” (Importance only: H = 14/14);
- “Salmonid spawner abundance and smolt output”(Likelihood: H = 13/14, Importance: H=14/14); and
- “Link between mainstem flows and groundwater in side channels”(Likelihood: H = 11/14, M = 1/14; Importance: H = 12/14, M = 2/14).

The CC gave an **intermediate** level of support to:

- “Rainbow trout habitat” (Likelihood: H = 9/14, M=4/14; Importance: H = 9/14, M=5/14); and “Squamish powerhouse stranding” (Likelihood: H = 6/14, M = 4/14. L = 3/14; Importance: H = 8/14, M = 4/14, L = 2/14).

The CC gave the **least support** to:

- “Channel Morphology” (Likelihood: H = 6/14, M = 3/14, L = 3/14; Importance: H = 6/14, M = 4/14, L = 3/14);
- “Benthos” (Likelihood: H = 4/14, M = 3/14, L = 6/14; Importance: H = 6/14, M = 3/14, L = 5/14); and
- Some CC members felt that these two components could be monitored less intensively, saving money.

Table 7.2: Summary table for rating the effect of monitoring component results on future decisions and relative importance of component for monitoring plan (Jan. 11, 2002). Abbreviations: H = High, M = Medium, L = Low, N = no rating submitted and no reason provided, A = abstained, ? = rating was ambiguous. "Likelihood of change" refers to the chances of changing future decisions on operations based on outcomes of this monitoring. For example, "If this component did significantly worse than expected from the PMs and this could be attributed to a negative impact of hydro operations (and not natural climatic variation), what are the chances you would change your decision in the future?

Monitoring Component	**Rating**	**Likelihood of change** (**L**ow, **M**edium, or **H**igh)	**Relative importance** (**L**ow, **M**edium, or **H**igh)
1. Refine Statistical Methodology (Precisely determine sampling methods and data analyses that will yield best learning benefits (e.g., statistical power) for costs) Cost: $25,000	**H:**	n/a	14
	M:		
	L:		
	N:		
	A:		1
	?:		
2a. Do operations affect salmonid spawner abundance and smolt output? (Assess salmonid spawner abundance and smolt output in both the Cheakamus and Mamquam (control) rivers for both mainstem and side channel populations) Cost (2a+2b): $457,000 in first year, then $326,300/year in subsequent years	**H:**	13	14
	M:		
	L:		
	N:	1	
	A:	1	1
	?:		
2b. How do operations affect rainbow trout habitat? (Assess abundance of juvenile and adult rainbow, relate to habitat features) Cost: see 2a above	**H:**	9	9
	M:	4	5
	L:		
	N:	1	
	A:	1	1
	?:		
2c. Do operations affect juvenile stranding below Squamish powerhouse? (install staff gauge at the Ashlu River bridge to accurately monitor stage changes, conduct additional stranding surveys during fish life history stages when there is an elevated risk of stranding) Cost: $10,000	**H:**	6	8
	M:	4	4
	L:	3	2
	N:	1	
	A:	1	1
	?:		

Monitoring Component	**Rating**	**Likelihood of change** (**L**ow, **M**edium, or **H**igh)	**Relative importance** (**L**ow, **M**edium, or **H**igh)
3. What is the link between mainstem flows and groundwater in side channels at flows less than 20 cms at Brackendale? (Monitor groundwater in side channels and characterize the linkage between mainstem low flows, floodplain groundwater systems, and side channel upwelling.) Cost: $41,000 in first year; $3,200/year for subsequent years	**H:**	11	12
	M:	1	2
	L:		
	N:	1	
	A:	1	1
	?:	1	
4. Are Benthos/Periphyton/Nutrients affected by dam operations? (Monitor nutrients, periphyton (epibenthic algae), and benthos at existing sites in Cheakamus River monitored during 1996 and 2000 and at control sites in Mamquam River.) Cost: $48,170	**H:**	4	6
	M:	3	3
	L:	6	5
	N:	1	
	A:	1	1
	?:		
5. Is channel morphology affected by dam operation? (Monitor changes in channel form, gravel quantity and quality, vegetation distribution). Cost: $70,000 in first year; $10,000/year for subsequent years	**H:**	6	6
	M:	3	4
	L:	3	3
	N:	2	2
	A:	1	1
	?:		

7.2 Review Period

The consultative committee did not discuss a WUP review period because they did not reach consensus on an operating alternative.

8.0 Summary and Recommendations

8.1 Summary

During the Cheakamus WUP process the CC made considerable progress in learning about the Cheakamus system, narrowing the range of potential operating alternatives and understanding the degree to which these alternatives met their fundamental objectives. Despite this progress, the consultative committee could not reach consensus on a single operating alternative for the Cheakamus Water Use Plan. Final CC preferences were split between lower and higher flow alternatives. The primary reasons for the split were different values with respect to chum and engineered side channel habitat, and scientific uncertainty about the relationship between flow and fish production in engineered side channels.

8.1.1 Final CC Preferences

At the final evaluation meeting, the CC examined the two most preferred alternatives from their previous meeting (15_20Min3_7DamA, 20Min7Dam), plus two intermediate alternatives designed to meet various concerns (15_20Min3_5_7Dam, 15_20Min3_7DamB). CC preferences were split between lower and higher flow alternatives (Figure 8.1). One group preferred lower flow alternatives based on the performance measures (PM's) for Chum and VOE. They accepted the FTC models and PMs as a basis for decision making, and found 2 to 4 of the final four alternatives to be acceptable. The other group preferred higher flow alternatives. They ultimately did not accept the FTC models and PMs as a basis for decision making, primarily because engineered side channels were excluded from fish habitat PMs. This group rejected 3 to 4 of the final four alternatives, and recommended continuing with the current Interim Flow Agreement (IFA) for another 3-5 years before deciding if different operations were warranted. They felt that there were too many remaining uncertainties to justify changing operations now. Despite considerable effort, the CC could not find common agreement on operating alternatives among these two groups.

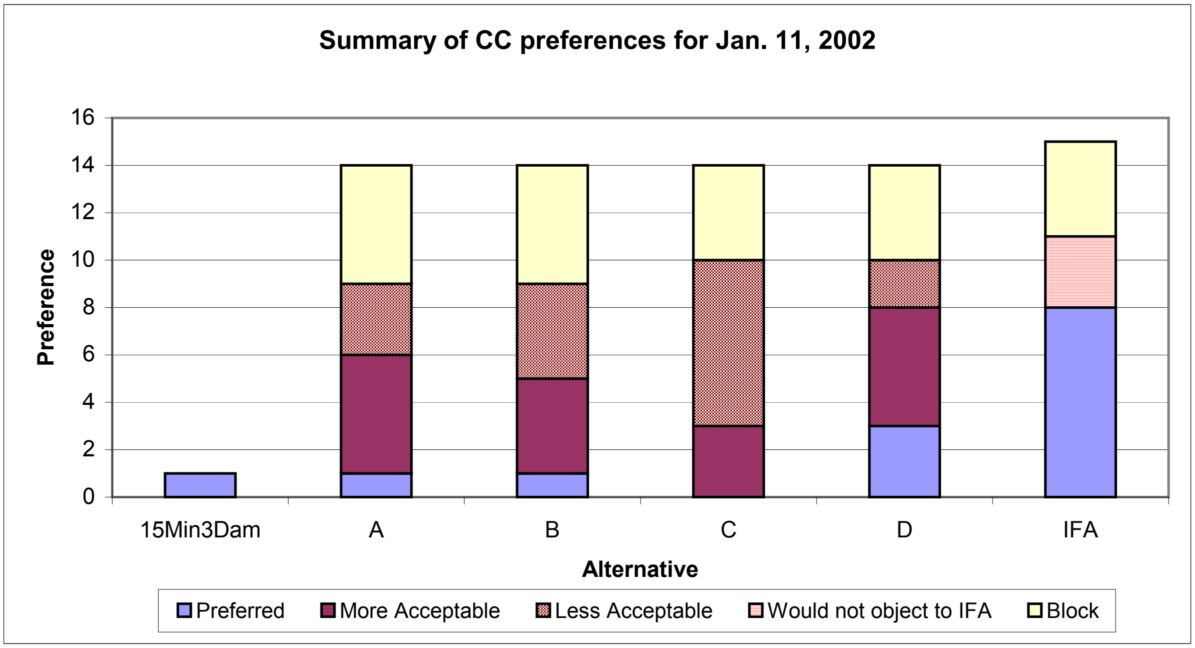

Figure 8.1: CC preferences for operating alternatives at the final evaluation meeting held January 11th, 2002. Flows increase moving from left to right. A = 15_20Min3_7Dam_1; B = 15_20Min3_5_7Dam; C = 15_20Min3__7Dam_2; D =20Min7Dam. IFA represents the "Interim Flow Agreement", or current operations.

8.1.2 Differences in Values

The two most important trade-offs between values during the final CC meetings were:

1. the relative importance of fish production in the mainstem vs. that from engineered side channels; and
2. the relative importance of chum versus that of other salmon species.

These values led to disagreement within the CC about the value of the FTC's performance measures, analyses and studies.

With respect to the first trade-off, some CC members saw engineered side channels as restoring the original river as close to pre-dam conditions as possible given the existing flood control dykes and other channel constraints. They felt that side channels should be watered for optimum fish production and wetland ecosystem health, not just kept from drying out. Some of these CC members wanted to see more engineered side channel projects, and to this end wanted higher flows in the river. Other CC members considered fish production from engineered side channels as less important than mainstem production. They felt that since these side channels were engineered to function under the flows that existed prior to the Interim Flow Agreement (i.e., less than the flows considered at the final meeting), they should be able to function under any of the current alternatives. They did not want to see more emphasis placed on engineered side channels if they would directly or indirectly harm mainstem production.

With respect to the second trade-off, some CC members were less concerned about mainstem chum production because they felt chum have lots of spawning habitat in the engineered side channels. Other CC members felt that chum were the salmonid most limited by mainstem spawning habitat area (which was reflected in the FTC's work) and therefore very important for deciding between operating alternatives.

8.1.3 Scientific Uncertainty

The key scientific uncertainties that contributed to the non-consensus outcome were:

1. the relationship between mainstem flow and fish production from engineered side channels; and
2. the relationship between mainstem flow and the quality of fish spawning and rearing habitat in engineered side channels.

The FTC work did not address the relationship between dam operations and the production of fish from engineered side channels for three reasons. First, the FTC work focussed on a fundamental objective of "maximising wild fish production" and they felt that engineered side channels were a lower priority than the mainstem for wild fish production. Second, the engineered side channels were originally designed to produce fish under flows less than those currently under consideration as of the final evaluation meeting. Third, this uncertainty did not become important for decision making until late in the consultation process, well after the FTC had completed their studies and developed their models for calculating the fish performance measures approved by the CC at their meeting on April 30, 2001. The FTC work did not address the relationship between dam operations and the quality of side channel habitat for similar reasons. However, the FTC did recognise that the connection between dam operations, quality of side channel habitat and side channel fish production was influenced by ground water seepage from the river. The comprehensive monitoring plan the FTC developed for the CC contains specific components for addressing these two uncertainties (Section 7.1).

8.1.4 Points of Agreement

Despite the lack of consensus at the final evaluation meeting, the CC did agree on a number points during the course of the WUP:

- CC members agreed on six fundamental objectives;
- CC accepted the set of PMs proposed at their April 30th 2001 meeting, though other factors not in the original set of PMs (e.g. fish production from engineered side channels) were subsequently raised as additional concerns;
- Up to the final meeting on 11th January 2002, all CC members preferred alternatives which had 20Min7Dam from April 1st to October 30th;
- the CC supported the components of the final comprehensive monitoring program the FTC developed with their approval (see Section 7.1);
- the CC supported a number of recommendations associated with the learning that took place during the WUP (Section 8.2); and
- most CC members preferred a "passive" adaptive management (AM) approach consisting of monitoring one operating alternative, rather than an "active" AM approach which would test multiple flows during the review period. On CC member (WLAP) preferred an active AM approach (Section 6).

8.1.5 Monitoring to Inform Future Water Use Plans

The FTC developed a comprehensive monitoring plan to address the critical points of scientific uncertainty and disagreement within the CC and to better inform the next WUP; the Consultative Committee members strongly supported its main components (Section 7.1). The CC recognised that it is essential to address critical scientific uncertainties that can affect future decision making, and to comprehensively assess the response of the system to whichever operating alternative is implemented. It is very important to refine the statistical and sampling methods to be used.

Monitored ecological indicators should include (in general order of priority): salmonid spawning and juvenile production; groundwater levels and fish production in groundwater-fed side channels in the Cheakamus River; rainbow trout habitat utilisation; stranding of juvenile fish in the Squamish River; riparian vegetation and channel morphology; and benthos, periphyton and nutrients.

8.2 Recommendations

The CC reviewed and rated a set of draft recommendations addressing issues both within and outside the scope of the Water Use Planning process. These recommendations address issues and concerns raised by the CC throughout the WUP process. Recommendations within the WUP process address operational considerations for the Cheakamus generating facility and would be considered in the actual BC Hydro Water Use Plan. Recommendations outside the scope of the WUP process address concerns identified during the course of the WUP process that would likely have benefits, but are not affected by changes to facility operations and therefore not the responsibility of BC Hydro. However, the CC felt that these non-WUP recommendations should be collected together for future reference. During the final meeting (January 11th, 2002), the CC members rated each recommendation as to whether they approved of or supported it ("A"), were indifferent ("I") to it, or disapproved ("D") of it. Table 8.1 summarizes the results by recommendation. Tables A7.3 and A7.4 (Appendix 7-A) show the results by CC member. Fourteen CC members participated in this rating exercise.

8.2.1 Recommendations Within the Scope of the WUP

The top two rows of Table 8.1 present recommendations that fall within the scope of the WUP process. Most CC members approved of both these recommendations. Recommendation 1 calls for changes in flow between flow regimes to be implemented gradually to prevent the stranding of fish. This recommendation is applicable to those proposed hybrid alternatives such as 15-20Min3-7Dam that have transitions between flow regimes within a year. Steve Macfarlane proposed this recommendation at the October 24th meeting where the CC evaluated the 15-20Min3-7Dam alternative for the first time. 13 of 14 CC members approved of this recommendation and only 1 did not. John Werring disapproved, noting that 20Min7Dam should be maintained year round, consistent with his preference for 20Min7Dam as an operational alternative (see Table 6.6). All 14 CC members approved of the second recommendation to provide BC Hydro the operational flexibility to maintain the best flows possible under varying reservoir inflow conditions. Table A7.3 (Appendix 7-A shows the results by CC member).

8.2.2 Recommendations Beyond the Scope of the WUP (non-WUP)

The bottom eight rows of Table 8.1 show recommendations that are outside the scope of the WUP process (*Non-WUP*). See Table 8.1 for a full description of the recommendation and the concern it is intended to address. Some CC comments have been paraphrased and included in the discussion below. Table A7.4 (Appendix 7-A) has individual CC ratings and comments for each recommendation.

Non-WUP 1: Review design and monitor flows for Farpoint channel (NVOS)

Most CC members (12 of 14) supported of this recommendation. Denise Mullen-Dalmer was indifferent. Ken Spafford disapproved noting that this recommendation is partially addressed in the monitoring program and in the selection of an operating alternative.

Non-WUP 2: Explore habitat enhancement opportunities on Squamish River

Most CC members (10 of 14) supported of this recommendation. Dave Cattanach, Denise Mullen-Dalmer and Ken Spafford were indifferent. Ross Neuman did not enter a rating for this recommendation. He was uncertain about its value because it was not a WUP issue.

Non-WUP 3: Improved co-ordination between agencies, Squamish Nation, BC Hydro and other interested parties to support integrated watershed management.

All CC members (14 of 14) supported this recommendation.

Non-WUP 4: Mainstem sediment recruitment

Most CC members (11 of 14) supported this recommendation. Bill Dickinson was indifferent. Ken Spafford did not rate this recommendation but indicated it had his potential supported depending on what actions might be allowed. Edith Tobe did not submit a rating noting that she did not feel well enough informed about the sediment issue to make a decision. Of those CC members who supported this recommendation, several had comments about necessary conditions for implementing this recommendation. Denise Mullen-Dalmer noted that her support was contingent upon ensuring that no actions would affect the WUP monitoring. Steve Macfarlane felt the actions should be based on the results of a hydrology/channel morphology study.

Non-WUP 5: Add large woody debris

Most CC members (10 of 14) supported this recommendation. Denise Mullen-Dalmer and John Werring were indifferent. Denise Mullen-Dalmer indicated that this recommendation could confound the results of WUP monitoring. Steve Macfarlane and Ross Neuman both disapproved. Steve Macfarlane noted that he could only support such a recommendation after he knew what the selected flow regime would be. Ross Neuman felt that actions under this recommendation could confound the results of WUP monitoring and should only be done once monitoring was completed.

Non-WUP 6: Identify floodplain areas for potential floodway restoration

Most CC members (11 of 14) supported this recommendation. Dave Cattanach and Denise Mullen-Dalmer were indifferent. Ken Spafford had "no opinion" and did not submit a rating. Denise Mullen-Dalmer was concerned about confounding effects on monitoring. Dave Cattanach would rather not see these things happen, but not strongly enough to disapprove. Lyle Fenton strongly emphasised his approval, giving it an "AA!" rating.

Non-WUP 7: Move or modify bridge above NVSO to promote lateral movement of the mainstem

Most CC members (10 of 14) supported this recommendation. Dave Cattanach, Denise Mullen-Dalmer and Doug McDonald were indifferent. Ken Spafford had "no opinion" and did not submit a rating. Dave Cattanach indicated he would rather not see this recommendation go forward, but did not feel strongly enough to disapprove.

Non-WUP 8: Improve communication between recreationalists and Squamish Nation

Most CC members (12 of 14) supported of this recommendation. Dave Cattanach was indifferent. Ken Spafford had "no opinion" and did not submit a rating.

Table 8.1: Summary of ratings for other possible CC recommendations. CC members rated each recommendation according to whether they approved (A), were indifferent (I), or disapproved (D). Tables A7.3 and A7.4. (Appendix 7-A) show the ratings and comments for each CC member.

<table>
<tr><th>Concern (Origin of Concern and/or Recommendation)</th><th>CC Recommendation</th><th>Rating (A, I, D)</th></tr>
<tr><td colspan="3">Recommendations within the scope of the WUP process</td></tr>
<tr><td rowspan="3">1. Possible stranding of fish during decreases in flow in the Cheakamus (e.g., if flows were changing from 20Min7Dam to 15Min3Dam in November)
(Steve Macfarlane)</td><td rowspan="3">Implement decreases in flow gradually over a 2-week transition period.</td><td>A = 13</td></tr>
<tr><td>I = 0</td></tr>
<tr><td>D = 1</td></tr>
<tr><td rowspan="3">2. Difficulty of maintaining minimum flows in low flow years / periods</td><td rowspan="3">The recommended minimum flows are targets which BC Hydro should endeavour to meet to the maximum extent possible, subject to water availability.</td><td>A = 14</td></tr>
<tr><td>I = 0</td></tr>
<tr><td>D = 0</td></tr>
<tr><td colspan="3">Other Recommendations beyond the scope of the WUP process</td></tr>
<tr><td rowspan="3">1. Maintaining sufficient water flows in the Farpoint side channels during periods of low river flow.
(Carl Halvorson)</td><td rowspan="3">Review design and maintenance of the water intake to Farpoint channel, and make the necessary improvements to ensure sufficient water flows (i.e., minimum of x cms at the entrance to the channel).
The flow in Farpoint channel should be continuously monitored to ensure it exceeds x cms at the entrance to the channel. If the flow in Farpoint channel falls below x cms, then NVOS, BC Hydro and DFO should immediately examine potential causes of the problem, and work together to fix them.</td><td>A= 12</td></tr>
<tr><td>I= 1</td></tr>
<tr><td>D= 1</td></tr>
<tr><td rowspan="3">2. Potential for using water from the powerhouse to maintain water in Pilchuk channels along the Squamish River. Preliminary surveys along the Squamish River show prime opportunities for restoration.
(Randall Lewis)</td><td rowspan="3">Habitat enhancement opportunities along the Squamish River should be explored and if viable, potentially submitted as a proposal to the Bridge-Coastal Restoration Program.</td><td>A= 10</td></tr>
<tr><td>I= 3</td></tr>
<tr><td>D= 0</td></tr>
</table>

Concern *(Origin of Concern and/or Recommendation)*	**CC Recommendation**	**Rating (A, I, D)**
3. Many factors constraining fish production in the Cheakamus River fall outside scope of WUP (e.g., habitat improvements to address footprint issues). While habitat improvements and/or infrastructure can address these issues, implementing such changes at the same time as changing hydro operations could confound the ability to assess the effects of the selected operating plan. *(FTC)*	DFO, the Province, SFN, SLRD, BC Hydro and other interested parties work together (outside of the WUP process) to integrate and coordinate future changes to habitat, and ensure the continued integrity of the comprehensive monitoring program associated with hydro operations.	A= 14 I= 0 D= 0
4. Maintaining sediment supply to Cheakamus River (a footprint effect). *(FTC)*	Develop / implement a plan to recruit representative sediments into the mainstem Cheakamus River. Transport and place accumulated Rubble Creek sediments downstream of the Hwy 99 Bridge into Cheakamus River mainstem for transport and recruitment (roughly 20% of the total Cheakamus River sediment budget).	A= 11 I= 1 D= 0
5. Maintaining supply of large woody debris to Cheakamus River (a footprint effect). *(FTC)*	Add large woody debris to provide greater habitat cover for juvenile fish.	A= 10 I= 2 D= 2
6. Negative effects of dykes on restricting floodplain and reducing available fish habitat. *(FTC, Doug McDonald)*	Identify / prioritize existing floodplain areas for potential future floodway restoration. This could entail potential breaching, re-engineering or removal of non-critical dykes, acquisition of floodplain properties and restoration of side and flood channels in existing floodplain areas. These modifications would allow the establishment of new side channel habitats, critical for juvenile salmonids and pink salmon spawning, increased area and diversity of floodplain habitat and reduce flood water elevations associated with unavoidable flood flows.	A= 11 I= 2 D= 0
7. Constraints on natural movement of channel. *(FTC)*	Move or modify bridge located upstream of the North Vancouver Outdoor School to promote lateral movement of mainstem. This would promote side-channel development, as well as the accumulation and release of suitable spawning substrates.	A= 10 I= 3 D= 0
8. Negative impact of kayaking and rafting on SFN bathing rituals. (*Randall Lewis)*	Improved communication between recreationalists and SFN to avoid negative impacts.	A= 12 I= 1 D= 0

9.0 Glossary

AM	Adaptive Management
AMPL	A Mathematical Programming Language, refers to hydro model used to simulate operating alternatives
CC	Cheakamus Consultative Committee
CCR	Consultative Committee Report
cms	Cubic Meters per Second
FTC	Fisheries Technical Committee
GHG	Greenhouse Gas
GWh	Gigawatt hours
HOPSC	Hydro Operations and Power Studies Committee
IFA	Interim Flow Agreement
IH	Impact Hypothesis
MW	Megawatts
PM	Performance Measure
RUA	Rated Usable Area, a measure of juvenile fish rearing habitat
VOE	Value of Energy
WUA	Weighted Usable Area, a measure of junveile fish rearing habitat
WUP	Water Use Plan

10.0 References

BCH 2002a. WUP Hydro Operations Report (*reference not complete*)

BCH 2002b. WUP Hydrology-Inflows Report (*reference not complete*)

Hammond, J.S., R.L. Keeney and H. Raiffa. 1999. Smart Choices: a practical guide to making better decisions. Harvard Business School Press. Boston, Massachusetts.

Kerr Wood Liedal Associates Ltd. (KWL). 1998. Review of Cheakamus River power project. Draft report. August 1998.

Marmorek, D.R. and I. Parnell. 2000. Summary of Progress on Cheakamus River Impact Hypotheses Fisheries Technical Committee. Draft report prepared by ESSA Technologies Ltd. Vancouver, BC for BC Hydro, Vancouver, BC. 80 pp.

NHC. 2000a. Analysis of Channel Morphology and Sediment Transport Characteristics of the Cheakamus River. BC Hydro Reference No. CMS-Mrphlgy. Prepared by Northwest Hydraulics Consultants. Report prepared for BC Hydro. November 20, 2000. 37 pp. + tables, figures and appendices.

NHC. 2000b. Flooding and Erosion at Selected Squamish Nation Archaeological Sites (Draft Report). BC Hydro Reference No. CMS-Mrphlgy. Prepared by Northwest Hydraulics Consultants. Report prepared for BC Hydro. December 6, 2000. 6 pp. + tables and figures.

Perrin, C.J. 2001. Trophic structure and function in the Cheakamus River for Water Use Planing. Draft Report. Report prepared by Limnotek Research and Development Inc. Report submitted to BC Hydro and the Resort Municipality of Whistler.

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

Province of British Columbia. 2000. *Creating Water Use Plan Alternatives. Identifying Appropriate Issues and Developing Preferred Strategies.*

RES. 2001. Cheakamus Floodplain Ecosystem and Wildlife Overview. February 13, 2001. Report prepared by Robertson Environmental Services Ltd. Report prepared for BC Hydro. 27 pp.

Robertson, I., K. A. Mcintosh, S. Bennett, S. Kesting, V. Palermo, P. Warburton and P. Kneen. 2001. An examination of species at risk in areas with BC Hydro facilities. Prepared for BC. Hydro. 92 pp.

Appendices

1. Cheakamus Consultative Committee, Technical Support and Meeting Dates
2. Performance Measure Information Sheets
3. Fisheries Studies – Summary and Evaluation (Purpose, budget, utility, transferability)
4. Fisheries Technical Committee Impact Hypotheses and Summary of Conclusions
5. Alternative Screening – Summary of Performance Measures (the full objectives by alternatives matrix)
6. Flow Information for Final Alternatives
7. Final Meeting Supplementary Notes (January 11th, 2002)
8. CD-ROM Table of Contents
9. Clarifying Comments

Appendix 1: Cheakamus Consultative Committee, Technical Support and Meeting Dates

A1.1 CC Mandate and Terms of Reference

Draft Final
Cheakamus Water Use Plan
Consultative Committee
Mandate and Terms of Reference

28 June 1999

Mandate:

Each member of the Cheakamus Consultative Committee is responsible for:
- Articulating their interests in water management;
- Ensuring continuity in representation;
- Listening to and learning about other water use interests;
- Developing an information base for discussion and review;
- Exploring implications of a range of operating alternatives; and
- Seeking consensus across water uses.

Purpose of Committee:

It is intended that the Cheakamus Consultative Committee will guide a broad consultation process leading to identification of: (i) multiple water uses in the Cheakamus and Squamish River systems, and (ii) means for achieving a “balance” between competing interests and needs.

The consultative process is expected to culminate with identification of water flows recommendations concerning operation of, and management of water flows past, Daisy Lake Dam and through the Cheakamus generating facility.

Objectives:

Recognizing the needs and values of all interested and impacted groups, the Cheakamus Consultative Committee will make recommendations for consideration by BC Hydro when preparing their Water Use Plan for the Cheakamus hydroelectric facility. Specifically, the committee will recommend:

1. the most appropriate water flow regime (or range of regimes) for the facilities, considering allocation of water to different water uses (e.g., flood control, fisheries, power generation, First Nations, aquatic ecosystem ‘health’, recreation, cultural impacts);
2. any conditions, mitigation, or compensation to be associated with the identified regime(s);
3. criteria for a water use monitoring program; and
4. timing for periodic review of the Cheakamus Water Use Plan.

Process:

In order to meet the above objectives, the committee will:

- Conduct proceedings using a consensus approach to decision-making;
- Follow the process detailed in steps 2 to 8 of the provincial government's *Water Use Plan Guidelines* dated December 1998;
- identify and confirm issues and the consultative process discussed at meetings and workshops;
- express issues in terms of specific water use objectives;
- compile and prioritize objectives and gather specific information on how water flows and timing affect those objectives;
- receive comments and feedback from the broader public;
- ensure that the public and other interested parties are informed of the issues under discussion and decisions taken;
- define operating alternatives to allocate water among different interests;
- identify and evaluate trade-offs between operating alternatives as they affect each water use objective;
- determine areas of consensus and agreement among interested and impacted groups; and
- document areas of consensus and disagreement concerning the final set of water flow recommendations.

The consultative committee should include (but is not limited to) the following interested parties:

- Local and regional Government
- First Nations
- MELP - Fisheries
- MELP - Water Management (Except Fisheries)
- DFO
- Community Interests
- Environmental & Recreational Interests
- Local Residents
- BC Hydro
- Ministry of Employment & Investment

Cheakamus Consultative Committee Authority and Responsibility:

In collaboration with the BC Hydro Cheakamus WUP Project Manager, the Cheakamus Consultative Committee will have the *Authority* to:

- define the composition and operation of the Cheakamus Consultative Committee;
- establish Sub-Committees, Working Tables and Technical Work Groups that will report to them on specific issues;
- request facilitation services for the Consultative Committee or any of its Sub-Committees;
- call meetings and open houses / public meetings;
- commission and issue communications materials to interested parties and the general public; and
- request that studies and data collection for specific issues associated with flow releases from the Cheakamus facilities be undertaken.

The Cheakamus Consultative Committee will have the *Responsibility* to:

- attend and openly participate in Cheakamus Consultative Committee meetings;
- review information on issues *prior to meetings* in preparation for discussion of the issues;
- establish who are the constituents of the Committee's representatives and keep them current on progress and decisions of the Committee;

- recommend the Scope of Work for tasks to be undertaken by Sub-Committees, Working Tables or Technical Work Groups and review the findings of such work;
- make recommendations concerning allocation of study/research work to outside consultants;
- deliver a *Consultation Report* to BC Hydro; and
- produce a signatory page to accompany the Draft WUP[12].

Deliverable:
- The Cheakamus Consultative Committee will prepare a *Consultation Report* documenting the overall consultation process, water use interests and objectives, information collected, operating alternatives reviewed, trade-off assessment, discussions and negotiations, and areas of final consensus and disagreement.
- A specific delivery date for the *Consultation Report* cannot be established until both the list of issues and the timing of data collection for priority issues are determined. Nonetheless, for planning purposes, the target date for delivery of the report is the end of May 2000.

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 Cheakamus hydroelectric facility.

Once completed, the Draft Plan will be reviewed by the Consultation Committee, then submitted to the BC Comptroller of Water Rights. The Comptroller will coordinate a final regulatory review.

BC Hydro Project Team:

To lessen the burden and workload on the Consultative Committee and any Sub-Committees, members of the BC Hydro CMS Project Team will be available to assist with both technical and administrative tasks.

Technical activities may include supporting the Cheakamus Consultative Committee by:
- managing 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.

Administrative tasks may include:
- arranging meetings;
- taking notes at Consultative Committee meetings or any Sub-Committee, Working Table, or Technical Work Group meetings;
- 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 publication of the *Consultation Report*; and
- presenting the Draft Water Use Plan to the Consultative Committee.

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[12] Only applies if the Consultative Committee had reached consensus on an operating regime.

Facilitator:

The following principles will apply to tasks involving facilitation, consensus building, and possibly mediation[13]:

- Appointment as a Facilitator is a privilege, not a right.
- The Facilitator serves, and answers to, the Consultative Committee, regardless of contractual arrangements covering payments for the facilitation services.
- The Facilitator should make every endeavour to ensure that all parties are heard and that all differences are resolved fairly, without unnecessary delay or expense.
- The Facilitator should be, and should remain, completely impartial between the parties, according equal attention and courtesy to all persons involved in the mission. He or she should take such steps as are necessary to ensure that each party has sufficient opportunity to state their case and to deal with the case put by others.
- In the event that the Facilitator is aware, or becomes aware of any circumstance or relationship which might cast doubt upon his or her impartiality, such matter or relationship should be disclosed immediately to the Consultative Committee.
- A Facilitator should exhibit conduct appropriate to the mission, without personal aggrandizement. At all times, a Facilitator is to demonstrate comportment consistent with operating in good faith and with the utmost honesty.
- A Facilitator should accept no payment, hospitality or other benefit without the knowledge and agreement of all parties. While the Facilitator is engaged in the service of the Consultative Committee, no payment, hospitality or other benefit should be accepted from any party concerned with the mission without the knowledge and agreement of the Consultative Committee.
- Appointment as a Facilitator should only be accepted when the candidate is satisfied he or she has the required knowledge, skills and experience.
- A Facilitator should bring to his or her mission both the knowledge, tools, and experience of his or her profession or calling and, where relevant, any personal knowledge, experience, or judgement.
- A Facilitator should come to decisions rationally and logically, without fear and without consideration of favour. All such decisions should be in accordance with the agreed rules, guidelines, or terms of reference governing the Facilitator's mission.
- As appropriate, the Facilitator may privately confer with individual parties, but nothing heard or learned in these circumstances should be allowed to undermine the requirement to maintain impartiality and provide equal treatment.
- While serving the Consultative Committee, the Facilitator should fully explain the reasons for any advice given, or decision made, whether procedural or otherwise.
- A Facilitator should not disclose information obtained in the course of his or her mission to anyone not properly concerned with the mission.
- Other than where specifically provided by the agreed rules, guidelines, or terms of reference for the mission, no information obtained by a Facilitator from one party should be confidential from the others or from the Consultative Committee.
- The Facilitator will be responsible for preparing a Record of Proceedings (meeting notes) for each meeting facilitated. All such notes will be distributed to each member of the Consultative Committee.

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[13] As used here, the term "Facilitator" applies to a person appointed to serve as a "neutral" party. That person's obligations to the Cheakamus Consultative Committee shall be interpreted in light of any agreed rules, guidelines, or terms of reference governing the appointment and execution of the Facilitator's mission.

Reimbursement Guidelines:

BC Hydro's CMS Project Team will arrange meeting facilities, issuing of communications, general secretarial and office services, photocopying, and so forth. Committee members are not expected to incur or absorb such costs.

It is, however, expected that there will be no reimbursement of minor costs associated with attending meetings. Significant costs will be reimbursed consistent with BC Hydro guidelines.

Consultation, facilitation and research work will be contracted out and bills for such works will be paid in accordance with contract provisions.

Table A1.1: Cheakamus WUP Consultative Committee membership – distribution of seats by caucus.

CAUCUS - June 1999	**Seats**	**Representing**	**Original Seat Holder**	**Changes and dates**	**Attended Evaluation Meetings** (out of 6)
Provincial Government	3	Fish & Wildlife	Ross Neuman	No change	6
		Water Management	Bijou Kartha	24 Oct 01: changed status to observer	1
		Employment & Investment	Denise Mullen-Dalmer	No change	5
Federal Government	2	Fisheries and Oceans	Steve Macfarlane	No change	6
		Coast Guard	John Mackie	No change	1
Squamish Nation	1	Squamish First Nation	Randall Lewis	No change	4
BC Hydro	2	Corporate Representative	Dave Cattanach	No change	6
		Corporate Representative	Ken Spafford	No change	6
Regional District	1	Squamish - Lillooet	None	15 Sept 99: Doug MacDonald (had already attended all meetings)	6
Municipalities	2	RMO Whistler	Jeff Ertell	No change (following 3 April 00 seat left vacant RMOW now observer).	--
		District of Squamish	Lyle Fenton	24 Jan 00: Jim Greenwood; 28 May 01: Jas Michalski	(Jas Michalski) 5
Cheakamus Watershed	3	Squamish IR 11	None	Never filled	--
		Resident	None	7 Feb 00: Lyle Fenton	5
		Commercial/Business	Carl Halvorson	No change	5
		Added seat - Sq River Valley	None	20 Mar 00: Bill Dickinson Sq. River Valley Residents (had attended most meetings).	4
Recreation	2	Commercial/rafting	None	18 Oct 99: Paula Jamieson, Sea to Sky Kayaking (1 mtg.)	0
				20 Mar 00: Pipo Damiano, Whitewater Assn. of BC (1 mtg)	0
		Provincial - Outdoor Recreation	None	18 Oct 99: Rob Way, Outdoor Recreation Council of BC	3

CAUCUS - June 1999	Seats	Representing	Original Seat Holder	Changes and dates	Attended Evaluation Meetings (out of 6)
Sport Fishing	2	Whistler Anglers	Dave Brown	No change	0
		Steelhead Society	Karl Wilson	20 Marc 00: Jon Hamilton	1
		Added Seat	None	20 Mar 00: Jerry Wintle Totem Fly Fishers	1
Environmental Groups	2	Sierra Legal Defence Fund	Randy Christensen	1 Nov 99: John Werring	5
		Squamish River Watershed	Edith Tobe	No change	5

Table A1.2: Cheakamus WUP Consultative Committee alternates.

Name	Organisation	Status	Final Evaluation Meeting
Angelo, Mark	Outdoor Recreation Council and BCIT	CC Alternate for Rob Way	
Bass, Cheryl	District of Squamish	CC Alternate for Jan Michalski	
Christensen, Randy	Sierra Legal Defence Fund	CC Alternate for John Werring	
Clark, Brian	Fish, Wildlife & Habitat Protection, MELP	CC Alternate for Ross Neuman	
Gerhart, Geoff	Whistler Angling Club	CC Alternate for David Brown	
Gowe, Bob	Fisheries & Oceans Canada – Coast Guard	CC Alternate for John Mackie	
Tattersfield, Pam	Squamish - Lillooet Regional District	CC Alternate for Doug MacDonald	2
Wilkinson, Jean	Squamish Estuary Conservation Society	CC Alternate for Edith Tobe	
Wisnia, Jim	North Vancouver Outdoor School	CC Alternate for Carl Halvorson	1 - partial
Schellenberg, Jim	Coast Guard		2

Table A1.3: CC meeting dates and topics.

#	Date	WUP Step	Purpose	Notes	File on CD-ROM
SC1	April 15, 1999		Pre-announcement meeting of *ad hoc* "steering committee"	✓	
SC2	May 6, 1999	**2**	Pre-announcement meeting of *ad hoc* "steering committee", preliminary definition of issues Draft CC Terms of Reference	✓	"SC2 Meeting Notes May 6, 1999.pdf"
1	June 23, 1999	**3**	Inaugural CC meeting: 1) Design and operation of CC; 2) Review of recent activities; 3) discuss summer work	✓	"1_(&2)_CC Meeting Notes June 23 & 28, 1999.pdf"
2	June 28, 1999		1) introduction to technical approach (decision analysis, resource valuation, adaptive management); 2) review of work program	✓	"1_(&2)_CC Meeting Notes June 23 & 28, 1999.pdf"
3	September 15, 1999	**4**	1) Review of summer activities; 2) Draft of CC "Master Plan"; 3) Overview of approach to developing and assessing alternatives (Smart Choices: "PrOACT"); 4) Begin selecting issues and defining objectives.	✓	"3_CC Meeting Notes September 15, 1999.pdf"
4	October 4, 1999		Issues and objectives	✓	"4_CC Meeting Notes October 4, 1999.pdf"
5	October 18, 1999		Issues and Objectives – focus on fisheries.	✓	"5_CC Meeting Notes October 18, 1999.pdf"
6	November 1, 1999		Finalize list of objectives; develop performance measures	✓	"6_CC Meeting Notes November 1, 1999.pdf"
7	November 15, 1999	**5**	Expert presentations on geography, hydrology, power studies, geodynamic and hydrodynamic process relevant to fish, FTC work.	✗	No meeting notes.
8	November 29, 1999		Review fundamental objectives, define means objective and performance measures, and mandate for FTC and HOPSC.	✓	"8_CC Meeting Notes November 29, 1999.pdf"
9	December 13, 1999		Establish technical committees, determine supplemental data and information required, discuss draft FOs (7 of them), Draft FO text	✓	"9_CC Meeting Notes December 13, 1999.pdf"
10	January 10, 2000		Confirming a consensus on the fundamental objectives, a presentation concerning Cheakamus flooding	✓	"10_CC Meeting Notes January 10, 2000.pdf" <incomplete>
11	January 24, 2000		Flooding presentation, FTC update (IH workshops), HOPSC update, constraints on operations.	✓	"11_CC Meeting Notes January 24, 2000.pdf"
12	February 7, 2000		Fluvial geomorphology and fish habitat, tenderfoot hatchery, tour of NVOS hatchery.	✓	"12_CC Meeting Notes February 7, 2000.pdf"
13	March 20, 2000		Introduce new CC members, HOPSC report, SFN heritage and cultural values, fish and aquatic ecosystem presentation.	✓	"13_CC Meeting Notes March 20, 2000.pdf"

#	Date	WUP Step	Purpose	Notes	File on CD-ROM
14	April 3, 2000	**5**	Candidate PMs, subgroup discussions to develop PMs	✓	"14_CC Meeting Notes April 3, 2000.pdf"
15	May 1, 2000		BC Hydro Operations and Finances, Review list of PMs, Discussion Draft Fundamental Objectives and PMs	✓	"15_CC Meeting Notes May 1, 2000.pdf"
16	May 29, 2000		Presentation on Cheakamus Hydrology, Draft letter to FTC	✓	"16_CC Meeting Notes May 29, 2000.pdf"
17	June 26, 2000		Presentations by FTC: Impact hypotheses, studies and models, schedule, flow diagram of process, summary of relevance of CMS literature to fisheries	✓	"17_CC Meeting Notes June 26, 2000.pdf"
18	October 23, 2000	**6**	Modelling water management alternatives, Methods for comparing alternatives, hands-on trade off analysis, developing alternatives.	✓	"18_CC Meeting Notes October 23 2000.pdf"
19	April 30, 2001		VOE, FTC-IH, Rearing RUA PM, Rearing WUA PM, Benthos PM, Spawning and Incubation PM, Fish PM example tradeoffs, Discussion of PMs for FOs 5-6, HOPSC (flow, power, flooding, recreation), Discussion of PMs for FOs 1-4.	✓	"19_CC Meeting Notes April 30, 2001.pdf"
20	May 28th and 29th, 2001		Scope of Consultative Report, Clarification of Alternatives, Review of performance measures, Features of alternative worth carrying forward, Which alternatives should be carried forward and which should be dropped, New alternatives to be examined Schedule	✓	"CC_Prereading_May_28_29_2001_Final.pdf" "20_CC Meeting Notes May 28_29, 2001.pdf"
21	July 3rd and 4th, 2001		Review of items from the May28th-29th meeting, Update and review of results for current set of alternatives, Review of Performance Measures, Rating of alternatives, Decisions on Alternatives, Other CC Decisions Schedule	✓	"CC_Prereading_July_3_4_2001_Final.pdf" "21_CC Meeting Notes July 3_4, 2001.pdf"
22	September 7, 2001	**7**	Review of items from the July 3rd and 4th meeting, Update and review of results for current set of alternatives, Review of Performance Measures, Rating of alternatives, Decisions on Alternatives, Other CC Decisions Schedule	✓	"CC_Prereading_September_7_2001_Final.pdf" "22_CC Meeting Notes September 7, 2001.pdf"

#	Date	WUP Step	Purpose	Notes	File on CD-ROM
23	October 4th, 2001	**7**	Review of items from the September 7th meeting, Update and review of results for current set of alternatives, Review of Performance Measures, Rating of alternatives, Decisions on Alternatives, Other CC Decisions Schedule	✓	"CC_Prereading_October_4_2001_Final.pdf" "23_CC Meeting Notes October 4, 2001.pdf"
24	October 24th, 2001		Reviewed: • Results and final 4 alternatives selected at October 4th meeting, • a consensus proposal from previous meeting, a table of concerns, and draft CC recommendations, • several hybrid alternatives within the range of the final four selected on October 4th. Conducted a preference rating exercise, consensus was not achieved, but defined two most preferred alternatives: 15-20Min3-7Dam, 20Min7Dam.	✓	"24_CC Meeting Notes October 24, 2001.pdf"
25	January 11 2002	**8**	a) to develop final CC recommendations for an operating alternative, a monitoring plan and other activities; b) outline areas of agreement and disagreement with respect to these recommendations.	✓	"25_CC Meeting Notes January 11, 2002.pdf"

A1.2 Fisheries Technical Committee Mandate

Cheakamus Water Use Plan Fisheries Technical Committee Deliverables

Deliverables to the CC are:

- listing of studies that will result in performance measures being established;
- recommended performance measures; and
- reporting on the effects of different flow regimes.

What will be needed to be developed to achieve the above:

- review of previous studies;
- determination of the appropriate indicators that will allow scope of studies;
- undertaking of studies;
- analysis of study results
- reaching agreement on appropriate performance measures;
- building of an environmental model; and
- undertaking environmental model runs for selected alternatives.

Selected Excerpts from the Terms of Reference for the Cheakamus Water Use Plan: Fish Technical Committee

For each question or issue, the mandate of the FTC will be to:

1. Select / recommend suitable indicators for addressing the question or issue[14].
2. Identify important data and knowledge gaps, if any, currently preventing adequate consideration of the question or issue.
3. Conduct information gathering, studies, research, and modelling essential to filling those data and knowledge gaps. The FTC will be responsible for developing any needed Terms of Reference (e.g., scope, duration, cost) to guide such activities.
4. Synthesize resulting data and information into a format that facilitates analysis of, and discussion concerning, the question or issue in terms of water flow management of, and / or regime (or range of regimes) for, the Cheakamus facilities.
5. Suggest alternatives related to operations and management of water flows past Daisy Lake Dam and through the Cheakamus generating facility.
6. Identify consequences, conditions, and biological ramifications associated with specific flow regime(s). (don't think that M&C is part of the WUP process, only to compare alternatives.
7. Present resulting findings, answer, review, analysis, or recommendation(s) to the CC.
8. When requested by the CC, produce a written report concerning the specific question or issue.

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[14] The CC is solely responsible for choosing performance measures to be used in alternative evaluation, based on technical input from the FTC.

The FTC will also be responsible for:

1. Designing the fish, aquatic ecology, and riparian zone portions of the performance monitoring and compliance assessment program to be implemented during operations under the approved Water Use Plan.
2. Formulating recommendations concerning the timing and nature of periodic reviews for the specific question or issue.
3. Providing the CC with periodic status reports.
4. Undertaking activities needed to fulfil any other assignments delegated to them by the CC.

Table A1.4: Fisheries Technical Committee membership and affiliation. This table lists all FTC members; however, personnel and commitments changed during the Water Use Planning process so not all of the listed members participated in the FTC throughout it. Table A1.5 provides a record of FTC meeting attendance and participation.

FTC member	Affiliation
Jesse Brown	Steelhead Society
James Bruce	BC Hydro
Barry Chilibeck	Fisheries and Oceans Canada
John Hamilton	Steelhead Society
Brent Lister	Consultant for Squamish Nation
Steve Macfarlane	Fisheries and Oceans Canada
Steve McAdam	BC Ministry of Fisheries
Ross Neuman	Ministry of Environment Lands and Parks
Ron Ptolemy	BC Ministry of Fisheries
Marvin Rosenau	Ministry of Environment Lands and Parks
Dan Sneep	Fisheries and Oceans Canada
John Werring	Sierra Legal Defence Fund
David Wilson	BC Hydro – Chair
Karl Wilson	Steelhead Society

Table A1.5: Cheakamus Water Use Plan Fisheries Technical Committee meeting dates, attendees and topics.

Date	Location	Attendees	Agenda
May 27, 1999	Vancouver	DW, JB, BL, DS, SM, SMC, BC, MR, RN	• FTC start up • Introduction of members • generic WUP aquatic issues
June 7-8, 1999	Squamish	DW, JB, BL, DS, SM, SMC, BC, MR RN	• Discussion of proposed studies: fish benthics, water quality, hydrology
Aug. 27, 1999	Vancouver	DW, JB, BL, DS, SM, SMC, BC, MR, RN	• Update of field studies
Sept. 23-24, 1999	Squamish	DW, JB, SMC, MR, RN, BL	• Orientation river float • Review of studies
Oct. ?, 1999	Vancouver	DW, JB, SMC, MR, RN, BL	• Field studies update

Date	Location	Attendees	Agenda
Nov. 18-19, 1999	Vancouver	DW, JB, BL, DS, SM, SMC, BC, MR, JW	• Review of benthic TOR • Update on field studies, presentations by Bob Turner (GSC) and Bob Newberry on geomorphology
Dec. 9-10, 1999	Squamish	DW, JB, BL, DS, SM, SMC, BC, MR, JW	• Review of field studies • Adaptive input presentation, Josh K. • Performance indicators Dave Bernard
Jan. 17, 2000	Vancouver	DW, JB, BL, DS, SM, SMC, BC, MR, JW, KW	• Intro to PM's • Review options and impact on WUP schedule • Monitoring field studies planning
Feb.11, 2000	Vancouver	DW, JB, BL, DS, SM, SMC, BC, MR, JW, KW, RP	• Discuss impact hypotheses
Feb. 29/00	Vancouver	DW, JB, BL, SMC, BC, MR	• transect selection from aerial photo interpretation
Mar. 9-10, 2000	Vancouver	DW, JB, BL, DS, SM, SMC, BC, MR, KW, RP	• Discussions on introducing large woody debris to river • Update on field studies • Fish periodicity chart
Mar.22, 2000	Vancouver	DW, JB, BL, DS, SM, SMC, BC, MR, JW, KW, RP	• Field studies update and TOR's for studies • RUA modeling approach • CMS monitoring studies, migrant trapping
Mar. 28, 2000	Vancouver	DW, JB, RN, DS, SMC, RP	• Steelhead fry historical data approach to RUA classification
Apr. 7, 2000	Vancouver	DW, JB, BL, DS, SM, SMC, BC, MR, JW, KW, RP,RN	• Content of FAT presentation • Intro to PM's • R2D modeling • Fish stomach content analysis • Additional resources for field surveys
May 4, 2000	Vancouver	DW, JB, BL, DS, SM, SMC, BC, MR, JW, KW, RP, RN	• Aerial photo compilation • Field studies update • schedule • CMS powerhouse findings
June 23, 2000	Vancouver	DW, JB, BL, DS, SM, SMC, BC, MR, JW, KW, RP, RN, JH	• Content of FAT letter to CC • Hydrology data and linkage to fish studies • Studies update
Aug. 10, 2000	Vancouver	DW, BL, DS, SMC, BC, MR	• Field studies update • Flow habitat work on Bridge R. and linkages to CMS WUP
Sept. 21, 2000	Vancouver	DW, JB, BL, DS, SMC, BC, JW	• Field studies update • Schedule and reports • R2D and RUA models linkage • Species at risk • Debris and FPA

Date	Location	Attendees	Agenda
Oct. 5, 2000	Vancouver	DW, JB, BL, DS, JW, RN	• RUA models • Adult steelhead and chinook migration and spawning • Pink salmon and Mamquam sampling
Nov. 16, 2000	Vancouver	JB, BL, DS, SMC, BC, JW, RP	• RUA model • Geomorphology study update • HIS curves, PM's
Dec. 4, 2000	Vancouver	DW, JB, BL, SM, SMC, BC, RP, RN	• Schedule and draft PM's • Field studies update • Draft impact hypotheses
Jan. 16, 2001	Vancouver	DW, JB, BL, DS, SMC, BC, RP, RN	• Schedule and workplan • Impact hypotheses and PM development • R2D model output demo • RUA model discussion
Feb. 15, 2001	Vancouver	DW, JB, BL, DS, SMC, BC, RP, RN, JW	• Review impact hypotheses, select those rejected • Fish PM specified • Aquatic ecosystem PM's
Mar. 7, 2001	Vancouver	JB, BL, DS, SMC, BC, RN, JW	• Review RUA and R2D models • Benthic and riparian PM's • FTC schedule
Mar. 23, 2001	Vancouver	DW, BL, DS, SMC, BC, RP, RN	• Further work on RUA and R2D models • Benthic PM definitions • Spawning/incubation PM • Deliverables to
Apr. 3, 2001	Vancouver	DW, JB, BL, DS, SMC, BC	• RUA sensitivity analysis with alternatives • R2D/HIS analyses and outputs • Impact hypotheses worksheets • Stranding and benthic PM's
Apr. 10, 2001	Vancouver	DW, JB, BL, DS, SMC, RN	• Impact hypotheses worksheets • PM info sheets • RUA/R2D benthic presentations to CC
Apr. 20, 2001	Vancouver	DW, JB, BL, DS, BC, SMC, RN	• Review of deliverables to CC • Fish and aquatic PM discussions
May 10, 2001	Vancouver	DW, JB, BL, DS, RN, RP	• PM info sheets • R2D/HSI curves • Spawning incubation PM • Immigration flows
May 22-23, 2001	Vancouver	DW, JB, BL, DS, SMC, RN, RP, JW	• Review flow alternatives descriptions • RUA and WUA results, habitat variability, migration flows • Spawning/incubation results • Resident fish
June 5, 2001	Vancouver	DW, JB, BL, SMC, RN, RP, BC	• Review CC requests from last meeting • Model result memo to CC • Monitoring plan outline
June 27, 2001	Vancouver	DW, JB, BL, SMC, RN, RP	• Review current flow alternatives • Draft monitoring plan

Date	Location	Attendees	Agenda
Sept 4, 2001	Vancouver	DW, JB, BL, SMC, RN, RP	• Continue work on monitoring plan • Review current set of flow alternatives
Oct 23, 2001	Brackendale	DW, JB, BL, SMC, RN, RP, DS	• Continue work on monitoring plan • Review current set of flow alternatives
Key to Attendees: DW- Dave Wilson , JB- James Bruce (BCH); BL- Brent Lister (FN Consultant); DS- Dan Sneep, SM- Steve Macfarlane , BC- Barry Chilibeck (DFO); SMC- Steve McAdam , RP- Ron Ptolemy , RN- Ross Neuman, MR- Marvin Rosenau (WLAP); JW- John Werring (Sierra Legal); KW- Karl Wilson ; JB- Jesse Brown JH- John Hamilton (Steelhead Society)			

A1.3 Hydro Operations and Power Studies Committee Mandate

Draft

Cheakamus Water Use Plan
Hydro Operations and Power Studies Technical Committee (HOPSC)

Terms of Reference
28 February 2000

Purpose:

The Cheakamus Consultative Committee (CC) requires scientific and technical support for issues concerning hydrology, hydro operations, and power production. The HOPSC will collaborate with and assist the CC in adequately addressing such issues.

Mandate and Scope:

The mandate of the HOPSC is to:

1. Conduct information gathering, studies, research, and modelling essential to filling data and knowledge gaps relating to issues concerning hydrology, hydro operations, and power production.
2. Synthesise data and information into a format that facilitates analysis of, and discussion concerning issues related to water flow management of, and range of operating regimes for, the Cheakamus facilities.

Where work requirements exceed the capabilities of existing resources, some work may be conducted by contractors under the direction of the HOPSC.

Upon request, the HOPSC will also assist the CC as follows:

1. Model the operating alternatives suggested by the CC. These alternatives are related to operations and management of water flows past Daisy Lake Dam and through the Cheakamus generating facility.
2. Provide modelling results and or data to other technical committees or CC sub-committees, where appropriate or required.
3. Discuss methodologies and findings, answers, reviews, analyses, or recommendation(s) with the appointed independent technical reviewer as per those terms of reference (attached).
4. Present findings, answers, reviews, analyses, or recommendation(s) to the CC.
5. Produce written reports, where required, concerning the specific question or issue.

Membership:

The Hydro Operations and Power Studies Committee can include any number of qualified individuals from any interested party. Technical representatives from groups that are CC members are especially welcomed. The HOPSC is not intended to be a ‘representative’ body; the main criterion for membership is the technical / scientific interest and knowledge of the individual. The HOPSC has also selected an independent reviewer, to assist members of the HOPSC. The technical reviewer is a member of the HOPSC.

The BC Hydro Project Team will provide the HOPSC with a qualified individual to “chair” the committee and be responsible for calling meetings, leading discussions and building consensus. Additionally, the Chair will be accountable to the CC for the quality and timely delivery of all necessary input and associated deliverables (e.g., data, information, maps, reports, model output).

A1.4 BC Hydro Project Team

To lessen the burden and workload on the Consultative Committee and sub-committees, members of the BC Hydro CMS WUP Project Team assisted with both technical and administrative tasks. The Team consisted of:

- Al Geissler as *Project Manager*, taking over from Gordon Boyd,
- Barry Wilkinson as the *Community Relations Task Manager*, with support from Andrew Coupe
- Dave Wilson as the *Environmental Task Manager*, with technical support from James Bruce and Darren Sherbot
- Cam Matheson as the *Aboriginal Relations Task Manager*
- Paul Vassilev as the *Power Studies Task Manager*, with technical help from Kathy Groves
- Michael Harstone as the *Resource Valuation Task Manager* taking over from Kristy McLeod.

Appendix 2:
Performance Measure Information Sheets

Appendix 2-A: Green House Gas Reduction (GHG)

Appendix 2-B: Squamish Nation

Appendix 2-C: Recreation

Appendix 2-D: Rearing

Appendix 2-E: Spawning Success

Appendix 2-F: Adult Migration

Appendix 2-G Fish Food (Benthos) Production

Appendix 2-A: Green House Gas Reduction (GHG)

MEMORANDUM

TO: Cheakamus Consultative Committee
FROM: Ken Spafford
DATE: June 15, 2001
SUBJECT: Greenhouse Gas Performance Indicators

During the last CC meeting, I was asked to circulate a description of a potential greenhouse gas (GHG) performance measure and its method of calculation. This is provided below along with some background information.

Potential Performance Measure

The following GHG measure is suggested for evaluating operating alternatives in the water use planning process.

$$\text{GHG Contribution (tonnes)} = (\text{Ebase} - \text{Ealt}) \times 306\ CO_2e$$

Where Ealt is the average annual energy production for the alternative being considered, measured in GWh.
And Ebase is the average annual energy production for the base case, measured in GWh.

Since tonnes of CO_2 equivalent is not a familiar unit to many people, this performance measure is probably more meaningful if it is expressed in terms of the costs associated with mitigating the additional CO_2 releases. Unfortunately, estimates of offset costs vary greatly, anywhere from zero to $120/tonne. For illustration purposes, the table below shows the impact of a $5 per tonne offset costs (which is representative of the high end of current trading in GHG credits and the low end of the estimated long-term cost of offsets).

Rationale and Background Information

While BC Hydro's existing generation system is dominated by hydroelectric projects, its most recent Integrated Electricity Plan (January 2000) concluded that new, highly efficient, combined cycle gas turbines provided the most appropriate trade-off between corporate and provincial costs, environmental, and social impacts. The plan adopted a strategy of serving about 10% of new resource requirements from "new green resources", but identified combined cycle gas turbines as the major resource addition.

Accordingly, the value of electricity used in the Cheakamus and other Water Use Plans is based on the estimated direct cost of replacing that electricity from the least cost new resources – i.e., new combined cycle gas turbines.

The greenhouse gas contribution of combined cycle gas turbines is lower than many of the marginal resources in the interconnected system. The following table provides typical CO_2 at-site emission data for a representative set of marginal generation resources in the interconnected system:

Source	**Emissions $CO_{2\ equiv}$** tonnes per GWh
Combined cycle gas turbine	340
Steam turbine (simple cycle)	530
Average of purchases and sales	490

In the short term, lost hydroelectric generation will be replaced by reduced electricity sales or increased purchases, which will increase CO_2 emissions by about 490 tonnes per GWh of reduced hydro generation. In the longer term, the lost hydroelectric generation will be replaced by a mix of 90 percent new combined cycle gas turbines and 10 percent new green resources, which will increase CO_2 emissions by about 306 tonnes per GWh (90% of a combined cycle gas turbine). A long-term average increase of emissions in the range of 306 tonnes per GWh is suggested for the Cheakamus Water Use Plan.

The above analysis does not include "upstream" emissions associated with gas exploration and delivery systems or other emissions that might occur during the life-cycle of the associated equipment. Inclusion of these upstream emissions would increase the total emissions of a typical combined cycle gas turbine by about 35%.

BC Hydro may be able to reduce or offset these emissions through development of other resource options or through programs designed to reduce emissions elsewhere. However, in either case, it is expected that mitigation of the CO_2 emissions will increase the cost of replacement electricity.

There is a great deal of uncertainty about the cost of CO_2 offsets, or even if offsets will be required, so it is reasonable to separate this component of costs rather than including it directly in the value of electricity. For example, the National Climate Change Process is estimating a range of offset costs from $0-120 per tonne. Currently, future market emission reduction credits are being traded in the range of $1-5 per tonne even though there is no obligation to meet CO_2 emission targets (purchases are all voluntary). If offsets were mandatory this cost would likely rise. A conservatively low figure of $5 per tonne was used in the table below to indicate the order of magnitude of potential offset costs for the Cheakamus Water Use Plan.

The following table provides an indication of the impact of applying the suggested performance measure to the alternatives discussed at our meeting on May 28th and 29th. For development of the table any of the alternatives could be taken as a "base case". The table below assumes the "Pass Inflow" alternative as the base case and computes the greenhouse gas savings for each alternative relative to this case.

Alternative	**Power**		**Greenhouse Gas Emissions**	
	Generation GWh	Value $M	**Emission Reduction**[15] (ktonnes/yr)	Est. Savings @ $5/tonne ($M/yr)
Power Optimal	840	39.2	257	1.29
Empty Reservoir	779	36.6	238	1.19
10 cms	802	37.4	245	1.23
20 cms	706	32.9	216	1.08
30 cms	588	27.2	180	0.90
Interim Flow	556	27.5	170	0.85

[15] For comparison, the estimated total greenhouse gas emission in B.C. in 1990 was about 51.2 Megatonnes. (Source: BC Climate Change Business Plan (October 2000) and Ministry of Environment website.)

Pass Inflow	**0.0**	**0.0**	**0.0 (Base Case)**	**0.0 (Base Case)**

Appendix 2-B: Squamish Nation

(Risk of flooding and erosion for cultural and heritage sites)

Description

The Squamish Nation privately evaluated a range of operating alternative to protect the integrity of their heritage sites and cultural values. The specific consideration that was evaluated for the WUP process was the flood risk to heritage sites and cultural values.

Means Objective

Minimize the risk of flooding and erosion to Squamish Nations heritage sites and cultural values.

Rationale

The Cheakamus watershed is entirely within the traditional territory of the Squamish Nation. Two Squamish Nation reserves are located adjacent to the lower Cheakamus River: Cheakamus I.R. No. 11, and Poquiosin and Skamain I.R. No. 13. The Squamish people have traditionally relied on the river and its watershed for food, transportation, recreation and cultural practices. Therefore, Squamish Nation is concerned about the potential impact different operating alternatives may have on heritage sites and cultural values. Heritage sites include burial grounds and ceremonial bathing locations, and old growth cedar in the riparian zone.

Methodology

Squamish Nation and BC Hydro representatives identified and mapped SN heritage sites. Northwest Hydraulics Consultants then evaluated the risk of flooding and erosion to three of these sites with respect to the two most extreme alternatives considered in the WUP process: Pass All Inflows and Power Optimal (NHC 2000b).

NHC did the following analyses:

- Evaluated the potential for flooding and erosion by the Cheakamus River under the existing operating regime at Daisy Lake;
- Assessed the effect of potential future operating regimes on flooding and erosion at the specified archaeological sites; and
- Assessed whether past or present Daisy Lake Reservoir operating regimes have produced more severe flooding and erosion at the selected sites than would have occurred under natural, unregulated conditions.

NHC concluded that for the three sites evaluated:

- flooding is not an issue for one site;
- flooding for a second site would commence at a discharge of about 1,200 cms, or a 100-year return period, a flow at which the storage capacity of the Daisy Lake reservoir has little or no effect on the flood flows; and

- a third site would be flooded at a discharge of just above 450 cms, so more frequent flooding of this site would occur if the Daisy Lake Reservoir was not operated to reduce the magnitude of frequent flood peaks.

All operating alternatives considered by the Cheakamus Consultative Committee incorporated the current BC Hydro reservoir operation practices and prevented flows above 450 cms at Brackendale (the flood criterion); therefore, none of the modelled alternatives put these sites at risk of flooding.

Appendix 2-C: Recreation

(Rafting, Kayaking, Sportfishing, General))

Description

There are four recreation performance measures: Rafting, kayaking, sportfishing and general (e.g., hiking and birdwatching). These performance measures pertain to the Cheakamus River only and are calculated as the average number of access days over 32 water years. The flows used to calculate these PMs are the average daily flows at the Brackendale gauge for each operating alternative.

Means Objective

Maximise the average number of access days over 32 water years for each recreational objective (rafting, kayaking, sportfishing, general (e.g., hiking and birdwatching)).

Rationale

The Cheakmus River is an important recreational destination. It provides quality rafting, kayaking, sporfishing, hiking and birdwatching opportunities. These activities have economic value for the local community and provide non-monetary values for all users; therefore, WUP operating alternatives should be evaluated with respect to their impact on these values. Given that there are not enough data available to develop quantitative models describing river usage, the quality of recreational experience, or the economic value of these activities as a function of river flow, it is assumed that value will be maximised under flow conditions that maximise access for each activity.

Methodology

A recreation subgroup developed the Recreation PMs at the April 3, 2001 Consultative Committee meeting. The subgroup drew on the expertise of participants, as well as data from a rafting study conducted in the summer of 2000 (Ref) to develop performance measures for rafting, kayaking, sport fishing, hiking and bird watching in and around the Cheakamus River. The group did not develop performance measures for recreation in Daisy Lake because it is off-limits for recreation (Order in Council - Garibaldi Civil Defence Zone). The group discussed the issue of how water diversion affects recreation activities in the Squamish Basin but was unable to reach consensus and did not develop a performance measure for this issue. The subgroup developed the following four performance measures for the Cheakamus River:

Rafting

Number of days during the rafting season (June to August, December to February) that the Brackendale gauge reading is between 34.9 cms (0.9 m) and 450 cms (2.7 m). (Note: prime rafting times are 8:30 a.m. – 4:30 p.m.).

Kayaking

Number of days during the kayaking season (April to September, December to January) that the Brackendale gauge reading is between 19.4 cms (0.7 m) and 450 cms (2.7 m). (Note: kayaking occurs during any daylight hours).

Sport Fishing

Number of days in the sport fishing season (mid March to 1 May; August to December) that the Brackendale gauge reading is between 19.4 cms (0.7 m) and 68.4 cms (1.2 m). (Note: sport fishing occurs from pre-dawn to post dusk. Steelhead = mid March to 1 May; salmon = August to December).

Hiking and Bird-watching

Number of days that the Brackendale gauge reading is between 5 cms (minimum release from dam) and 68.4 cms (1.2 m). The upper flow value represents point at which flow begins to limit access. (Hiking and birdwatching go on all year in this area, although peak 'eagle viewing' activity occurs from December through January).

The performance measures for each of the four recreation PMs are calculated using the modeled average daily flow at the Brackendale gauge. The Hydro operations model results are imported into an MS Access database and database queries are used to filter the data using the flow range and period criteria noted above. The queries first sum the number of days falling within the specified flow range and period and then divide this number by 32.

Data Needs	Status
1. Daily Brackendale Gauge flows (cms) generated from BC Hydro's operations model	*ongoing*

Critical Uncertainties

The following are critical uncertainties associated with the PM:

Critical Uncertainty	Implications to Decision Making Process
1. Daily spill data generated from BC Hydro's operations model may not necessarily reflect true operating practice of Daisy Dam.	Inaccuracies in the operations model are likely to be small relative to the volume of flow that must be managed. They are also likely to be similar between operating strategies.
2. Link between the specified flows and the actual benefit for the recreational objective; "access days" does not equal actual usage. Carl Halvorson noted that rafting will take place just about any time there are customers and a raft can float.	Most CC members considered the recreational performance measures as "soft", and discounted them in decision making, or used them as a proxy for higher flows in the upper river.
3. The actual relationship between flow and river use – the PMs used a "knife edge" transition for kayaking and sportfishing; the lower flow boundary for these PMs (19.4 cms) was very close to the median Brackendale target flow of many operating alternatives (20 cms).	Perceived by some CC members as subjectively favouring higher flow alternatives, so they discounted the results in decision making. A change from a minimum flow target of 19 cms to 20 cms would have a disproportionate effect on the PM.
4. No data on the relationship between flow and "economic impact" or "quality of recreational experience".	Led to CC members discounting recreational PMs in decision making.

Appendix 2-D: Rearing

(Steelhead Trout, Chinook, and Coho Salmon)

Description

The rearing Performance Measure (PM) will be comprised of two parts:

1. *Habitat Area*: A measure of the amount of usable habitat available to rearing fish (ha).
2. *Temporal Habitat Stability*: A measure of temporal stability of habitat (ha) though out the summer rearing phase.

These PM components will be calculated for rearing steelhead, chinook, and coho fry, as well as steelhead parr. The primary measure of interest is Habitat Area. The Temporal Habitat Stability PM will only be used informally by the FTC to assess whether or not there is concern. It will not be used in trade off analysis because too little is known about its effect of fish growth to develop a benefit function (i.e., what level of daily variability is good for fish?).

The PM's will be calculated for each year of simulation (1967 - 1998) and summarized as median and 90^{th} percentile statistics. The median value indicates how well a given operating strategy meets the rearing objective, while the 90^{th} percentile value will be indicative of how consistently a given operating strategy in meets the rearing objective between hydrologic years.

Means Objective

The objectives associated with each of the rearing PM components described above is as follows:

1. *Habitat Area:* Maximise the amount of usable habitat available to rearing steelhead, chinook, and coho fry, as well as steelhead parr.
2. *Temporal Habitat Stability:* Minimize, but do not eliminate, the variability of available rearing habitat so as to provide a stable environment for the growth of steelhead, chinook, and coho fry, as well as steelhead parr.

Both means objectives are sub-components of the 'global' fisheries objective to maximise the number of wild fish.

Rationale

Steelhead trout, chinook salmon and coho salmon fry all rear in the Cheakamus River basin for at least one summer growing season before migrating out to sea. This growing phase is an important determinant of overall abundance and long term persistence of these species as it affects over-wintering survival and ultimately, the size and abundance of out migrating smolts[1].

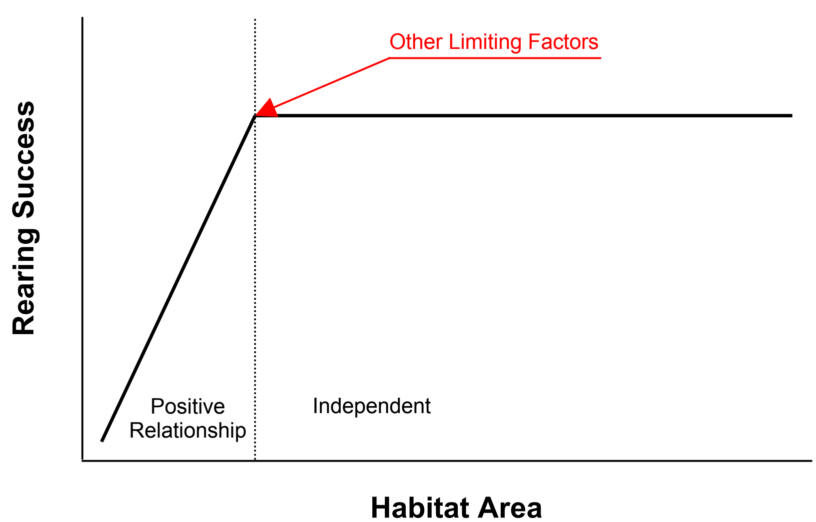
Summer growing conditions vary according to prevailing environmental conditions, the key components of which include water temperature, food supply, and the quantity of quality rearing habitat. These environmental factors do not persist at constant levels through time. Rather they vary from day to day within the growing season, as well as from year to year, and are largely in response to daily and seasonal changes in flow. This is particularly the case with habitat, which is the focus of the present PM. The rationale for such a PM can be broken up into two parts; one for each of the two PM components described above.

Habitat Area

The relationship between rearing habitat and water flow is a complex one because it can vary both in terms of quality, as well as in terms of quantity. One method commonly used to help simplify the relationship is to combine the quantity and quality aspects into a single measure of an ‘equivalent area of prime habitat’. One such measure is the concept of Weighted Usable Area (WUA)[2] or the equivalent used here, Rated Usable Area (RUA)[3]. Once expressed in these terms, the relationship of habitat to flow becomes one that is typically shaped like a dome. Initially, habitat increases rapidly with flow. The rate of increase however, gradually declines with flow and eventually reaches a maximum value (i.e., WUA or RUA). As flows increase beyond this maximum value, habitat area begins to drop. The rate of this habitat loss is often much less than the initial rate of increase[3].

The linkage between rearing success and the quantity of quality rearing habitat is also complex. In the absence of other influencing (i.e., limiting) factors such as food supply, rearing success will always increase as the area of habitat increases. However, when other limiting factors are involved (as is often the case), the relationship becomes one where rearing success initially increases with habitat, but the rate of increase gradually declines to a point where it plateaus. In this plateau region, further increases in habitat have little or no effect on rearing success (Figure 1). This plateau region also defines a river’s productive capacity for a given life history stage or fish size, and can be expressed as a maximum density of fish[4]. For the purposes of this PM however, it will be assumed that no other limiting factors exist in this system, and that rearing success will always increase with the quantity of quality rearing habitat. The limiting effects of other factors, in particular food supply, will be treated as a separate PM.

Figure 1. *Theoretical relationship between rearing success and habitat area, demonstrating the effects of other limiting factors such as food availability.*



Temporal Stability in Habitat

Flows in Cheakamus River are variable from day to day. A large part of this variability is the result of precipitation and runoff events that affect local inflows. Dam operations can contribute or attenuate this variability as well. Given that the quantity of quality habitat varies as a function of flow[1], these daily changes in flow inevitably cause changes in usable habitat. However, as described above, the relationship of habitat to flow is typically dome shaped. As a result, day-to-day variability in habitat may not necessarily track the changes in flow. There are conditions (typically at higher flows) when the amount of habitat is relatively insensitive to changes in flow. Alternatively, there are times when habitat is highly sensitive to flow (such as during low flow periods) and may at times become so low as to cause crowding.

Fish communities can withstand crowded conditions if they are of short enough duration, but persistent crowding, through either increased duration or increased frequency of its occurrence, could be detrimental. The threshold duration at which at which fish communities begin to experience irreversible effects due to crowding is unknown and is likely to be river specific. For the purposes of PM modeling however, a five-day duration threshold will be assumed.

Another aspect of temporal variability important to rearing fish is the shift in location of usable habitat. As flow changes, so does the location of prime habitat, and hence the location of feeding stations. If such changes are dramatic and frequent, they could potentially cause fish to waste energy and feeding time trying to locate new feeding stations and re-establishing social hierarchies. This in turn could compromise the potential for growth. Unfortunately, too little is known about this impact to assess its relative importance as well as develop a direct measure.

Both aspects of temporal variability are incorporated in the PM components described above. The potential impacts associated with crowding will be incorporated into the habitat area component while the impacts associated with spatial change will be tracked independently as the temporal habitat variability component.

Methodology

Scope

Each of the species for which this PM is relevant have different rearing habitat requirements that are in part an inherent component of their behaviour, and part a result of size differences due to age. These differences allow these fish to live in sympatry without strong inter-specific competition for resources. Consequently, there is no single species that can act as a surrogate when trying to evaluate rearing success.

The PM will be calculated for the following species, life history stages and reaches:

Reach	Coho	Chinook	Steelhead[1]	
	Fry	Fry	Fry	Parr
1	✓	✓	✓	✓
2				
3	✓	✓	✓	✓
4	✓	✓	✓	✓
5	✓	✓	✓	✓
6	✓	✓	✓	✓
7	✓	✓	✓	✓
8	✓	✓	✓	✓
9	✓	✓	✓	✓
10				
11			✓	✓
12			✓	✓
13			✓	✓
14				

[1] Referred to as rainbow trout in the resident reaches 11, 12, & 13

Timing

The period over which the rearing PM is calculated depends on the species and life history stage[2]. The dates bracketing the each of the species specific rearing periods are as follows:

Coho fry	April 01 to October 31
Chinook fry	February 15 to October 31
Steelhead fry	July 21 to October 31
Steelhead parr	April 21 to October 31

The rearing PM will be calculated for each year of the simulation exercise (1962 - 1998).

Calculation

Calculation of the Rearing PM begins by transforming the 31-year, daily spill data set (m^3s^{-1}) generated from BC Hydro's operations model to a daily rearing habitat (ha) time series. The transformation procedure is a simple two-step process that is done separately for each reach. The algorithm is as follows:

For each Reach,

1. *Add daily, reach specific, cumulative inflows to the daily spill data.*
2. *Using a quantitative relationship between total reach discharge and rearing habitat, convert the reach-specific daily flow data (m^3s^{-1}) to a daily measure of usable rearing habitat (ha). The relationships are species and life specific and are illustrated in Figures 2a to 2d)*

Next Reach

Once the daily spill data have been converted, the resulting reach specific habitat data are summed to obtain separate daily measures of anadromous (Reach 1-9) and resident (Reaches11-13) fish rearing habitat. Before summing, each reach will be assigned a weight reflecting it's relative importance to the species and life history stage of interest (At this time, all reaches are given equal weight). The summing procedure is important as it minimizes the number of time series, and hence the number of PMs, that must be calculated and analyzed. The result of the summing procedure is a set of six habitat data sets, one for each species and life history stage in the anadromous and resident fish reaches. The functional form of the process described above is as follows:

$$A\_Hab_{d,s} = \sum_{r=1}^{9} Hab_s\left(Q_{D,d} + Q_{R,d}\right) * RI_r \qquad [1]$$

$$R\_Hab_{d,s} = \sum_{r=11}^{13} Hab_s\left(Q_{D,d} + Q_{R,d}\right) * RI_r \qquad [2]$$

where,

$A\_Hab_{d,s}$	=	Anadromous Habitat Area (ha) at a daily time step
$R\_Hab_{d,s}$	=	Resident Habitat Area (ha) at a daily time step
d	=	day
s	=	species or life history stage
$Hab_s(\,)$	=	Functional relationship between flow and habitat*
$Q_{D,d}$	=	Modeled spill from Daisy Dam at a daily time step
$Q_{R,d}$	=	Reach specific, cumulative inflow at a daily time step
RI_r	=	Weighting factor reflecting relative importance

The transformation process is carried out only for the days bounded by the rearing periods described above for each species. As a result, each of the six data sets will consist of 31 time series of daily rearing habitat area, one for each year of simulation. To reduce the size of each data set further, each annual time series of each data set is summarized as two statistics:

1. The amount of habitat available to rearing fish, and
2. The temporal stability of that habitat over the rearing period.

The statistic chosen to best represent the amount of rearing habitat for a given year was the lowest 5-day median habitat area. It recognizes the fact that fish populations are able to tolerate short-term decreases in habitat, yet are limited when such decreases become prolonged. A five-day period is assumed to be an adequate representation this threshold tolerance level. In reality, the true threshold value is unknown. The

* Functional relationships between flow and habitat were defined in two ways. One is based on air photo interpretation of habitat area at different flows (referred to as Rated Usable Area or RUA) and the other is based on the results of a 2 dimension flow model (referred to a Weighted Usable Area or WUA). Both rely on suitability criteria to evaluate habitat quality, though they are defined differently for each method. The two methods are complementary to each other, attempting to overcome some of their respective shortcomings. Both functions will be used in the PM calculation, resulting in two independent values of the PM for analysis.

statistic is calculated by first finding the median value of each 5-day sequence of a given time series and then selecting the lowest of all values, i.e.;

$$Min_y {}_{d=3}^{n-2}\left[Median\left(h_{d-2}, h_{d-1}, h_d, h_{d+1}, h_{d+2}\right)\right]_{y=1}^{31} \qquad [3]$$

where,

y = year

h_d = daily habitat area

The temporal habitat variability component of the PM was created to track potential impacts of frequent, large magnitude changes in habitat. However, because these impacts are poorly understood, a direct measure was not possible. Rather, an indirect measure was developed based on the daily change in discharge. The PM component assumes that 1) habitat location changes with flow; 2) larger changes in flow result in more dramatic spatial shifts in habitat location; and 3) the greater the change, the worse it is for fish.

The temporal habitat variability component of the PM is calculated by first transforming the daily discharge data into a new variable of daily differences in discharge using the following equation:

$$\delta h_d = h_{d+1} - h_d \qquad [4]$$

The new daily data are then summarized and reported as the range of daily habitat change (δh) bracketed by the 10th and 90th percentile values, i.e.,

$$_{y=1}^{31}\left[\delta h_{d90} - \delta h_{d10}\right] \qquad [5]$$

where,

h_{d90} = daily habitat change occurring 90 % or more of the time

h_{d10} = daily habitat change occurring 10 % or more of the time

A smaller value of this statistic is assumed indicative of a stable environment conducive to maximal growth. As with the habitat area component, the statistic will be calculated for each year.

The final step of the PM calculation will be to determine the median and variability (defined by the 10th and 90th percentiles) of each component across all years. The annual median is a measure of how well an operating strategy is meeting the objective of interest, while the annual variance statistic provides a measure of how consistently the objective is being met between hydrologic years.

Data Needs

The following data/functional relationships will be required to calculate the PM:

Data Needs	Status
1. Daily spill data generated from BC Hydro's operations model	*Ongoing*
2. Daily cumulative inflow to each of the 14 reaches in the study area	*Completed*
3. Functional relationships between discharge and rearing habitat for each species and life history stage of interest.	*Completed*
4. Periodicity of the rearing phases of each species and life history stage of interest	*Completed*

Key Uncertainties

The following are critical uncertainties associated with the PM:

Key Uncertainty	Implications to Decision Making Process
1. Daily spill data generated from BC Hydro's operations model may not necessarily reflect true operating practice of Daisy Dam.	Inaccuracies in the operations model are likely to be small relative to the volume of flow that must be managed. They are also likely to be similar between operating strategies.
2. Daily cumulative inflow data to each of reach was based on a rather simple area-based methodology with some correction for geographic differences in precipitation. Accuracy of the inflow data is likely to be suspect.	Although inaccuracies may exist, they will be the same for all operating alternatives tested. Relative differences in PM's between operating alternatives are preserved. Inaccuracies likely to be small such that they are not likely to seriously affect PM rankings.
3. Functional relationships between discharge and rearing habitat are based on methodologies that have yet to be validated. Though there is confidence in the output, the extent to which these relationships reflect reality is unknown.	Assume the relationships to be true for the purposes of decision making. Although the relationships may potentially be in error, the error would be the same for all operating alternatives, hence preserving the relative differences needed to rank alternatives. The relationships are reasonable and potential errors are unlikely to alter rankings. Verification should be part of a monitoring program.
4. The PM does not directly account for potential detrimental effects, in any, that may arise when changing flows cause shifts in the location of prime habitat. The nature and magnitude of such impacts is poorly understood.	Use an indirect measure based on flow along as a surrogate and assume the impact to be real and significant. Resolve the uncertainty in the long term through monitoring and scientific experimentation.
5. It is assumed that rearing habitat is a limiting factor to fish production in the system. Whether this is the case remains uncertain, as the functional form of the habitat vs. fish relationship is unknown.	Assume that this is the case as a precautionary measure. Resolve the uncertainty in the long term through monitoring

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Appendix 2-E: Sp awning Success

(Steelhead Trout, Chinook, Chum and Coho Salmon)

Description

The spawning success PM combines the habitat requirements of spawning adults through a measure of suitable spawning habitat area (WUA) and the incubation conditions during the subsequent egg incubation period. The PM is comprised of three components, of which one is used in trade off analysis, and the others as support for interpretation purposes. The three PM components are:

1. *Effective Spawning Habitat Area (m^2)*: Average area of suitable spawning habitat that remains wetted throughout the subsequent egg incubation period. The average value is calculated as the sum of daily suitable spawning habitat weighted by the daily probability that redds are created.
2. *Redd Survival*: The proportion of redds created during the spawning period that remains wetted during the incubation period and hence survives to hatch.
3. *Area per Redd (m^2/redd)*: Density of surviving redds in the area of effective spawning habitat.

These PM components will be calculated for spawning steelhead trout, chinook, coho and chum salmon. They will be calculated for each year of simulation (1967 - 1998) as well, and summarized as median and 90^{th} percentile statistics. The median value indicates how well a given operating strategy meets the rearing objective, while the 90^{th} percentile value will be indicative of how consistently a given operating strategy in meets the rearing objective between hydrologic years.

Means Objective

The objectives associated with each of the spawning success PM components described above are as follows:

1. *Effective Spawning Habitat Area (m^2)*: Maximise the amount of effective spawning habitat available to steelhead trout, chinook, coho, and chum salmon.
2. By corollary, the effective spawning habitat objective can be achieved by:
   a) Maximizing redd survival
   b) Maximizing the area per redd (for a given escapement)

The means objectives are sub-components of the 'global' fisheries objective to maximise the number of wild fish.

Rationale

Steelhead trout, chinook, chum and coho salmon are known to spawn in the Cheakamus River downstream of the canyon (Reaches 1 to 9). Availability of spawning habitat is assumed to be limiting the potential production of all salmonid species in the river, though empirical evidence in support of this assumption is sparse. Quantity and quality of spawning habitat is flow dependent. Consequently, changes to the flow regime, through changes in Daisy Dam operations, have the potential to affect the productive capacity for salmonids. This effect can occur in two ways. Firstly, by directly affecting the availability of suitable spawning habitat, and secondly, by affecting the incubation success of eggs that have been laid. Because, these two impact pathways are somewhat linked, they were combined as a single life history event where the end point of spawning success is defined as the hatch of alevins.

Spawning

Salmonids are specific in their habitat requirements for spawning. Among the key determinants of suitability include adequate water depth, velocity and substrate. The preferred range of each variable can vary between species and therefore, when they are combined to weight the utility of habitat units, they can be used to determine the area of suitable spawning habitat (Weighted Usable Area or WUA)[1]. It is important to note that this approach to quantifying suitable spawning habitat does not predict the precise location of spawning activity. Rather, it identifies those areas where spawning could potentially occur from those areas where spawning is unlikely. Consequently, it will always over estimate the area of spawning habitat when compared to empirical measures. Though untested, it is assumed that this bias remains constant with river discharge, and is therefore a good relative measure of spawning habitat response to changes in discharge. The relationships used in the present context were derived from two-dimensional hydraulic analysis[2] and are listed in Appendix 1.

Incubation

Incubating eggs tend to be highly resilient to periodic dewatering events during development up until the eyed stage. Once at the eyed stage, the developing embryos become extremely sensitive to dewatering, and die within hours of such events[3]. Thus, the lowest daily average discharge experienced during the incubation period is likely an important determinant of egg survival during the spawning period. Embryos found in redds below the waterline during this low flow period would likely survive to hatch, where as those found above the waterline would likely perish of either desiccation or freezing.

Effective Spawning Habitat

Effective spawning habitat is a measure of habitat that attempts to integrate spawning and incubation requirements into a single variable. The measure recognizes that spawning success is the result of both life history stages and that they cannot be examined in isolation of one another. Where fish spawn on a given day is related to the spawning habitat available on that day, which in turn is a function of the day's discharge. Successful incubation of redds created on that day will depend on whether the redds stay submerged in the water column until hatch. Once hatched, the resulting alevins become mobile in the gravel and hence become less susceptible to dewatering[2].

Calculation of the effective spawning habitat measure assumes that on any given day, the density of redds is proportional to the area of suitable spawning habitat and the number of females arriving on the spawning grounds. Suitable spawning habitat is estimated using the WUA measure described above, while the number of females is determined using a run timing algorithm described in the 'Timing' section below. The distribution of redds within a given section of river is proportional to an area's suitability rating on a scale of 0 to 1 (derived from WUA calculations, where 0 = unsuitable and 1 = prime).

Methodology

Scope

Each species for which the PM is calculated has a different spawning period and set of habitat requirements that are inherent components of their behaviour. Such differences allow these fish to live and grow without strong inter-specific competition for resources. Consequently, no single species can be used as a surrogate for others when trying to evaluate spawning success.

The PM will be calculated for the following species and reaches:

Reach	Coho	Chinook	Chum	Steelhead[1]
1	na	na	na	na
2	na	na	na	na
3	✓	-	✓	-
4	✓	✓	✓	✓
5	-	-	-	-
6	na	na	na	na
7	✓	✓	-	✓
8	✓	✓	-	✓
9	na	na	na	na
10	na	na	na	na
11	na	na	na	na
12	na	na	na	na
13	na	na	na	na
14	na	na	na	na

1. Referred to as rainbow trout in the resident reaches 11, 12, & 13
2. na = not applicable or not available

Timing

The period over which the spawning success PM is calculated depends on the species and life history stage[2]. The dates bracketing each critical, species-specific spawning and developmental periods are as follows:

Species	Female Escapement[2]	Critical Dates				
		Start Spawn	Peak Spawn	End Spawn	Eyed Stage[1]	Hatch
Steelhead	500	Mar 21	May 01	May 15	May 15	Jul 7
Coho	2000	Nov 01	Dec 15	Feb 07	Dec 31	Mar 31
Chinook	500	Aug 01	Sep 21	Oct 15	Aug 31	Mar 31
Chum	15,000	Sep 21	Nov 21	Dec 31	Dec 15	Apr 15

1. Calculated as the number of degree days from the peak spawn date.
2. Calculated as roughly 50% of average historical escapement.

Spawning activity, reported as the number of created redds on day '*d*' for each species, will be distributed through time using a continuous, skewed probability distribution function:

$$redds_{d=StartSpawn}^{EndSpawn} = Pdf(d) \cdot Female\,Escapement \quad [1]$$

The probability distribution function (Pdf) is created numerically using the normal distribution function with the critical spawning dates as input. The full *Pdf* is described by the following two equations:

$$Pdf_{d=StartSpawn}^{PeakSpawn} = \frac{\left(\frac{1}{\sqrt{2\pi}\cdot sd1} e^{-(d-PeakSpawn)^2 / 2\cdot sd1^2}\right)}{\sum_{d=StartSpawn}^{EndSpawn} Pdf(d)} \quad [2]$$

$$Pdf_{d=PeakSpawn}^{EndSpawn} = \frac{\left(\frac{1}{\sqrt{2\pi}\cdot sd2} e^{-(d-PeakSpawn)^2 / 2\cdot sd2^2}\right)\cdot Adj}{\sum_{d=StartSpawn}^{EndSpawn} Pdf(d)} \quad [3]$$

where,

sd1 = (Peak Spawn – Start Spawn)/3

sd2 = (End Spawn – Peak Spawn)/3

$$Adj = \frac{\left(\frac{1}{\sqrt{2\pi}\cdot sd1} e^{-(PeakSpawn)^2 / 2\cdot sd1^2}\right)}{\left(\frac{1}{\sqrt{2\pi}\cdot sd2} e^{-(PeakSpawn)^2 / 2\cdot sd2^2}\right)} \quad [4]$$

The spawning success PM will be calculated for each year of the simulation exercise (1962 – 1998).

Calculation

The spawning success PM is calculated in a series of steps as follows:

For Each Year of Simulation

For Each Reach (Table 1)

1. *For Each day between Eyed Stage and Hatch (Table 2)*
   Add daily cumulative local inflow of Reach to daily total spill from Daisy Dam.
   Next day
2. *Find minimum discharge (Q_{min}) during incubation period*
3. *For Each day between Start Spawn and End Spawn (Table 2)*
   Calculate Q_d by adding daily cumulative local inflow of Reach to daily total spill from Daisy Dam
   Using Q_d, calculate usable spawning habitat area WUA_d
   Using Q_d ,Q_{min},and look up tables in Appendix 1, calculate effective spawning habitat area (Eff_WUA_d) as a proportion of WUA_d that remains wetted during the incubation period
   Calculate number of redds created ($Redds_d$) using Eq. 1
   Calculate daily redd density ($Density_d$) as
   Calculate daily number of surviving redds ($Survival_d$) as

$$Eff\_WUA_d \cdot Redds_d / WUA_d \qquad [5]$$

Next day

4. *Calculate annual reach average Eff_WUA_r as*

$$\sum_{d=StartSpawn}^{EndSpawn} Eff\_WUA_d \cdot Pdf(d) \qquad [6]$$

Next Reach

1. *Calculate total annual average Eff_WUA as*

$$\sum_{reach=1}^{n(Table\ 1)} Eff\_WUA_{reach} \qquad [7]$$

2. *Calculate annual redd survival as*

$$\frac{\sum_{r}^{reach} \sum_{d=StartSpawn}^{EndSpawn} \mathrm{Survival}_{r,d}}{Female\ Escapement} \qquad [8]$$

3. *Calculate annual redd density as*

$$\frac{\sum_{r}^{reach} \sum_{d=StartSpawn}^{EndSpawn} \mathrm{Survival}_{r,d}}{total\ Eff\_WUA} \qquad [9]$$

Next Year

The final step of the PM calculation will be to determine the median and variability (defined by the 10^{th} and 90^{th} percentiles) of each PM component across all years. The annual median is a measure of how well an operating strategy is meeting the objective of interest, while the annual variance statistic provides a measure of how consistently the objective is being met between hydrologic years.

Data Needs

The following data/functional relationships will be required to calculate the PM:

Data Needs	Status
1. Daily spill data generated from BC Hydro's operations model	*Ongoing*
2. Daily cumulative inflow to each of the 14 reaches in the study area	*Completed*
3. Functional relationships between discharge, suitable spawning habitat area (WUA), wetted area, and proportion of redds that survive winter incubation for each reach of interest.	*Completed*
4. Periodicity of the spawning period, eyed stage of development, and hatching for each species of interest.	*Completed*

Critical Uncertainties

The following are critical uncertainties associated with the PM:

Critical Uncertainty	Implications to Decision Making Process
1. Daily spill data generated from BC Hydro's operations model may not necessarily reflect true operating practice of Daisy Dam.	Inaccuracies in the operations model are likely to be small relative to the volume of flow that must be managed. They are also likely to be similar between operating strategies.
2. Daily cumulative inflow data to each of reach was based on a rather simple area-based methodology with some correction for geographic differences in precipitation. Accuracy of the inflow data is likely to be suspect.	Although inaccuracies may exist, they will be the same for all operating alternatives tested. Relative differences in PM's between operating alternatives are preserved. Inaccuracies likely to be small such that they are not likely to seriously affect PM rankings.
3. Functional relationships between discharge and spawning habitat are based on a methodology that has yet to be validated. Though there is confidence in the output, the extent to which these curves reflect reality is unknown.	Assume the relationships to be true for the purposes of decision making. Although the relationships may potentially be in error, the error would be the same for all operating alternatives, hence preserving the relative differences needed to rank alternatives. The relationships are reasonable and potential errors are unlikely to alter rankings. Verification should be part of a monitoring program.
4. The PM does not account for potential detrimental effects, in any, that may arise when changing flows cause shifts in the location of prime habitat.	Must assume that there are none. Verify in a monitoring program.
5. It is assumed that effective spawning habitat is a limiting factor to fish production in the system. Whether this is the case remains uncertain, as the functional form of the habitat vs. fish population size relationship is unknown.	Assume that this is the case as a precautionary measure. Resolve the uncertainty in the long term through monitoring.

References

1. **Bovee, K.** 1982. A guide to stream habitat analysis using Instream Flow Incremental Methodology. U.S. Fish and Wildlife Service. Instream Flow Information Paper 12.
2. **Chillibeck, B.** *In Progress*. Habitat Analysis using River 2 D Software.
3. **Reiser, D.W. and R.G. White.** 1981. Influence of stream flow reductions on salmonid embryo development and fry quality. Idaho Water and Energy Resources Research Institute. University of Idaho. Project A-058-IDA. 154 pp.
4. **Groot, C. and L. Margolis (eds.).** 1991. Pacific Salmon Life Histories. UBC Press. Vancouver. 564 pp.

Appendix 1: Chum Habitat Suitability Index Information

Wilson David, HIS Data – Chum Salmon Spawning

To: Wilson David
From: dblister & associates <dblister@telus.net>
Subject: HIS Data – Chum Salmon Spawning
Cc: Brown Jesse, Bruce James, Chilibeck Barry, McAdam Steve, Neuman Ross, Ptolemy Ron, Sneep Dan, Warring John
Bcc:
Attached:

Date: Jan. 23, 2001

As a contribution to the FTC's HIS exercise, I attach Tables 1 and 2 with water depth and velocity data for chum salmon redds at Big Qualicum River. Table 1 includes the data listing and notes on study conditions, while Table 2 includes frequency distributions. Velocities were at nose level rather than mean column velocity.

Mean values for chum redd depth and velocity at Big Qualicum are compared in the following table to values for chum salmon in 5 Oregon streams. While means were quite similar, variation was significantly higher in the Oregon situation, perhaps reflecting the greater number of study streams.

	Big Qualicum River (n=56)	**Oregon streams (n = 214)**
Velocity at 0.12 off bottom		
mean (m/s)	0.71	0.73
SD	0.21	0.65
Depth		
mean (m)	0.37	0.30
SD	0.15	0.41

Oregon data were from A.K. Smith. 1973. Development and application of spawning velocity and depth criteria for Oregon salmonids. Trans. Amer. Fish. Soc. 102: 312-316.

Brent Lister

Table 1: Water depth and velocity data for chum salmon redd sites, Big Qualicum River (B. Lister, Jan. 2001).[1]

Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)
0.88	0.41	0.24	1.14
0.49	0.66	0.34	0.30
0.98	0.73	0.50	0.46
0.43	0.63	0.30	1.01
0.27	0.49	0.34	0.57
0.30	0.62	0.46	0.68
0.40	0.97	0.43	0.71
0.32	0.81	0.30	0.83
0.24	0.69	0.30	0.68
0.38	1.08	0.23	1.11
0.40	0.63	0.21	1.02
0.41	0.31	0.27	0.61
0.30	0.68	0.49	0.62
0.76	0.71	0.43	0.74
0.64	0.62	0.30	0.68
0.27	0.53	0.15	0.62
0.32	0.50	0.38	0.59
0.47	0.50	0.35	0.57
0.32	0.59	0.30	0.50
0.43	0.83	0.43	0.56
0.24	0.74	0.27	0.68
0.21	0.68	0.24	0.77
0.26	1.08	0.37	0.44
0.34	0.71	0.44	0.68
0.27	0.93	0.30	0.51
0.24	1.26	0.37	0.78
0.34	1.06	0.33	0.61
0.30	0.91	0.46	0.85

[1] Data collected by Canadian Department of Fisheries. Conditions relating to data collection were as follows:

- Data obtained on November 22, 1964 under stable, controlled flow conditions during early stages of spawning when competition for redd sites would have been minimal.
- Measurements (n=56) were taken at all chum redd sites encountered in a 1 km (approx.) river section.
- Water depths and velocities at individual redd sites were measured on undisturbed stream bed at upstream edge of redd.
- Velocity was measured with a Gurley meter 0.12 m above the stream bed.
- Stream substrate was not documented. Surface bed material size would have been in the gravel-cobble range, tending more toward cobble (Bovee code 5 and 6).

Table 2: Frequency distributions of water depth and velocity at Big Qualicum River chum salmon redd sites (B. Lister, Jan. 2001)

	Midpoint of class (m/s)	Frequency	Suitability Index
Velocity			
1	0.35	2	0.12
2	0.45	4	0.24
3	0.55	10	0.59
4	0.65	17	1.00
5	0.75	8	0.47
6	0.85	4	0.24
7	0.95	3	0.18
8	1.05	5	0.29
9	1.15	2	0.12
10	1.25	1	0.06
		56	
Depth	0.15	1	0.05
	0.25	14	0.64
	0.35	22	1.00
	0.45	14	0.64
	0.55	1	0.05
	0.65	1	0.05
	0.75	1	0.05
	0.85	1	0.05
	0.95	1	0.05
		56	

Appendix 2-F: Adult Migration

(Chinook, Coho, Chum, Steelhead)

Description

The adult migration performance measure is the average number of days less than 10 cms at the Brackendale gauge over 32 water years (1967-1998). This PM is calculated over the species-specific adult in-migration period for chinook, coho, chum and steelhead.

Means Objective

Minimize the average number of days below 10 cms during the adult in-migration period for chinook, coho, chum, and steelhead.

Rationale

The FTC evaluated this impact hypothesis (#4):

> "Operations at Daisy Dam affect the frequency, duration and magnitude of moderate flows that affect upstream migration . . . Changes to adult in-migration timing will affect spawning success . . . and influence the abundance of wild fish."

The FTC rejected this hypothesis; however, they hypothesized that a threshold flow of 10 cms measured at Brackendale would allow for adult passage and access to spawning habitat, particularly in the late fall and winter period.

Anecdotal information collected by Squamish First Nation fisheries crews during low flows in fall 2000 observed that adult chum had difficulty gaining access to certain groundwater-fed side channel spawning areas. Also in 2000, a higher than normal incidence of partially spawned females was observed in these side channels, perhaps reflecting stresses associated with difficult conditions for channel entry and upstream movement.

Results of steelhead and chinook salmon radio tracking studies suggest that flows in the Cheakamus River mainstem do not have a significant influence on run timing. There are no barriers to migration within the Cheakamus mainstem that require high flows for passage, irrespective of the flows released at Daisy Dam. This conclusion is supported by other studies in BC and Pacific Northwest that suggest sudden drops in barometric pressure, not the sudden increase in flow, is likely the key trigger for in-migration when passage is not an issue. (Allen, 1959; Foerster, 1968; Holtby et al, 1989).

The FTC currently holds the view that when flows at Brackendale are greater than 10 cms, there will be no in-migration problems for returning adults. An appropriate performance measure for adult salmon and steelhead upstream migration in the Cheakamus mainstem would therefore be the number of days when river flow at Brackendale drops below 10 cms.

Methodology

The performance measure is calculated using the modeled average daily flow at the Brackendale gauge. The AMPL Brackendale flow output for each alternative is filtered to extract the total number of days where the flow is below 10 cms during the in-migration period for each species (Table A2.1). This total is then converted to the average over the 32 water years used in modeling (1967-1998).

Table A2.1: Start and end dates for the in-migration period used to calculate the Adult In-migration performance measure. These dates are taken from the FTC Cheakamus River fish periodicity table.

Species	Start	End
Chinook	June 7	September 21
Coho	September 15	December 31
Chum	October 7	November 30
Steelhead	January 15	May 30

Data Needs	Status
1. Daily Brackendale Gauge flows (cms) generated from BC Hydro's operations model	*ongoing*
2. Field observations during chum spawning periods coinciding with low flows	*See Monitoring plan*

Critical Uncertainties

The following are critical uncertainties associated with the PM:

Critical Uncertainty	Implications to Decision Making Process
1. Daily spill data generated from BC Hydro's operations model may not necessarily reflect true operating practice of Daisy Dam.	Inaccuracies in the operations model are likely to be small relative to the volume of flow that must be managed. They are also likely to be similar between operating strategies.
2. Not certain that all off-channel spawning areas are readily accessible at very low flows. Need confirmation. Further analysis is being undertaken to assess the effects of low river flows in 2000 on salmon spawning distribution.	Ongoing field observations by SFN crews while assessing spawning populations.

References

1. **Allen, G.H.** 1959. Behaviour of Chinook and Silver Salmon. Ecology V 40: p. 108

2. **Foerster, R.E.** 1968. The sockeye salmon. Bull. Fish. Res. Bd. Canada 162. 422 p.

3. **Holtby, L.B., T.E. MacMahon, and J.C. Scrivener.** 1989. Stream temperatures and inter-annual variability in the emigration timing of coho salmon smolts and fry and chum salmon fry in Carnation Creek, British Columbia. Can. J. Fish. Aquat. Sci. 46: 1396 - 1405.

Appendix 2-G: Fish Food (Benthos) Production

(Steelhead Trout, Chinook, and Coho Salmon)

Description

The food production PM is calculated from modeled estimates of benthos biomass and relates to the food requirements of rearing steelhead, chinook, and coho fry, as well as steelhead parr. Separate biomass estimates will be calculated for each reach and season under consideration (Tables A2.2 and A2.3 respectively) that will in turn be averaged (Eq. 3 and 4) to provide annual PMs for anadromous and resident sections of the river.

The annual PMs will be calculated for each year of simulation (1967 - 1998) and summarized as median and 90th percentile statistics. The median value indicates how well a given operating strategy meets the food production objective, while the 90th percentile value will be indicative of how consistently a given operating strategy in meets the objective between hydrologic years.

Means Objective

The PM described above is linked to the following means objective:

1. Maximise benthos biomass, and hence availability of food for rearing salmonids.

This objective is a component of the 'global' fisheries objective of maximizing the number of wild fish in Cheakamus River.

Rationale

Benthic invertebrates are well known to be key indicators of water quality, availability of food for fish, and of ecosystem structure and function (Rosenberg and Resh 1993). They are ubiquitous, being present in the river across all space and time scales. There are a large number of species that can provide an integrated measure of stress response. They are sedentary, allowing effective spatial analyses of disturbance. They are a fundamental food source for fishes, allowing analyses of temporal and spatial change in that food supply. They have long enough life cycles to allow temporal analysis of response to stress. The result is that benthic invertebrates can provide a continuous monitor of the water they inhabit enabling analysis of effects of physical (e.g., flow) and chemical (e.g., nutrients) manipulation.

The invertebrate community of Cheakamus River is comprised almost entirely of aquatic insects typical of pristine mountain rivers. From Studies carried out in 1996 and 2000, orders occurring in greatest abundance and biomass included the mayflies and dipterans which together represented > 90% of community abundance and > 60% of community biomass. Density of the stoneflies was < 5% of community density, but because of large mean size, stonefly biomass comprised roughly 17% and 14% of community biomass respectively. Other taxa represented < 4% of community abundance and < 2% of community biomass. They included springtails, namatode worms, Hydra sp., spiders, beetles, water mites, freshwater clams, flatworms, oligochaete worms, other annelid worms, and terrestrial Lepidoptera.

Average invertebrate density across all seasons and locations was 31,151 animals/m^2 in 1996, increasing to 52,959 animals/m^2 in 2000. These densities are very high and are at the top end of values found in other oligotrophic systems receiving some level of nutrient enrichment. There was almost complete similarity between the composition of benthos and prey ingested by fish. This association was strong evidence that measures of benthos abundance composition and biomass were relevant indicators of food availability for fish.

Using multiple regression techniques, a model was developed using data collected in 1996 and 2000 to predict benthic invertebrate biomass. Results of the analysis suggested that peak biomass of periphyton (PB), distance from a reservoir or lake (DFR), coefficient of variation of discharge (Qcv), and phosphorus concentration were key determinants. Input of peak biomass of periphyton into the benthos model was accomplished using a second model that predicted PB. Independent variables that provided the best fit of that model included flow (Q), phosphorus concentration, and biomass of mayflies, stoneflies and non-insect taxa. Relationships in both models agree with findings in the literature (Perrin 2001).

The finding that both magnitude and variation of flow are significant predictors of benthic biomass supports the hypothesis that Daisy Dam releases can have profound effects on the benthic invertebrate community. The similarity between the composition of benthos and stomach contents of Cheakamus River salmonids suggests that changes to the benthic invertebrate community could have implications to the food availability and hence, growth of rearing salmonids.

Methodology

Scope

The Fish Food Availability PM is not species-specific, though it is intended to apply to all rearing salmonids. It is calculated separately for the anadromous and resident fish sections of the river, and is based on weighed reach-specific calculations corresponding to Perrin (2001) sample sites.

Table A2.2: Reach locations of PM calculations.

Section	Reach	Sample Site*	Weight
Resident	11	CH-5	0.25
Anadromous	8	CH-6	0.25
	4	CH-7	0.25
	1	CH-8	0.25

* From Limnotek (2001)

Timing

The Fish Food Production PM is calculated separately for each season. Start and end dates for the calculation correspond to the seasonal sampling periods defined by Perrin (2001) which cover a maximum of 2 months of each season (Table A2.3). This restriction ensures that the times for which the model is calculated corresponds to the database from which it is derived. The seasonal PM's are calculated for each year of the simulation exercise (1962 - 1998). Seasonal weightings may be applied to collapse the seasonal values into a single PM for trade-off purposes.

Table A2.3: Seasonal timing of PM calculations.

Season	Start Date	End Date	Weight
Winter	Jan 18	Feb 28	0.25
Spring	May 16	Jun 29	0.25
Summer	Aug 15	Sep 27	0.25
Fall	Nov 14	Dec 29	0.25

Calculation

Calculation of the fish food availability PM is as follows:

For Each Year of Simulation
For Each Season (Table A2.3)
For Each Reach (Table A2.2)
For Each day between Start Date and End Date (Table A2.3)
Add the daily cumulative local inflow of Reach to the daily total spill out of Daisy Dam.
Next day
Calculate Average Reach Discharge
Calculate Discharge Coefficient of Variation
Calculate Benthos Biomass
Next Reach
Calculate Weighted Sum of Reach Biomass Estimates
Next Season
Calculate Weighted Average of Season Biomass estimates
Next Year

Most of the calculations in the algorithm above are straightforward. The only exception is the calculation of benthos biomass that requires the following simulation algorithm:

For Day = 1 to 16

1. *Calculate Benthos Biomass (TOTBIO) using Eq. 1 and result of Step 3**
2. *Distribute benthos biomass (TOTBIO) as follows:*
   - ✓ *0.40 x TOTBIO = biomass of mayflies > 1mm in size (EPHEMBIO)*
   - ✓ *0.05 x TOTBIO = biomass of stoneflies > 1 mm in size (PLECOPBIO)*
   - ✓ *0.03 x TOTBIO = biomass of all non-insect invertebrates (OTHERSBIO)*
3. *Calculate Periphyton Biomass (PB) using Eq 2, and result of Step 2*

Next Day

**TOTBIO calculation on day 1 uses a starting PB value of 5 $\mu g \cdot cm^{-2}$ of chlorophyll a.*

Total benthos biomass is given as the TOTBIO value calculated at the end of a 16-day simulation. The equations used in the algorithm to calculate benthic and periphyton biomass are as follows:

$$TOTBIO = (54.828*((PB+1)^{0.437})*((DFR+1)^{0.457})*((Qcv+1)^{-3.028})*(SRP+1)^{-1.145})*((TP+1)^{0.54}))-1 \quad [1]$$

where:

TOTBIO is biomass of benthic invertebrates (mg dry weight/sample)
PB is peak biomass of periphyton ($\mu g \cdot cm^{-2}$) calculated from Eq 2.
DFR is distance from a lake or reservoir measured in Km
Qcv is the coefficient of variation discharge (no units)
SRP is SRP concentration ($\mu g \cdot L^{-1}$) and
TP is TP concentration ($\mu g \cdot L^{-1}$).

$$PB = (4.84*((Q+1)^{-0.415})*((SRP+1)^{0.530})*((EPHEMBIO+1)^{0.205}) *((PLECOPBIO+1)^{-0.165})*((OTHERSBIO+1)^{0.25}))-1 \quad [2]$$

where:

PB is peak biomass of periphyton (μg·cm^{-2} of chlorophyll a)
Q is reach-specific mean flow for the period of accrual measurements (m^3·s^{-1})
SRP is Soluble Reactive Phosphorus concentration (μg·L^{-1})
EPHEMBIO is the biomass of all mayflies >1 mm in size (mg dry weight/sample)
PLECOPBIO is the biomass of all stoneflies >1 mm in size (mg dry weight/sample)
OTHERSBIO is the biomass of all non-insect invertebrates (mg dry weight/sample)

To convert the resulting density estimate to an absolute measure of biomass, the result is multiplied by an average wetted area value.

$$Benthic\ Biomass = TOTBIO * WA(reach, Q_{avg}) \quad [3]$$

where:

WA(reach, Q_{avg} is the functional relationship of wetted area given the average seasonal discharge (Q_{avg}) and reach.

The DFR, SRP, and TP variables were found not vary between seasons and were therefore, held constant in the model. They did however, vary between reaches (Table A2.4).

Table A2.4: Reach differences in the variables used to estimate benthic biomass that are not flow related.

Reach	Distance From Reservoir (DFR)	Soluble Reactive Phosphorus (SRP)	Total Phosphorus (TP)
1	25.0 km	3.3 μg·L^{-1}	27.3 μg·L^{-1}
7	16.0 km	2.4 μg·L^{-1}	15.8 μg·L^{-1}
8	13.7 km	1.2 μg·L^{-1}	12.2 μg·L^{-1}
11	4.2 km	1.3 μg·L^{-1}	13.4 μg·L^{-1}

The result of the algorithm is a table of reach specific, seasonal estimates of benthos biomass for each of the 30 years of simulation. These estimates will be averaged to give an estimate of annual benthic biomass using the following two equations:

$$Benthic\ Biomass_{Anadromous} = \sum_{Season=1}^{4} \sum_{Reach=1}^{n} Biomass_{Season,Reach} \times Wt_{Season} \times Wt_{Reach} \quad [4]$$

where:

Benthic Biomass$_{Anadromous}$	=	*Annual average biomass of benthic invertebrates across all reaches accessible to anadromous salmonids (Reaches 1, 7, and 8).*
Biomass$_{Season,Reach}$	=	*Reach and season specific biomass estimates.*
Wt$_{Season}$	=	*Seasonal weighting factor where* $\sum_{Season=1}^{4} Wt_{season} = 1$ *(Table A2.3)*

Wt_{Reach} = *Reach weighting factor where* $\sum_{Reach=1}^{n} Wt_{reach} = 1$ *(Table A2.2)*

$$Benthic\ Biomass_{Resident} = \sum_{Season=1}^{4} Biomass_{Season} \times Wt_{Season} \qquad [5]$$

where:

$Benthic\ Biomass_{Anadromous}$ = *Annual average biomass of benthic invertebrates in Reach 11.*

The final step of the PM calculation is to calculate the median and variance (defined by the 10^{th} and 90^{th} percentiles) of the annual PM values across all years. The annual median is a measure of how well an operating strategy is meeting the food production objective, while the annual variance statistic provides a measure of how consistently the objective is being met between hydrologic years.

Data Needs

The following data/functional relationships will be required to calculate the PM:

Data Needs	Status
1. Daily spill data generated from BC Hydro's operations model.	*Ongoing*
2. Daily cumulative inflow to each of the 14 reaches in the study area.	*Completed*
3. Functional relationship between discharge and wetted area for each reach.	*Incomplete*
4. Functional relationships between discharge and reach x season specific benthic biomass.	*Completed*
5. Season and reach specific weighting factors.	*Incomplete*

Key Uncertainties

The following are critical uncertainties associated with the PM:

Critical Uncertainty	Implications to Decision Making Process
1. Daily spill data generated from BC Hydro's operations model may not necessarily reflect true operating practice of Daisy Dam.	Inaccuracies in the operations model are likely to be small relative to the volume of flow that must be managed. They are also likely to be similar between operating strategies.
2. Daily cumulative inflow data to each of reach was based on a rather simple area-based methodology with some correction for geographic differences in precipitation. Accuracy of the inflow data is likely to be suspect.	Although inaccuracies may exist, they will be the same for all operating alternatives tested. Relative differences in PM's between operating alternatives are preserved. Inaccuracies likely to be small such that they are not likely to seriously affect PM rankings.

Critical Uncertainty	Implications to Decision Making Process
3. Functional relationship between discharge and benthic food production is based on limited range of flow conditions. For some scenarios, extrapolation has to be done to calculate PM values, introducing potential errors in biomass predictions.	The errors introduced by extrapolation can lead to misleading conclusions. The biases are not necessarily the same for all operating strategies and could affect relative ranking. Though the models are deemed adequate for decision-making, confirmation through continued monitoring of benthos production is necessary.
4. Converting the biomass density estimate to a measure of total biomass requires use of a usable wetted area estimate. Total wetted area was used here. This assumes that the entire wetted area of a reach has equally optimum conditions. This is not likely to be the case. HIS functions that are used to define hydraulic utility are unknown at this time.	Introduces a positive bias to all biomass calculations. Uncertain at this time whether bias will be same for all strategies, thus allowing comparisons to proceed without error. If biases are not the same, the errors could affect relative ranking. Will have to assume constant bias at this time. Confirmation through monitoring will be necessary
5. It is assumed that benthic food production is a limiting factor to fish production in the system. Whether this is the case remains uncertain, as the functional form of the benthos vs. fish production relationship is unknown.	Assume that this is the case as a precautionary measure. Resolve the issue in the long term through monitoring

References

1. **Perrin, C.J.** 2001. Trophic Structure and function in the Cheakamus River for Water Use Planning. Prepared for BC Hydro and Resort Municipality of Whistler by Limnotek Research and Development Inc. Vancouver. 70 p.

2. **Rosenberg, D.M. and V.H. Resh.** 1993. Introduction to freshwater biomonitoring and benthic macroinvertebrates. *In:* D.M. Rosenberg and V.H. Resh. Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman and Hall. New York. 488 p.

Appendix 3: Fisheries Studies – Summary and Evaluation

(Purpose, budget, utility, transferability)

A3.1 FTC Studies Summary Table

Study Objective	Status	Reference Citation
Determine how Cheakamus Facility operations affect the frequency, duration and magnitude of flows that cause changes in the geomorphology of the Cheakamus River mainstem and consequently the quantity and quality of fish habitat.	completed	**Northwest Hydraulic Consultants.** 2001. Analysis of Channel Morphology and Sediment Transport Characteristics of the Cheakamus River. Prepared for BC Hydro & Power Authority. 40 pp. + App.
Document the physical processes that characterize the quantity and quality of mainstem rearing and spawning habitat for juveniles and adults and how this habitat changes as a function of discharge.	completed	**Latitude Geographics Group Ltd.** 2001. Cheakamus river Water Use Plan: GIS Development and 2D Fish habitat Analysis. Prepared for BC Hydro. 57 pp + App. **Melville, C.** 2001. Water Quality Monitoring on the Cheakamus River 2000. Final Report. 26 pp. **Sneep, J.** 2001. Cheakamus River Juvenile Salmonid Distribution Assessment September 1999 to July 2000. 32 pp. + App.
Determine how changes in discharges from Daisy Dam affect nutrients and fish food supply (invertebrates) and hence, affect juvenile fish growth and survival.	completed	**Perrin, C.J.** 2001. Trophic structure and function in the Cheakamus River for water use planning. Report prepared by Limnotek Research and Development Inc. for BC Hydro and Resort Municipality of Whistler. 67 pp. **K.A. McIntosh and I. Robertson.** 2001. Cheakamus Floodplain Ecosystem and Wildlife Overview. 26 p. + maps.
Determine how Daisy Dam operations affect mainstem flow discharges which in turn affect upstream migration and spawning distribution of adult salmonids and outmigration timing of smolts.	completed	**McCubbing, D. and C. Melville**. 2000. Chinook Spawning Migration in the Cheakamus river, Based on Radio Tracking in the summer of 1999. Prepared for BC Hydro by Instream Fisheries Consultants. 35 pp. **McCubbing, D. and C. Melville.** 2000. Steelhead trout escapement monitoring on the Cheakamus River- an evaluation of the potential application of automated counter technologies utilizing radio tracking data from 2000. 31 pp. **Golder Associates Ltd.** 2000. Salmon distribution in the Lower Cheakamus River, B.C.: BC Hydro Water Use Plan. Report 002-1742. 7 p. + app. **Korman, J. and R. Ahrens.** 2001. Escapement Estimation of Winter-Run Steelhead on the Cheakamus River: Stock Assessment and Monitoring Implications. Prepared for CMS WUP FTC. 37 pp. **Melville, C. and D. McCubbing.** 2000. Assessment of the 2000 Juvenile Salmon Migration from the Cheakamus river, Using Rotary Traps. Prepared for BC Hydro by Instream fisheries Consultants. 42 pp.

Study Objective	Status	Reference Citation
Determine how Daisy Dam operations affect flow discharges which could directly affect water temperatures and hence, emergence times of incubating salmonids, summer growing conditions, and over-wintering survival.	completed	**McAdam, S.** 2001. Water Temperature Measurements on the Cheakamus River- Data Report June, 1999 to December, 2000
Investigate the interaction between groundwater and surface waters and potential impacts on salmon habitat	incomplete	See Cheakamus Monitoring Plan Sec. xxx
Determine the resident fish use in the Cheakamus upstream of the barrier	incomplete	See Cheakamus Monitoring Plan Sec. xxx
Investigate the impact of Cheakamus River powerhouse operations on juvenile stranding in the Squamish River.	incomplete	See Cheakamus Monitoring Plan Sec. xxx

A3.2 Executive Summaries of FTC Study Reports

Northwest Hydraulic Consultants. 2001. Analysis of Channel Morphology and Sediment Transport Characteristics of the Cheakamus River

Executive Summary

This study is a contribution to the Water Use Plan (WUP) being developed by BC Hydro and watershed stakeholders for the Cheakamus River. BC Hydro owns and operates the Cheakamus Project. The project was commissioned in 1957 and consists of Daisy Lake Dam, Daisy Lake, and a diversion to a powerhouse on the Squamish River. The objectives of our study were to evaluate the historic changes in the morphology of the Cheakamus River and their relationship to the operation of Daisy Lake Dam and to assess whether or not altering different operating regimes could reverse any observed changes. BC Hydro provided two potential new flow regimes for analysis.

The Cheakamus Project has altered both the hydrology and coarse sediment supply of the Cheakamus River downstream of Daisy Lake. Storage and diversion have reducing flows during the snowmelt freshet and the annual peak flow has also been reduced, by about 15% at the Brackendale gauge site. Daisy Lake also traps large woody debris and coarse sediment carried down from the upper watershed. While some of this material was historically deposited on the site of Daisy Lake, and estimates of delivery to the lower river are very approximate, coarse sediment supply to the lower Cheakamus River may have been reduced by up to 50% by interception in Daisy Lake.

A detailed assessment of the morphologic changes in Reaches 4, 5 and 6 (between Culliton Creek and Cheekye River) was completed from historic air photos dating to 1946. Reaches 5 and 6 are laterally stable, single-channel reaches that are now less stable than in the past, primarily due to growth and reorganization of bars during the large floods of the past twenty-five years. Reach 4 shows an opposite trend, to greater lateral stability and less complexity. Narrowing of the main channel and loss of connectivity of side and back channels on the floodplain are the main changes, both reducing habitat complexity. These morphologic changes have resulted mainly from human interference by bridge construction, bank protection and dykes, reduced coarse sediment supply due to interception at Daisy Lake, Rubble Creek and Cheekye River fans, and reduced LWD supply.

Two limiting potential flow regimes were examined in the report: Scenario A, where inflows are passed through Daisy Lake, and Scenario B, where Daisy Lake is operated for power generation. Scenario A is similar to the flow regime that would occur if Daisy Lake were not constructed; Scenario B is similar to the one that occurred from 1957 to 1994. Scenario B would result in few further changes to the morphology of the lower Cheakamus River. Scenario A would probably result in a slightly wider and deeper channel, and possibly, bed lowering and a coarser substrate. Scenario B would not reverse the observed channel pattern changes in Reach 4; instead, the increased peak flows would likely continue the trend to a sinuous single-channel reach.

It is our view based on inspection of the streambed that flushing releases are not now required on the Cheakamus River. Flows might be released during the snowmelt freshet to prevent establishment of pioneer vegetation on bar surfaces. It is estimated that from 250 to 350 m3/s would be required at the gauge near Brackendale to overtop the bars, although the required duration and frequency are not known. Removal of existing pioneer vegetation would require a much larger flow, equivalent to that needed for general mobilization of the bed material. Return periods for these flows are estimated to be greater than 20 years and the flow releases would be large enough that they would flood low-lying areas and result in significant morphologic changes along the river. It would be simpler and more effective to remove the vegetation mechanically, perhaps in conjunction with habitat restoration activities.

Some of the changes in the morphology of the lower Cheakamus River have resulted from trapping of coarse sediment and large woody debris, rather than from reduced peak flow. Mitigation for these footprint impacts might consist of:

- Supplying coarse sediment stored on the Rubble Creek or Cheekye River fan to the Cheakamus River or supplying gravel from other sources at convenient sites along the river to mitigate interception by Daisy Lake.
- Constructing connected, open side channels in Reaches 3 or 4, or maintaining the existing side channel in Reach 6 to mitigate for the simplified stream channel.
- Alternatively, mitigation might involve moving the road and removing the bridge in Reach 4 (or replacing the existing bridge), purchasing floodplain property, removing dykes and bank armour and allowing Reach 4 to re-establish a multiple-channel pattern. Re-creation of the previous pattern in this reach would take many years.
- Placing debris to create habitat at sites where it is likely to remain, such as at the heads of side channels, in side channels, or where it can be anchored, primarily as logjams at key sites, to mitigate for reduced LWD supply.

Latitude Geographics Group Ltd. 2000. Cheakamus River Water Use Plan: GIS Development and 2D Fish Habitat Analysis. 8 pp. + App.

Executive Summary

Phase One of this project provided the Cheakamus Water Use plan with GPS data collection for base mapping of the Cheakamus River. This project included GPS field data capture of riverine and land-based features. These features were interpreted and input into a GIS database. Hardcopy and digital softcopy map products were created for project planning. Phase Two of this project includes air photo data capture for digital data analysis and classification of aquatic habitat polygons. Phase Two methods are included in the document "*Mapping Aquatic Riverine Features: Using GIS for Digital Data Capture and Air Photo Analysis*" included in Appendix III of this report. Reach breaks and sample site maps are included in Appendix IV of this report.

Melville, C. 2001. Water Quality Monitoring on the Cheakamus River 2000. Final Report. 26 pp.

Executive Summary

Flow discharge into the Cheakamus River is currently regulated by BC Hydro through Daisy Lake Reservoir and Dam and the Cheakamus generating plant, a 155 MW storage and diversion project. A Water Use Plan (WUP) process commenced for the Cheakamus in 1999 to review flow releases related to fisheries and other purposes.

To assist in developing a flow regime for the Cheakamus River below Daisy Dam, the Fisheries Technical Committee (FTC) conducted studies to provide information on salmonid populations and their habitat. This study was commissioned to provide water quality data on the lower 16.7 km (anadromous section) of the Cheakamus River to assist in the interpretation of data derived from other studies.

The study documents seasonal and locational patterns of variation in turbidity (NTU), alkalinity (pH units), conductivity (μS/cm), temperature (°C) and salinity (ppt). Eight reaches along the lower Cheakamus River were sampled from May 1999 to December 2000, and the collected data were combined with water quality data obtained by Limnotek Research and Development (LRD) in a previous study (November 1999 – May 2000).

Result for turbidity measurements indicated that individual rainfall events had the greatest impacts on turbidity levels. In addition, all sites showed sustained high turbidity during freshet. The influence of tributaries was variable: while the Cheekeye River did not significantly influence turbidity on the Cheakamus mainstem, the turbidity of Culliton Creek was strongly correlated to mainstem turbidity. It should be noted that due to inconsistent sample methods, variance in temporal readings may reflect the differences in sample methods rather than actual turbidity differences.

Tributaries had small influences on the relative conductivity of the mainstem flow. The Cheekye River and Culliton Creek increased the relative conductivity of the Cheakamus by 20% and 5%, respectively at the sampling sites. Relative conductivity was lower at all sites during spring/summer snowmelt. Results for total dissolved solids (TDS) followed a similar pattern to that of conductivity.

Measurements of alkalinity on the Cheakamus River showed no substantial variances between sampling stations. However, because statistically significant differences existed between pH samples, results should be used for spatial rather than temporal comparisons.

Temperature sampling indicated that maximum and minimum water temperatures occurred in August and November, respectively. Inflow of Culliton Creek increased mainstem temperatures by 4% on average at the sampling site. It should be noted that because temperatures were taken at random times during the day, only a broad spatial comparison should be made.

Salinity was only measured for the Cheekye River, where a measurement of 0.1 ppt was recorded on each sampling day, except during high flow events.

Sneep, J. 2001. Cheakamus River Juvenile Salmonid Distribution Assessment September 1999 to July 2000. 32 pp. + App.

Executive Summary

The Cheakamus River juvenile salmonid distribution assessment project was initiated in response to a lack of knowledge regarding juvenile salmonid distribution and habitat requirements in the lower Cheakamus River. Study findings were intended to contribute to an understanding of the relationship between the annual river flow regime and the seasonal availability and suitability of juvenile salmonid habitat. Fish inventory and habitat data were collected during four sample sessions from September 1999 to July 2000 in an area extending from the Cheakamus River's confluence with the Squamish River to the lower extent of the Cheakamus Canyon, a distance of just over 16 km. In total, seven salmonid species, including: chinook Oncorhynchus tshawytscha, chum Oncorhynchus keta, coho Oncorhynchus kisutch, pink salmon Oncorhynchus gorbuscha, cutthroat trout Oncorhynchus clarki, steelhead trout Oncorhynchus mykiss, and Dolly Varden char Salvelinus malma; as well as unidentified cottid species were captured in the study area. Salmonid species contributed to 95.8% of the catch of 6308 fish.

Coho represented 75.3% of the total salmonid catch and were captured in each of the study sampled habitat types. In total, 2064 coho fry were captured, contributing 45.3% to the total coho catch and 63.6% to the total catch of salmonid fry. High catch rates in Swift Creek and the upper reaches of the Cheakamus

River suggest these areas may provide important rearing habitats for coho during summer and spring. Prime habitat conditions for coho rearing and high summer catch rates were also recorded in the BC Rail and Outdoor School man-made sidechannels. Coho fry were only recorded in the catch during the spring and summer sample sessions, with absence in the fall and winter due to incubation requirements. Coho parr contributed 53.3% to the total coho catch and 88.7% to the total catch of salmonid parr. A peak coho parr catch rate of 7.6 fish/trap in Swift Creek during winter was the highest catch rate of coho parr in any 'natural' habitat and highlighted the area's importance as overwintering habitat.

Steelhead represented 7.7% of the total salmonid catch and were captured in the main channel sites, the natural and man-made sidechannels, and Culliton and Brohm Creeks. In total, 225 steelhead fry were captured, contributing 48.1% to the total steelhead catch and 6.9% to the catch of salmonid fry. Steelhead fry were recorded within each of the sampled habitat types (i.e., main channel, natural and man-made sidechannel, and tributary); however, relative to coho, catch rates of steelhead fry were generally low throughout the study area. Higher catch rates of steelhead in Brohm Creek, relative to most of the other sampled sites, confirmed the presence of important steelhead rearing habitats documented during previous studies. Steelhead parr contributed 51.9% to the total steelhead catch and 8.9% to the total catch of salmonid parr in the study. Steelhead parr were captured during each sample session, though the highest catch rates were generally recorded in fall and winter, with reduced catch rates in spring and summer.

Chinook represented 5.9% of the total salmonid catch, with catch rates lowest of the three primary species of investigation. Chinook were sampled in the main channel sites, the natural sidechannels, and in Swift Creek, but were not recorded in the man-made sidechannels. In total, 297 chinook fry were captured, contributing 83.7% to the total chinook catch and 9.2% to the total catch of salmonid fry. Highest catch rates of chinook fry were recorded during spring, with absence in the fall catches reflecting the incubation period of the species, and the low catch rates recorded in late winter likely corresponding with the early post-emergence period. Chinook parr contributed 16.3% to the total chinook catch and 2.1% to the total catch of salmonid parr in the study. Highest catch rate of chinook parr in natural sidechannel habitat during the fall suggests the area may provide important rearing habitat. Chinook parr were only captured during the fall sample session.

Diel catch rates suggested a temporal trend in the use of nearshore habitats throughout the study area. Increased use of these habitats at night, possibly for feeding, is likely related to increased cover offered by darkness.

Fork length measurements were taken from 2391 salmonids captured by minnow trap and pole-seine. Size differences between sample sessions reflect fish growth during the study period. In general, fish sizes for each species and life stage during each season were consistent between reaches.

Perrin, C.J. 2001. Trophic structure and function in the Cheakamus River for water use Planning

Executive Summary

In May 1997 an interim flow order was implemented under the direction of the Provincial Comptroller, requiring approximately 45% of local inflow to Daisy Lake Reservoir to be released to the Cheakamus River year round. This interim rule was maintained through to the present. Long term water releases from Daisy Lake Dam will be set following recommendations from a water use plan (WUP) that is intended to define a flow regime to satisfy demands for water by all users and interests in the river corridor. The WUP began in 2000 and is presently nearing completion. In its early stages, the WUP required information and knowledge of ecosystem response to manipulation of water releases from the Daisy Lake Reservoir. To contribute to this information, biological, chemical and physical measurements were made at several sites throughout the Cheakamus River in each season 2000. These data were combined with similar data collected in 1996 to meet 3 objectives:

1. Describe similarities and differences in river hydraulics and the composition, abundance, and biomass of the benthic community between 1996 (before the flow rule was implemented) and 2000 (after the flow rule was implemented).
2. Determine the relative importance of independent physical, chemical and biological variables that affect benthic invertebrate biomass in the Cheakamus River.
3. Develop a model to predict biomass of benthic invertebrates in the Cheakamus River from a range of independent variables and apply the model to show the effect of hydraulic variables on benthos biomass.

Benthic invertebrate biomass was the endpoint of interest because it was recognized as a key indicator of availability of food for fish and because it was considered an indicator of ecosystem function.

More water was released to the lower Cheakamus in 1996 than in 2000 and a greater proportion of local inflow was released to the lower Cheakamus River in 1996 than in 2000. But, most water in 1996 was released in spring and summer when diversion to the turbines was minimal. With the 45% flow rule in effect in 2000, approximately 55% of flows year round were diverted to the turbines. Including error associated with daily adjustments to the radial arm gates at the Daisy Dam, 44.1 – 47.1% of local inflow was released to the lower Cheakamus River in 2000 in all seasons, meeting expectations of the 45% flow rule. These seasonal differences in release of water distinguished the two years, not the overall mean annual water release.

A general effect of the flow rule was to produce a more natural hydrograph than was apparent without the flow rule. The rule increased the relative contribution of water released from the reservoir on all reach flows in winter and fall months. It maintained the relative contribution of water releases on all reach flows in spring and summer. The flow rule had greatest effects on flows in reaches close to the reservoir but it also affected flows in reaches far from the dam, despite attenuation of its effect due to inflows from major tributary streams.

Soluble nutrient concentrations and molar N:P ratios in 2000 supported evidence from 1996 that algal growth in the Cheakamus River was limited by phosphorus (P). Major P sources included the Cheakamus River headwaters, the Whistler wastewater treatment plant (WWTP), Rubble Creek, Culliton Creek, and the Cheekye River. In 1996, P input from Rubble Creek was enough to increase mean annual soluble reactive phosphorus (SRP) concentrations in the Cheakamus River but this effect was not apparent in 2000. In 2000, water released from Daisy Dam under the 45% flow rule attenuated effects of phosphorus loading from Rubble Creek resulting in no change in mean annual SRP concentrations in the Cheakamus River upstream and downstream of the confluence with Rubble Creek. The stage III 1997 upgrade at the WWTP was effective in dropping SRP concentrations in effluent to 82.8 µg L -1 in 2000 from 176 µg L -1 in 1996. However, lower river flows in 2000 compared to 1996 decreased dilution rates and caused the mean annual SRP concentration downstream of the WWTP to increase from 2.6 µg L -1 in 1996 to 5.1 µg L -1 in 2000. P input from Culliton Creek doubled SRP concentration in the Cheakamus River from 1.2 µg L -1 to 2.4 µg L -1. Further P loading from the Cheekye River increased it 3.3 µg L -1.

The invertebrate community was comprised almost entirely of aquatic insects typical of pristine mountain rivers. Orders occurring in greatest abundance and biomass included the mayflies and dipterans which together represented □90% of community abundance and >60% of community biomass in 1996 and 2000. Density of the stoneflies was □5.2% of community density, but because of large mean size, stonefly biomass was 17.5% and 13.7% of community biomass in 1996 and 2000 respectively. Other taxa represented <4% of community abundance and <2% of community biomass. They included springtails, nematode worms, Hydra sp., spiders, beetles, water mites, freshwater clams, flatworms, oligochaete worms, other annelid worms, and terrestrial Lepidoptera. Average invertebrate density across all seasons and locations was 31,151 animals/m^2 in 1996, increasing to 52,959 animals/m^2 in 2000. These densities were very high and they were at the top end of values found in other oligotrophic systems receiving some level of nutrient enrichment. There was almost complete similarity between the composition of benthos and prey ingested by fish. This association was strong evidence that measures of benthos abundance composition and biomass were relevant indicators of food availability for fish.

Using multiple regression techniques, a model was developed using data collected in 1996 and 2000 to predict benthic invertebrate biomass using information on other variables. Independent variables providing a best fit to the data included peak biomass of periphyton (PB), distance from a reservoir or lake (DFR), coefficient of variation of velocity (Ucv), and phosphorus concentration. The model was highly significant (P<0.001), explaining 72% of the observed variation in benthos biomass, with low co-linearity among independent variables. Input of peak biomass of periphyton into the benthos model was accomplished using a second model that predicted PB. Independent variables that provided the best fit of that model included flow, phosphorus concentration, and biomass of mayflies, stoneflies and non-insect taxa. Relationships in both models agreed with findings in the literature.

Both models were linked and run through a time series to explore effects of flow and P concentration on biomass of benthic invertebrates and PB. Results showed a hyperbolic effect of flow on each endpoint. Low flows supported greater amounts of benthos and PB than high flows. A very small increase in flow at very low flows produced a large decline in PB and benthos biomass. But, at high flows, the proportionate change in PB and benthos biomass was relatively small. This response indicated high sensitivity to change in flow within a range of low flows (e.g., <20 $m^3 \cdot s^{-1}$) and low sensitivity to change in flow at moderate to high flows (e.g., >50 $m^3 \cdot s^{-1}$). The model showed that a fish would be exposed to high but variable amounts of food at low flows and lower but more stable amounts of food at moderate to high flows. If the wetted area of a reach declines at very low flow compared to what it is at high flow, the model suggested that with relatively small amounts of available habitat at low flow, food supply may be highly variable in relation to small variation in flow. At high flow with optimum availability of habitat, the model indicated lower but stable amounts of food would prevail. Extreme variability in velocity (Ucv=0.8) lowered benthos biomass and lowered the sensitivity of benthos to change in flow at low flows. Low Ucv caused benthos biomass to increase and it increased sensitivity of that biomass to change in flow, particularly at low flows. High P concentration accentuated the sensitivity of biomass to change in flow within a range of low flows and low P concentration reduced the sensitivity of biomass to change in flow. This response is what is expected under changing nutrient deficiency. As P deficiency increases in algae, growth responses to changing conditions related to flow are diminished. At surplus P, growth responses to changing physical conditions are optimised, resulting in more extreme change in biomass to those changing physical conditions.

The predictive model is a tool to explore independent and interactive effects of change in physical and chemical characteristics of the Cheakamus River on benthic invertebrate and periphyton biomass. It can be used to examine potential impacts of water management decisions. Other functional relationships could be examined with the existing data used to develop the model. To pursue ease of use, it is recommended that a spreadsheet interface be written to allow routine use of the model. It is also recommended that monitoring of the Cheakamus River continue. The data will provide ongoing evidence of the "health" of the Cheakamus River and contribute to the existing database used to improve predictive modeling that may be used to explore options for future upgrades to the WWTP, water releases at the Daisy Dam, and potentially water withdrawals for water supply in the Whistler area. With Whistler and Vancouver potentially making the short list for the 2010 Winter Olympics, the need for further development of the Cheakamus River corridor and corresponding advanced stewardship of the Cheakamus River will be greater than it is at present. Periodic updating of the present model with monitoring data will support decisions on water use, flow control, water allocation, and wastewater treatment that must be made in future years.

K. A. McIntosh and I. Robertson. 2001. Cheakamus Floodplain Ecosystem and wildlife Overview. 26 p. + maps

Executive Summary

This overview report describes the floodplain ecosystems identified along the Lower Cheakamus River and discusses the avian and mammal populations that depend on the river and/or riparian ecosystems for survival.

Floodplain ecosystems along the Lower Cheakamus River, from Daisy Lake Dam to just above the confluence with the Squamish River, were mapped and assessed in terms of their health. A one-day visit to classify and assess the floodplain ecosystems in and along the river was conducted on September 18, 2000. A total of 38 polygons were field-checked.

Three floodplain ecosystems were identified along the Lower Cheakamus River: low bench floodplain, medium bench floodplain and high bench floodplain. The health of these units was assessed using a combination of structure, process and function (D. McLennan pers. comm). Structure was assessed based on the biotic structure, species composition and site structure. Process was assessed based on the hydraulic regime, nutrient cycling and biotic interactions. Function was assessed based on the terrestrial function of the habitat.

Floodplain ecosystems along the Lower Cheakamus River are healthy and continue to evolve through the process of erosion and sediment deposition. In terms of ecosystem health and wildlife values, it is recommended that the current flow regime be maintained. If new flow regimes are recommended, as a result of the WUP process, the 2-D model developed by the fisheries biologists should be used to model how water levels in floodplain ecosystems will impacted.

The American dipper, common merganser, spotted sandpiper, harlequin duck, kingfisher and bald eagle are species characteristic of the study area. Increased water levels and flows have the potential to impact these species through: 1) flooding of ground nests along the riverbanks and 2) starvation of fledged young due to turbid waters and changes to fish and insect prey availability.

Shrews, red-backed voles, heather voles and snowshoe hair inhabit ecosystems along the edge of the river. Flooding associated with increased water levels may result in the loss of a portion of the local populations of these species. As with the aquatic bird species these mammal species have adapted to living in areas subject to flooding. It is speculated that once flood waters recede, these areas will be re-colonised.

Impacts of water level and flow changes on bats are not anticipated to be large providing aerial insectivore populations along the river are not drastically reduced. If insect populations are significantly reduced, then local populations of bats may experience food shortages.

McCubbing, D. and C. Melville. 2000. Chinook Spawning Migration in the Cheakamus river, Based on Radio Tracking in the summer of 1999. Prepared for BC Hydro by Instream Fisheries Consultants. 35 pp.

Executive Summary

A total of 14 chinook salmon (two jacks) were radio tagged with oesophagus implanted transmitters and tracked through their upstream spawning migrations. Evidence for selectivity of reach, habitat and preferred flows was accumulated in a year of above average river discharge due to excessive snow pack. High flows reduced the number of fish available and restricted capture of these fish to an area round RK7, thus restricting the collection of data on some project objectives. Tagged fish were between two and five years old and of equal sex ratio for adults. Tagging occurred from late July to early September.

Observations from tracking work indicated that female chinook salmon tended to spawn in the upper reaches of the river between river kilometre (RK) 11.5 and 15, whilst male spawning was more spread out between RK 5-15. Migration flows of 30-50m^3/s were utilised during both migration and spawning of adults, although higher flows may also have been used for migration, with sampling impossible under such conditions. Post spawning drift of carcasses was evident in many fish resulting in a failure to recover tags or fish.

Comparison made with historical spawning data and dead pitch information indicated probable yearly variations in spawning behaviour and the subsequent likelihood of carcass recover. Spawning patterns observed in this study might be specifically related to the high discharge conditions recorded in 1999, although radio-tracking data is currently limited to small numbers of fish and one sample year. Spawning appeared later by about two weeks than is typical on this river. A failure to detect female spawners in the lower river may be a function of flow/tagging restrictions and does not preclude the possibility of spawning in this area.

Further information on spawning distribution and migration flows would be required to advance the potential for accurate escapement estimates of chinook salmon on this watershed. In particular during years of high summer discharge. Methods for achieving these aims are briefly discussed.

McCubbing, D. and C. Melville. 2000. Steelhead trout escapement monitoring on the Cheakamus River- an evaluation of the potential application of automated counter technologies utilizing radio tracking data from 2000.

Executive Summary

A total of 18 Steelhead trout were radio tagged with oesophagus implanted transmitters and tracked through their upstream spawning migrations in the Cheakamus River watershed in the spring of 2000. Radio-tagged fish were between four and seven years old and of equal sex ratio. Fish were captured and tagged by angling from February through to late May. Evidence for selectivity of fish spawning reach, habitat for spawning and preferred migration flows was accumulated. Low escapement, also determined by swim count data reduced the number of fish that were tagged restricting the collection of data.

Observations from tracking data indicated that steelhead trout spawned in Cheakamus River upstream of the Cheekye River confluence and within the Brohm River. Two discrete areas of Cheakamus River were utilized for spawning by tagged fish. The upper reaches of the river between river kilometre (RK) 10 and 15 and the area from the Long-house at RK5 to the bailey bridge at RK7. Fish, which spawned in the

Brohm River utilized the entire accessible length from its confluence with the Cheekye to the Cat Lake turn off from Highway 99. Approximately 50% of the fish tagged entered the Brohm River to spawn. These were predominantly two ocean maiden spawners caught before April 1st. Cheakamus River spawners included a mix of two and three ocean spawners and were largely encountered by anglers after April 1st.

Migration flows of, 20 to 30m^3s^{-1} were utilized by Brohm River spawners to reach holding areas in the Cheakamus upstream and downstream of the Cheekye confluence (RK2-7). Small increases, of 10-15 m^3s^{-1} in Cheakamus River discharge appeared to act as a trigger for migration up the Cheekye and subsequently the Brohm River. Upper river (RK10-15) steelhead spawners utilized much increased river discharges from 40 to 100 m^3s^{-1} for both upstream migration and during spawning activity.

Comparison made with historical swim data indicated possible temporal patterns in migration behaviour, although radio-tracking data is currently limited to small numbers of fish and one sample year. A period of high steelhead abundance in the lower river (RK3 to 7) in April, observed in a number of swim count studies may be related to a build up of both Brohm River and Cheakamus River steelhead stocks in this area. Current escapement estimates of steelhead trout abundance should be considered as total watershed escapement unless a method for assessing the individual size of Brohm River and Cheakamus River is developed.

Golder Associates Ltd. 2000. Salmon distribution in the Lower Cheakamus river, B.C.: BC Hydro water Use Plan. Report 002-1742. 7 pp. + App.

Executive Summary

BC Hydro is currently involved in a review of flow releases for fisheries and other purposes as part of their Water Use Plan (WUP) for the Cheakamus River Hydro Project. As part of this initiative, the Fisheries Technical Committee is supporting a number of fisheries studies to provide background information on existing salmonid fish populations and their habitats to assist in the development of a flow regime for the Cheakamus River below the Daisy Dam.

The Squamish Nation and Fisheries and Oceans Canada (FOC) are currently conducting an annual chinook (Oncorhynchus tshawytscha) and coho (O. kisutch) enumeration program in selected systems in the Squamish River watershed. The program has successfully provided enumeration data for chinook and coho since 1996. Included in this program is the lower section of the Cheakamus River, from Road's End (i.e., Butterfly Creek) to its confluence with the Squamish River. Chinook and coho adult spawners are enumerated by visual observations (i.e., foot and boat surveys). Anecdotal information for chum (O. keta) and pink (O. gorbuscha) adult spawners was also collected during these field surveys.

In an effort to integrate initiatives being conducted in the Cheakamus River the Squamish Nation agreed to provide adult salmon distribution data to BC Hydro for the lower section of the Cheakamus River based on data collected during their annual survey of adult spawning populations for the Squamish/Cheakamus River systems. The distribution of salmon in the section of the Cheakamus River located downstream of Road's End (i.e., Butterfly Creek) to its confluence with the Squamish River was conducted by visual observations by four Squamish Nation field crew under the supervision of a Registered Professional Biologist (Golder Associates Ltd.). Adult spawner surveys were conducted by the Squamish Nation field crew from September 1st , 1999 to February15th, 2000. The surveys focused on deadpitch and live counts for chinook and coho, with the collection of anecdotal information for chum and pink adult salmon. Visual observations were either conducted by foot survey or by floating down the river starting at Road's End according to methods described by FOC in 1996.

Chinook, coho and chum spawning, holding and carcass recovery locations were primarily observed in Reach 2 (upstream of the Cheekye-Cheakamus confluence), in Reach 3 (downstream of the Bailey Bridge), and in the upper section of Reach 4 near Road's End. Chinook spawning occurs primarily in the mainstem of the channel based on enumeration data collected since 1997 (Golder 1998, 1999, 2000). Coho and chum were observed to be spawning primarily in side-channels to the Cheakamus River, including the constructed BC Rail Channels and Moody's Channel, and in natural side-channels.

Korman, J. and R. Ahrens. 2001. Escapement Estimation of Winter-Run Steelhead on the Cheakamus River: Stock Assessment and Monitoring Implications

Executive Summary

Results from a snorkel survey of adult steelhead returns to the Cheakamus River collected between 1996 and 2000 are presented and compared with other information on current stock status and historical trends. Steelhead escapement was determined by periodic swim counts conducted over the majority of the migration and spawning period. Observer efficiency was estimated as the ratio of externally marked fish observed by the divers relative to the number of tagged fish known to be in the survey area from a concurrent radio telemetry study. The radio telemetry study also provided an estimate of survey-life. Total run size was computed based on a maximum likelihood implementation of the area-under-the-curve method and confidence bounds were computed based on a likelihood ratio test. A simulation analysis was conducted to evaluate bias and precision in escapement estimates under different sampling intensities and assumptions about variation in observer efficiency and survey-life.

Average and peak counts were 42/48, 34/56, 36/50, and 14/25 in 1996, 1997, 1999, and 2000, respectively. In 2000, observer efficiency averaged 41% with a coefficient of variation of 35%. Survey-life averaged 36 days with a CV of 71%. The most likely steelhead escapements to the Cheakamus River and 95% confidence bounds were 290 (130-491), 290 (140-329), 200 (181-219) and 120 (91-158) in 1997, 1997, 1999, and 2000, respectively. Confidence bounds in escapement estimates were wider in earlier years because fewer swims were completed and they were concentrated over a smaller portion of the total migration/spawning period. Confidence limits increased considerably in all years when uncertainty in observer efficiency and survey-life were incorporated in the analysis. Peak counts across the 4 sample years were on average 20% of the estimated escapement and explained 75% of the variation in escapement. The simulation analysis demonstrated that reduced sampling intensity and increased variation in observer efficiency and residence time decreased precision of escapement estimates but did not result in any significant bias. Negative bias in escapement estimates could be produced in the simulations if run timing was highly skewed and the swim surveys did not cover the entire migration period.

Recent escapements were compared to our estimate of the peak observed historical escapement of approximately 1000 fish. In the absence of more reliable information, this estimate represents the most defensible guess at the carrying capacity of the Cheakamus River for steelhead. The most likely escapement in 2000 was less than 15% of the estimated carrying capacity and below 3 independent estimates of a minimum conservation requirement. When all uncertainty was considered in the analysis, there was a 50% probability that the 2000 escapement was less than the conservation requirement, but very little chance that escapement was below this limit in 1996, 1997, and 1999.

Recent trends in steelhead escapement conflict with juvenile survey data collected over the same period. Escapement declined by almost 50% between 1999 and 2000, while juvenile survey data showed an increase over this same period from 80 to 108 fry/100 m^2. We provide evidence to support the notion that escapement monitoring provides more reliable trend and absolute abundance information compared to data collected from juvenile surveys on the Cheakamus River. Recommendations for future monitoring activities are provided.

Melville, C. and D. McCubbing. 2000. Assessment of the 2000 Juvenile Salmon Migration from the Cheakamus river, Using Rotary Traps. Prepared for BC Hydro by Instream fisheries Consultants. 42 pp.

Executive Summary

This report presents the results of the 2000 salmonid smolt and fry outmigration on the Cheakamus River. The primary objective of this project was to establish a long term monitoring program for salmonid smolt outmigration in the Cheakamus River. This program will be used to track flow changes as a result of the Interim Flow Agreement (IFA) implemented on this watershed in May 1997.

Two rotary screw traps were operated from March 27 until June 20, 2000 to catch migrating salmonids. Petersen estimates were obtained for: chum fry (*Oncorhynchus keta*), chinook fry (*Oncorhynchus tshawytscha*), chinook smolts, steelhead smolts (*Oncorhynchus mykiss*) and coho smolts (*Oncorhynchus kisutch*). Migration timing was obtained for pink fry (*Oncorhynchus gorbushcha*), steelhead parr, and coho fry. Two other non-salmonid species were captured; the Coast range Sculpin (*Cottus aleuticus*) and the Pacific Lamprey. Pooled Petersen estimates and Schaefer estimates were also calculated where sufficient data were available.

Length and weight data were collected from a representative sample of the population stratified across age class and run timing. Although age data from scale samples are not yet available, indications are growth rates and condition factors are comparable to other coastal streams in BC.

Evidence of temperature and flow relationships to migration timing was examined. Smolt migration activity increased when water temperatures exceeded 7º C. Chum and pink fry migrated was probably related to emergence time, whilst coho and chinook fry migration appeared related to river discharge increases during spring freshet.

McAdam, S. 2001. Water Temperature Measurements on the Cheakamus River- Data Report June, 1999 to December, 2000.

Executive Summary

The temperature in the Cheakamus River and the potential impacts to the aquatic habitat downstream caused by fluctuating flows have been identified as a potential issue of significance by the Cheakamus Water Use Plan Fisheries Technical Committee. The FTC also wanted to investigate whether flow operations affected local temperatures near tributaries due to variation in the dilution capacity of the mainstem. Commencing in June 1999, thirteen thermistors were installed at locations ranging from upstream of the Daisy Reservoir to below the confluence of Cheekeye Creek. Although some thermistors stopped functioning, most remained in operation until they were pulled out in December, 2000.

The general pattern of seasonal variation was similar at all sites, with the exception of Rubble Creek, which shows a strong ground water influence, and Culliton Creek, which is a cool meltwater-driven tributary. Aside from these two tributaries, all other sites vary within a band of about 3º C, with some site-specific patterns present within that range.

Direct effects of Daisy Reservoir on downstream temperatures are present but small and localized. Through most of the year the sites upstream from the reservoir and downstream vary within 1º C, with no discernable seasonal pattern to this variation. During summer, temperatures downstream of the dam averaged 1.2º C greater than upstream which indicated that the reservoir causes a minor warming effect. Due to the presence of Rubble Creek immediately downstream from the dam this warming effect persists only for a short distance.

However, extremely similar thermographs upstream of Culliton and Cheekye Creeks suggests these sites have reached a climatically driven equilibrium. Comparison of the two equilibrium thermographs with the thermograph upstream of Daisy Dam shows that temperatures upstream of the dam are consistently cooler than the equilibrium, most likely due to the proximity to meltwater sources. The proximity to meltwater sources is also the most likely explanation for the consistent 1º C difference between temperatures downstream of Rubble Creek and the downstream equilibrium. By the time water has reached the anadromous section of the river it has reached the thermal equilibrium, therefore indicating that whole river effects of operations, if present, would be limited to areas affecting resident fish.

The diversion of a large proportion of inflows may affect temperatures locally downstream of tributary inputs due a decreased in the dilution capacity of the Cheakamus River. For the area directly downstream of Culliton Creek, average temperature estimates over the September to April incubation period differ by an insignificant amount. This effect would be definitely be localized since the temperature is at the climatic equilibrium before the next site downstream (upstream of the Cheekye) is reached. The biological effect might also be diminished since current understanding suggests the stretch of river downstream of Culliton Creek is not a preferred spawning area due to the high silt load.

Appendix 4: Fisheries Technical Committee Impact Hypotheses and Summary of Conclusions

A4.1 FTC IH Synthesis Final Report.

In a series of impact hypothesis workshops (described in Marmorek, D.R. and I. Parnell 2000, on the attached CD), the Fisheries Technical Committee developed and evaluated explicit impact hypotheses about the effect of flow on components of the Cheakamus River Fish and Aquatic Ecosystem. The purpose of the impact hypothesis process was to clarify key uncertainties, develop methods to address those uncertainties, prioritize research and develop performance measures by which to evaluate WUP alternatives.

A4.1.1 Impact Hypotheses

Five main impact hypotheses resulted from the workshops:

- H.1 Effect of flow on short-term hydraulic suitability
- H.2 Effect of flow on long-term channel morphology
- H.3 Effect of flow on stream productivity
- H.4 Effect of flow on temperature
- H.5 Effect of Squamish River valley powerhouse on fish stranding

The linkage among these hypotheses is shown in Figure A4.1. Several other impact hypotheses were considered and rejected or incorporated into one of the five.

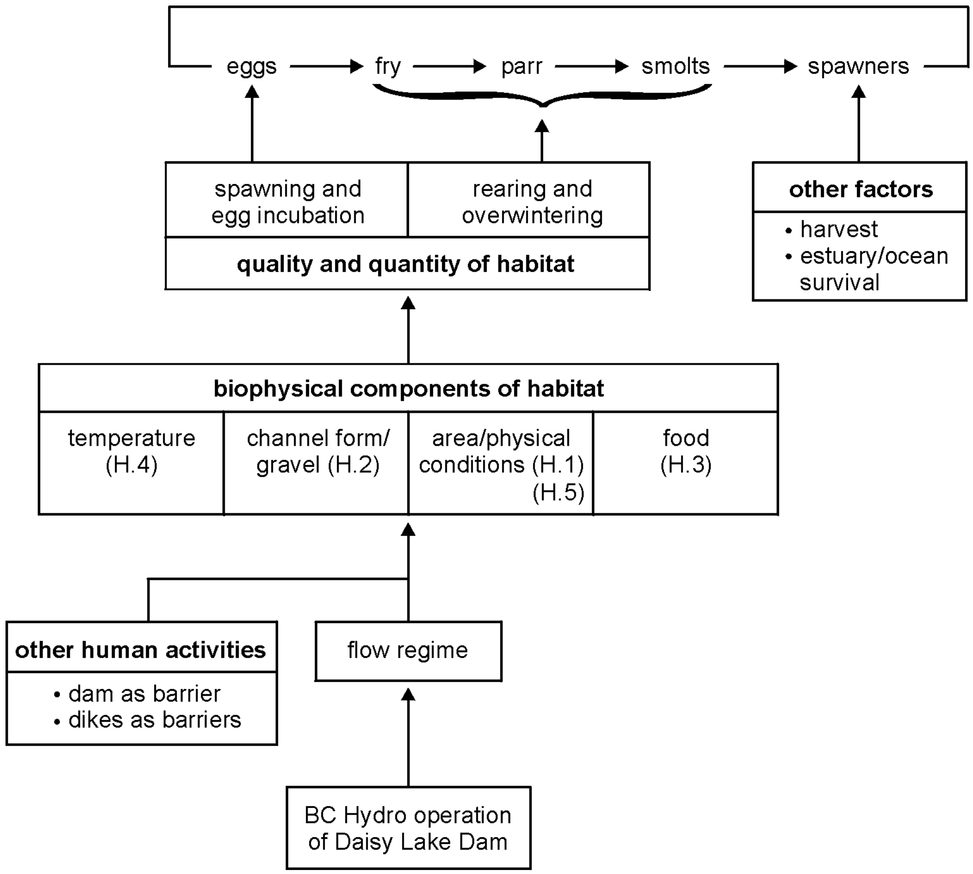


Figure A4.1: Overview synthesis of the hypothesized impacts of Daisy Lake Dam operation on Cheakamus River fish populations. The numbers in the figure boxes represent individual impact hypotheses that can be extracted from this larger overall hypothesis. For example, H.1 represents the hydraulic suitability hypothesis.

A4.1.2 Recommended Fish and Aquatic Ecosystem Objectives:

The FTC reviewed the preliminary fundamental and means objectives for Fish and Aquatic Ecosystems developed by the Cheakamus Consultative Committee. They recommend the following revised set of objectives, which reflect the impact hypotheses shown in Figure A4.1:

5) Maximise wild fish populations

- Maximise quantity and quality of fish habitat in the Cheakamus River below Daisy Lake Dam (H.1).
- Maximise food production for fish in Cheakamus River below Daisy Lake Dam (H.3).
- Maintain appropriate temperatures for fish in Cheakamus River below Daisy Lake Dam (H.4).
- Minimize impact on fish and fish-habitat in the zone influenced by the powerhouse in Squamish River valley (H.5).

6) Maximise the area and integrity of the aquatic and riparian ecosystem

- Maximise quantity and quality of floodplain habitat for aquatic organisms other than fish (covered in fundamental objective #5), native riparian plants and resident wildlife populations.
- Maximise continuity and integrity of fluvial processes in floodplain zone of Cheakamus River below Daisy Lake Dam (H.2).

A4.1.3 Strategy to Reduce Uncertainty and Develop Performance Measures

Recognizing the large uncertainty that surrounds several components of the Cheakamus River fish and aquatic ecosystem, the FTC proposed the following strategic approach to developing performance measures:

- focus on preliminary modelling of habitat performance measures, together with pre-design work for planned flow comparisons and/or monitoring programs;
- conduct field research throughout the spring, summer, and fall of 2000 to provide the physical and biological information necessary to develop models that relate flow to physical and biological changes in the Cheakamus system;
- test models and develop performance measures for evaluating dam operating alternatives in the fall of 2000; and
- continue to refine this approach through winter and into the spring of 2001.

A final set impact hypothesis evaluations and PMs were presented to the CC at their meeting on April 30th, 2001. These are summarized in the following sections.

A4.2 Impact Hypothesis Assessment Sheets

A4.2.1 Hypothesis #1

Operations at the Cheakamus Facility affect the frequency, duration and magnitude of flows that cause changes in the geomorphology of the Cheakamus River mainstem. This in turn, affects the quantity and quality of fish habitat and hence, the numbers of wild fish sustained in freshwater habitats influenced by operations of BC Hydro's facility.

Status

Rejected

Rationale

Influence of operations on hydrology:

An assessment of historical and present Cheakamus River hydrology showed that combined operations of the generation facility and Daisy Dam has little influence on the frequency, magnitude and duration of the flood events necessary to affect channel morphology[1].

Sediment load and transport:

Review of the dam operation, the sedimentation of the reservoir and role of tributaries below Daisy Lake indicated although the dam likely reduced sediment transported to the lower river, the amount was small and it's influence on sediment quality and river morphology not well established.

Influence of on River Geomorphology:

Morphological effects in the lower river could not be attributed to sediment recruitment alone. Dyking and reduction of the river floodplain have a major influence on the resulting shape and pattern of the Cheakamus River that ultimately influence the long term quality and quantity of fish habitat.

Key Uncertainties

Lack of resolution and influence of timescale

Recommendations

Though not WUP related, three action items were identified as crucial for the improvement of Cheakamus River geomorphology to be discussed at FTC.

1. Develop and implement a plan to recruit representative sediments into the mainstem Cheakamus River to establish a natural predevelopment sediment regime. Transport and place accumulated Rubble Creek sediments downstream of the Hwy 99 Bridge into the Cheakamus River mainstem area so they are available for transport and recruitment.
2. Identify and prioritise existing floodplain areas for potential floodway restoration. This would entail potential breaching or removal of non-critical dykes, acquisition of floodplain properties and restoration of side and flood channels in existing floodplain areas. These modifications would allow the establishment of new side channel habitats, critical for juvenile salmonids and pink salmon spawning, increased area and diversity of floodplain habitat and reduce flood water elevations associated with unavoidable flood flows.
3. Move accumulated Rubble Creek sediments downstream of the Hwy 99 Bridge into the Cheakamus River mainstem. This source of sediment represents roughly 20% of the total Cheakamus River sediment budget.
4. Move or modify the bridge located upstream of the North Vancouver Outdoor School to promote the lateral movement of the mainstem. This would promote side-channel development, as well as the accumulation and release of suitable spawning substrates.
5. Strategic placement of wing dams or other structure to promote the sinuosity of the Cheakamus River mainstem.
6. Consider physical works to promote and/or protect side-channel development, accessibility, and utility.

References

1. Northwest Hydraulic Consultants. 2000. Analysis of Channel Morphology and Sediment Transport Characteristics of the Cheakamus river. Prepared for B C Hydro - CMS WUP .Draft report. 37 pp.

A4.2.2 Hypothesis #2

Operations at Daisy Dam affect the frequency, duration and magnitude of moderate flows that directly affect the quantity and quality of mainstem rearing habitat for fry and parr, and of mainstem spawning habitat. Such changes to habitat can influence The production of seaward migrant fry or smolts and hence, the abundance of wild salmonid fish.

Status

Accepted, but with the following refinements that add species and life history specificity:

Species	Life Stage	Comments
Steelhead/ Rainbow Trout	Incubation	Tributary inflows are high during spawning period and would attenuate dam influences. Spawning populations of steelhead typically number in the 10^2 to 10^3's and are not expected to exceed this order of magnitude. Given the length of accessible spawning, there will be ample spawning habitat (it will not be limiting) irrespective of dam release and escapement. There may be however, a significant risk of redd stranding, and consequently egg mortality, because egg incubation occurs during the descending limb of the spring freshet.
	Rearing	Summer rearing success may be compromised by the lack of suitable habitat if flows are too low.
	Overwintering	The biological processes affecting overwintering survival are uncertain.
Chinook	Spawning/ Incubation	Both quantity and quality of spawning habitat were deemed to be important determinants of spawning success. Given that incubation flows during winter are typically much lower than those experienced during the fall spawning period, a balance may have to be found between fall and winter flows to ultimately maximise spawning success.
	Rearing	Downstream migrant trapping (DMT) data analysis suggests that a significant proportion of the chinook fry remain in the Cheakamus River mainstem during summer to rear. Summer rearing success may be compromised by the lack of suitable habitat when flows are too low or too high.
	Overwintering	Although the DMT data analyses suggest a period of out migration/redistribution during the fall, a significant number of chinook juveniles remain in the Cheakamus to overwinter. Impacts of flow on winter survival are uncertain.
Chum	Spawning/ Incubation	Both quantity and quality of spawning habitat and redd stranding were deemed to be important determinants of spawning success. Given that incubation flows during winter are typically much lower than those experienced during the fall spawning period, a balance may have to be found between both factors to ultimately maximise spawning success.

Species	Life Stage	Comments
Coho	Spawning/ Incubation	Both quantity of quality spawning habitat were deemed to be important determinants of spawning success. Given that incubations flows during winter are typically much lower than those experienced during the fall spawning period, a balance may have to be found between flows to ultimately maximise spawning success. Since the coho spawning period overlaps to a considerable extent with chum, the flow regime developed for chum may also serve to reduce risks for coho.
	Rearing	Summer rearing success may be compromised by the lack of suitable habitat when flows are too low or high.
	Over-wintering	Impacts of flow on winter survival are uncertain.

Rationale

River flows affect wetted area, water depth, and water velocity, which are important determinants of habitat quantity and quality.

Key Uncertainties

1. Which reaches are most important to each species for each function (i.e., spawning, rearing, overwintering)?
2. Role, if any, of daily flow fluctuations on fish survival and production.
3. How the lateral distribution of eggs varies with spawning flows, and affects vulnerability to stranding during incubation.
4. What habitat features are most important for egg and smolt survival (e.g., side channels, cover, velocities, depth)?
5. The influence of flows on overwintering survival.
6. How groundwater channel flow levels influence fish production in those environments (see Impact hypothesis #7).
7. Over-wintering success may be an issue, though it's relative importance and relationship to flow is largely unknown.

Recommendations

1. Include chum spawning success as a critical species for WUP evaluation as they are an important food source for benthos, fish and wildlife communities (including eagles, which are linked to recreation values) in the area. (We don't know what factors control eagle abundance and survival in the CMS.)
2. Pink salmon should not be directly considered for PM development because their success in the river appears to be related to lack of suitable small gravel spawning substrate than the adequacy of flows. Substrate availability is not likely to improve with flow management practices at the dam, and is therefore not a WUP issue. This issue would be better addressed through the physical works recommendations listed for Hypothesis #1 assessment. The FTC does not wish to negate the importance of pink salmon. Rather, the FTC will prepare an informal statement for each flow alternative on whether or not a flow related risk exists for pink salmon (i.e., flag issues as they arise).

References

1. Melville, C. and D. McCubbing. 2000. Assessment of the 2000 Juvenile Salmon Migration from the Cheakamus River, using Rotary Traps. Prepared for the CMS WUP by Instream Fisheries Consultants 42 pp.
2. Sneep, J. 2001. Cheakamus river Juvenile Salmonid Inventory and Habitat Use Assessment September 1999 to July 2000. Draft report. 34 pp.
3. Bruce, J. 2001. Habitat Suitability Weighting Functions for Summer Rearing Salmonids. Draft report.

A4.2.3 Hypothesis #3

Operations at Daisy Dam affect the frequency, duration and magnitude of moderate flows that directly affect fish food supply and hence, affect juvenile fish growth and survival. This in turn, will have an effect of the abundance of wild fish populations.

Status

Accepted. Juvenile salmonids in the Cheakamus River depend primarily on benthic invertebrate organisms, specifically bottom-dwelling aquatic insects, as their food source. Benthic biomass and fish food supply is affected, both directly and indirectly, by flow and the variability in flow. The effects of flow on fish food supply are complex, involving influences of flow on algal periphyton, which is the primary food source for benthic invertebrates, as well as direct effects on the food organisms themselves. (see Fig. 1 in PM summary attachment), and need to consider effects of flow on the food supply for benthic organisms (periphyton), as well as direct effects. Other important factors include nutrient concentrations (phosphorous) and the distance from Daisy Dam, which causes blockage of insect drift).

Rationale

A comprehensive benthic invertebrate study (Perrin, 2001) found a statistically significant relationship between benthic biomass and a number of variables, including flow and the variability in flow.

Key Uncertainties

None

References

1. Perrin, C.J. 2001. Trophic structure and function in the Cheakamus river for water use planning. Report prepared by Limnotek Research and Development Inc. for BC Hydro and Resort Municipality of Whistler. 66 pp.

A4.2.4 Hypothesis #4

Operations at Daisy Dam affect the frequency, duration and magnitude of moderate flows that affect upstream migration and spawning distribution of adult salmonids and outmigration timing of smolts. Changes to adult migration will affect spawning success while changes to smolt outmigration could affect marine survival. Both factors could influence abundance of wild fish.

Status

Rejected. However, the FTC hypothesises that a threshold flow of 10 cms, measured at Brackendale, would provide for adult passage and access to spawning habitat, particularly in the late fall and winter period.

Rationale

Although upstream migrations of adult salmon and steelhead are often associated with increases in river flow, studies indicated that flow changes are usually not essential to facilitate migration. In the presence of artificially stabilised flows, adult salmon movements are associated with changes in rainfall and barometric pressure, and peak run timing is unaffected by the absence of natural freshet events. [1,2]

At Cheakamus River, flow did not appear to be a significant influence on upstream movement of radio-tagged chinook salmon and steelhead.[3,4] The early portion of the winter steelhead run, in February and March, commonly migrates into the river under low discharge conditions, in the range of 10-20 cms at Brackendale.

Upstream distribution of salmon spawning at Cheakamus River also does not appear to be influenced by river flow level. Counts of adult chinook, coho and chum salmon, recorded by river reach, indicate that spawning is just as well distributed in a low flow year (2000) as in a year of relatively high flows (1999).[5] Movement of adult chum and coho salmon into groundwater side channels, however, may be more difficult at some sites in a low flow year.

Trapping of downstream migrant juvenile salmon and steelhead in the Cheakamus River indicates that flows do not measurably influence outmigration timing and that, as in other cases,[6] water temperature is the more influential factor.

Key Uncertainties

All groundwater fed off-channel areas may not be readily accessible to chum and coho salmon spawners when Cheakamus River mainstem flows are low.

Recommendation

The influence of Cheakamus mainstem flow on groundwater side channel flows and salmon utilisation of off-channel habitat should be assessed as part of a monitoring program (see Hypothesis #7).

References

1. Allen, G.H. 1959. Behaviour of chinook and silver salmon. Ecology 40: 108-113.
2. Fraser, F.J., E.A. Perry and D.T. Lightly. 1983. Big Qualicum River Salmon Development Project, Volume 1: a biological assessment, 1959-1972. 198 pp.
3. McCubbing, D., and C. Melville. 2000. Chinook spawning migration in the Cheakamus River, based on radio tracking observations in the summer of 1999. Prepared for BC Hydro, Burnaby. 35 pp.
4. McCubbing, D., and C. Melville. 2000. Steelhead trout escapement monitoring on the Cheakamus River – an evaluation of potential application of automated counter technologies utilising radio-tracking data from 2000. Prepared for BC Hydro, Burnaby. 20 .
5. Golder Associates. 2001. Chinook and coho enumeration in the Squamish watershed: year 4. Prepared for Squamish Nation and Fisheries and Oceans Canada, Vancouver, BC.
6. Holtby, L.B., T.E. McMahon and J.C. Scrivener. 1989. Stream temperatures and inter-annual variability in the emigration timing of coho salmon smolts and fry and chum salmon fry in Carnation Creek, British Columbia. Can. J. Fish. Aquat. Sci. 46: 1396-1405.

A4.2.5 Hypothesis #5

Operations at Daisy Dam affect the frequency, duration and magnitude of moderate flows that directly affect water temperatures and hence, emergence times of incubating salmonids, summer growing conditions, and over-wintering survival. All will influence the abundance of wild fish.

Status

Rejected

Rationale

Monitoring during 1999 and 2000 demonstrated that water temperatures equilibrate to ambient climatic conditions downstream of tributaries. Alterations to the thermal regimes in areas directly downstream of tributaries would be minor, and should not have a measurable biological effect upon rearing, or in areas where eggs incubate.

Key Uncertainties

None

Recommendations

None

References

A4.2.6 Hypothesis #6

Operations at Daisy Dam affect the frequency, duration and magnitude of moderate flows that directly affect vulnerability of juvenile fish to predators. High predation rates reduce egg to freshwater survival and hence affect the abundance of wild fish.

Status

Rejected

Rationale

Predation is a natural process and an essential part of riverine ecology. Bull trout appear to be the only fish species capable of posing a potential predatory threat to juvenile salmonids 1. These fish however, are relatively few in number (in the hundreds) and are considered a blue listed (vulnerable) species 2,3. It was the general opinion of the FTC that the benefits of predation to bull trout far outweigh the potential risks to the other salmonid stocks.

Juvenile salmonids are most vulnerable to predators as out-migrating fry 4. However, this phase of their life history typically occurs at a time when tributary inflow to the Cheakamus River mainstem is generally rising. The likelihood that flows would get so low as to induce the crowding conditions necessary to noticeably increase predation risk is very low, and would not be altered significantly by releases from Daisy Dam.

Key Uncertainties

Actual predation risk, and the magnitude of its effect on salmonid fry to smolt survival is unknown. Risk assessment by FTC is based on very limited information. It would be extremely difficult to actually measure how flow affects the vulnerability of juveniles to predation, since flow could also independently affect the distribution of both predators and prey.

Recommendations

none

References

1. Lagler, K.F. and A.T. Wright. 1962. Predation of the Dolly Varden on young salmons in an estuary of southeastern Alaska. Trans. Amer. Fish. Soc. 91: 90-93.
2. Korman, J. and R. Ahrens. Escapement Estimation of Winter-Run Steelhead on the Cheakamus River: Stock Assessment and Monitoring Implications. Prepared by Ecometric Research Inc. for BC Hydro Cheakamus River Water Use Planning Fisheries Technical committee. 37 pp.
3. Conservation Data Centre, MELP. 2000 Provincial Vertebrate Animal Tracking List.
4. Taylor, E.B. and J.D. MacPhail. 1983. Burst swimming and size-related predation of newly emerged coho salmon. Trans. Amer. Fish. Soc. 546-551.

A4.2.7 Hypothesis #7

Operations at Daisy Dam affect the frequency, duration and magnitude of flows that cause changes to the surface flow - groundwater interactions of the Cheakamus River mainstem. This in turn changes the upwelling characteristics of groundwater fed off- affecting the quantity and quality of spawning, rearing, and over-wintering fish habitat in these channels. This has a direct effect on the abundance of wild fish.

Status

Suspended. Issue too poorly understood to develop a meaningful performance measure within the WUP time frame, and hence cannot to be used for decision-making.

Rationale

The interaction between groundwater and surface flows was deemed to be an important ecological factor for the following reasons:

1. Groundwater upwelling has long been known to be an important determinant of habitat quality for spawning chum and coho. Upwelling tends to flush incubating eggs with O_2 rich waters and can attenuate ambient water temperature fluctuations, particularly in freezing conditions. Both factors would contribute to increased egg to fry survival.
2. Upwelling from deep sources could bring anoxic waters to the surface, and could potentially be a hazard to O_2 sensitive aquatic organisms such as the larger benthos and fish.
3. Groundwater temperatures tend to be less variable than surface waters. Thus, upwelling areas could provide thermal refuge to rearing fish during periods of seasonal temperature extremes.
4. As water passes through a channel, there is a continual exchange between surface and subterranean flows (i.e., upwelling and downwelling events). This zone of exchange is known as the hyporheic zone and has been found to support a unique community of aquatic organisms. Although this zone has been identified as an important constituent of riverine ecosystems, it's relative importance and relationship to other zones (e.g., riparian, benthic, and pelagic zones), is poorly understood. It is the general opinion of the FTC that changes to the hyporheic zone could have implications for the health of benthic communities and hence, effect fish food availability.
5. The importance of Daisy Dam releases to the nature and function of the hyporheic zone is largely unknown and would require long term study to resolve. Data collected to date however, does suggest that such a relationship exists. Dykes likely interrupt the connectivity between the hyporheic zone and the channel.

Key Uncertainties

1. Relationship between Daisy Dam releases and groundwater flow dynamics is poorly understood.
2. Role of hyporheic zone (interface between groundwater and surface flows) in riverine ecosystem function (including fish food and fish production) is poorly understood.
3. Thermodynamics of surface flow - groundwater interactions is poorly understood, including how groundwater attenuation of thermal extremes may influence habitat quality (i.e., how important is it to growth and/or survival).
4. Quality of upwelling waters is largely unknown. If from deepwater sources, it may be anoxic. If the rate of flow through the aquifer is slow, high nutrient uptake may be possible.
5. The role of river sinuosity to hyporheic zone development is poorly understood.
6. The relationship between Daisy Dam releases and the nature and function of the hyporheic zone is largely unknown.

Recommendations

The following items are recommended:

1. Carry out a literature review of hyporheic zones to better understand its role in riverine ecosystem function. This information will be used to flag potential issues that may arise with changes to Daisy Dam operations.
2. Consider the hypothesis and associated uncertainties as a key issues to be resolved in a comprehensive monitoring program. Results of the literature review and WUP modelling exercises will provide the foundation for study design.

References

1. Jordan-Knox Q.S., D. M. Allen and J.J. Claque. Preliminary models of groundwater-surface water interactions within Cheakamus River Valley, BC.

A4.2.8 Hypothesis #8

Operations of the Cheakamus River powerhouse on the banks of the Squamish River affect the frequency, duration and magnitude of water levels immediately downstream of the powerhouse canal confluence. Such changes to downstream water levels cause stranding of juvenile fish, and hence affect the abundance of wild fish in the Squamish River.

Status

Rejected for the purposes of decision making. Juvenile stranding is still viewed as a potential risk, although the magnitude of that risk has been judged to be low, it remains unquantified. As a result, the implications to wild fish abundance remain uncertain.

Rationale

Fish stranding was observed below the Cheakamus powerhouse in October,1994. when the powerhouse flow was reduced from 32 to 0 cms,. following 3 weeks of steady discharge. A study to investigate the risk of stranding was carried out from late September, 1995 through February, 1996 (BC Hydro, 1996) which found rates of stage change between 60 cm/h (3.5 km downstream of the powerhouse) and 30 cm/h (12 km downstream). Juvenile chinook appeared to be the least susceptible to stranding while steelhead fry were the most susceptible due to their preference for side channels and shallow habitat. No stranded fish were found during the study period but relative densities of all species in shallow habitat declined by mid to late fall.

Some members of the FTC visited the potential stranding area on October 13, 2000. Powerhouse flows were increased at 1100 hrs from 0 to 30 cms, held for an hour, then reduced back to zero. Total stage change at the upstream end of the cobble bar was approximately 30 cm with stranding risk highest at the upstream end of the bar, an area with shallow gradient. Although fish stranding was not observed, this lack of stranding was likely related to a combination of the short period of elevated flows prior to dewatering and reduced fish use of the near shore areas in the fall.

Key Uncertainties

The following uncertainties have been identified:

1. The true magnitude of stranding risk is unknown, as are the times of the year with the higher risk of stranding.
2. If stranding does occur, its effects on wild fish abundance depend, at least in part, on the aerial extent of impact - a measure that is largely unknown.
3. Continuous peaking operations could prevent juvenile fish from colonising high-risk areas. Whether this occurs is uncertain.
4. Stranding risk to spawning salmonids and resulting redds remains uncertain, though it is likely to be low, based on observations to date.

Recommendations

1. In the short term, relate the timing of key life history events to the general hydrology of Squamish River to identify critical high-risk periods, e.g., early spring when Squamish flows are below 100 cms and fish are moving into nearshore areas. This information will be used to flag potential stranding issues.
2. Install a staff gauge at the Ashlu bridge to accurately monitor stage changes.
3. Continue to monitor stranding risk on an informal basis to supplement the flow and life history based on identification of high risk periods.
4. Using the information above, design and implement a monitoring program that will document the aerial extent of the stranding impact as well as measure the risk of stranding on a seasonal basis.
5. If required, consider physical works within the Squamish channel, particularly the large gravel/cobble bar immediately downstream of the powerhouse canal confluence, as a means to mitigate stranding risk.
6. Consider using peaking to discourage spawning salmonids use of zones vulnerable to stranding.

References

1. Memo from DFO (D Sneep) Fish Stranding Assessment Below the CMS Powerhouse on the Squamish River.
2. BC Hydro. 1996. Squamish river Fall and winter Flow Ramping Studies: Fall and winter fish habitat use and fish stranding assessment. E5862. Prepared by Sigma Engineering Ltd.
3. BCH Memo from Al Laidlaw to David Wilson analysing Squamish River Flows and Stage Changes.

A4.3 Summary of FTC PMs

A4.3.1 Summary of Fish and Aquatic Ecosystem Performance Measures (PMs)

Fisheries Technical Committee

This summary was originally presented to CC on April 30th, 2001. It was updated December 20, 2001 to reflect the PMs actually used.

Figure A4.2 shows how the four PMs developed by the FTC cover different components of the salmon life cycle. Each of these PMs are explained in the attached material. In addition, we explain why we believe it is not appropriate to develop riparian ecosystem PMs at this time.

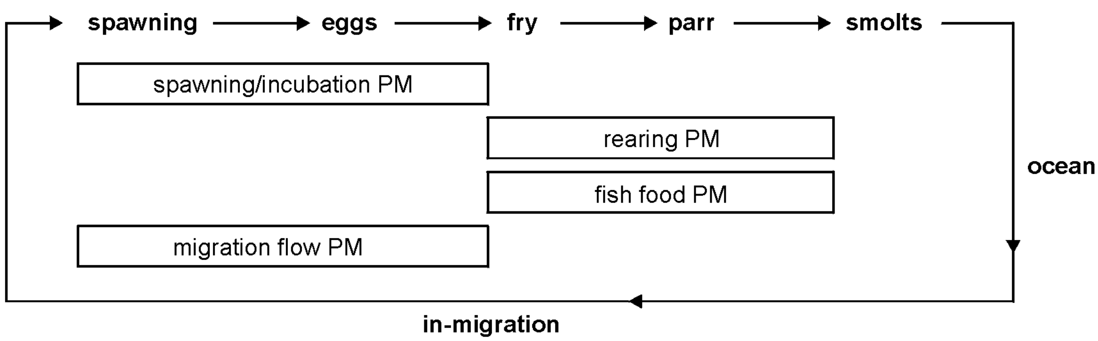
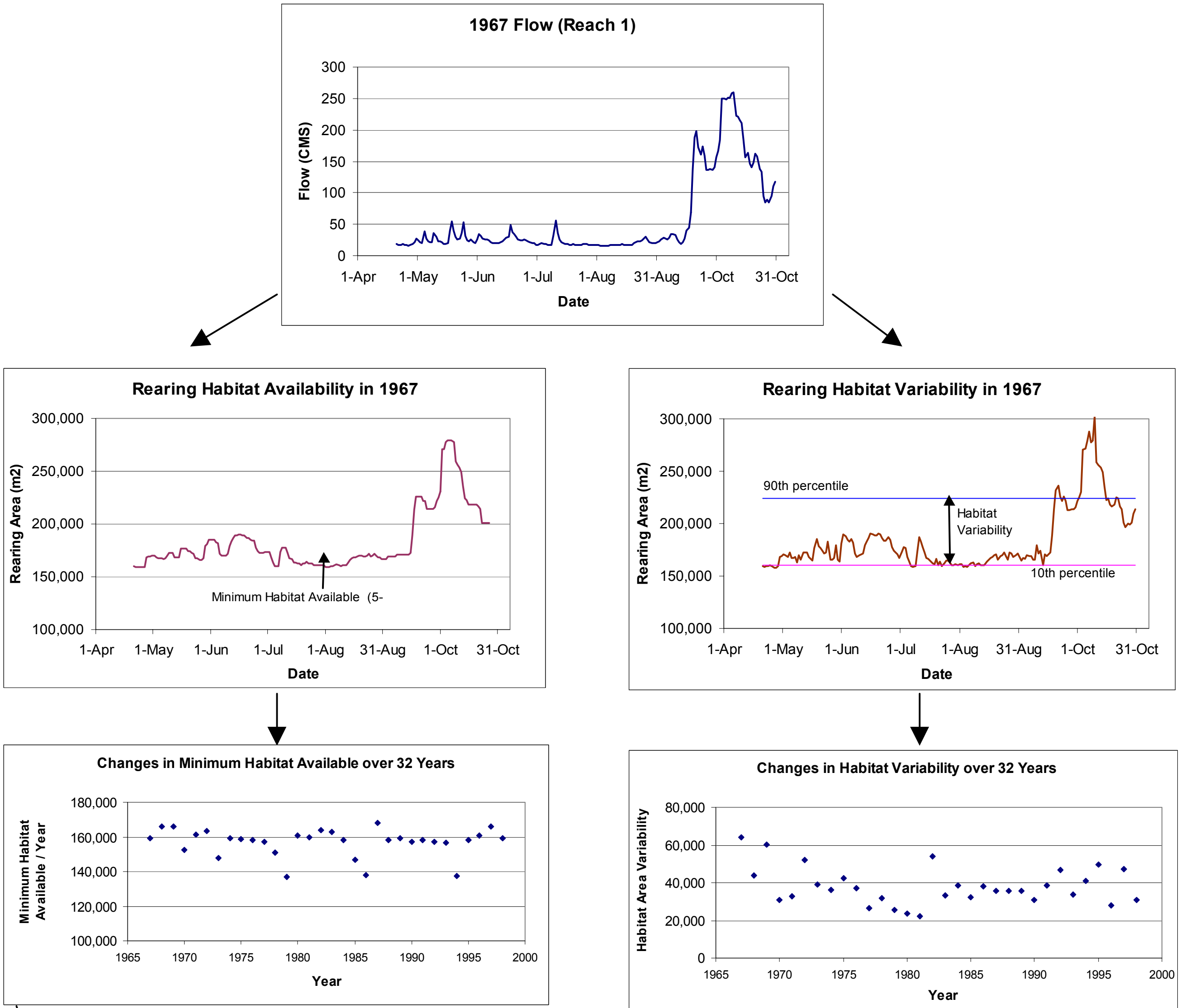


Figure A4.2: Salmon life cycle and fish / aquatic ecosystem PMs used to assess operating alternatives.

A4.3.2 Summary of FTC Methods for Rearing Habitat PMs

Questions	Methods used by FTC to find answers
Q1. How does the area of different types of rearing habitats change with flow? [Hypothesis 2]	A1a. Analyse air photos of eight reaches taken during dam releases of 5, 10, 20, 40 and 80 cms in 1999 and 2000. A1b. Use 2-D modelling of five reaches to show changes in depth and velocity with flow.
Q2. What types of rearing habitats are most important to each species?	A2a. Analyse results of 1999-2000 electroshock studies to determine which habitats are 'prime,' 'adequate,' 'marginal,' or 'unsuitable,' for coho, chinook, and steelhead fry, plus steelhead parr (RUA or Rated Usable Area for Rearing). A2b. Use information from the literature to estimate the relative value for rearing of different substrates, depths and velocities. Use 2-D model to compute WUA, or Weighted Usable Area, for rearing.
Q3. Which reaches are most important contributors to each species' rearing area, and how does this vary with flow?	A3. Look at the total rearing area at each flow, and how much each reach contributes to that total.
Q4. What PMs are used to assess the *relative* impact of each operating alternative on the ability of each species to successfully rear its juveniles?	A4. Details are described in the PM Information Sheet. In general, we compute two PMs: an index of Habitat Availability and an index of Habitat Variability. We use both the RUA and WUA methods since they each emphasise different features of the habitat. An annual index of *Habitat Availability* is estimated from the *minimum* rearing area available to each species during its rearing period (e.g., April 21 to October 30 for coho and chinook fry). A higher value is better. We compute this index based on the flows produced by a given operating alternative for each of the 32 water years in the historical record. The PM used for Habitat Availability is the median of the 32 annual Habitat Availability indices. We also report the 10th and 90th percentiles for this PM (roughly the 4th lowest and 4th highest annual Habitat Availability index in the 32-year period). See Figure ES.1. An annual index of *Habitat Variability* is estimated from the *range* of rearing areas available to each species within its rearing period in a given year. An intermediate level of habitat variability is considered to be preferred (i.e., not too stable, not too variable). However, the FTC does not know what level of variability is preferred, and is currently using this PM as a descriptive indicator. We are doing further work on refining this PM. For each year, we compute the Habitat Variability index based on the difference between the 90th percentile and 10th percentile of the daily rearing areas over the rearing period. This is computed for each of the 32 water years in the historical record. The PM used for Habitat Variability is the median of the 32 annual Habitat Variability indices. We also report 10th and 90th percentiles for this PM. See Figure ES.1. Ultimately, this PM was not used due to the scientific uncertainty in optimum variability.



Performance Measure	32-yr Median	Range (10th - 90th percentiles)
Habitat Availability ('000's of m^2)	**158**	146 – 165
Habitat Variability ('000's of m^2)	**36**	27 - 52

Figure A4.3: Derivation of Rearing PMs for one operational alternative. Flows (top graph) are used to compute daily amount of rearing habitat for a given year. The minimum amount of rearing habitat during each year (5-day median) is used as an annual index of *Habitat Availability*. The range of rearing habitat during each year (difference between 10th and 90th percentile) is used as an annual index of *Habitat Variability*. We use the median of these indices over 32 years as PMs, and their range (10th and 90th percentiles, which are roughly the 4th lowest and 4th highest values over 32 years).

A4.3.3 Summary of FTC Methods for Spawning / Incubation PM

Questions	Methods used by FTC to find answers
Q1. How does the area of usable spawning habitat change with flow? [Impact Hypothesis 2]	A1. Use 2-D modelling of flows within 5 reaches to estimate how much usable spawning area is available on each day of the spawning period for chinook, chum, coho and steelhead.
Q2. How is the survival of eggs affected by flow fluctuations during the egg incubation period?	A2. Use 2-D modelling to roughly estimate how eggs are likely to be distributed within the channel during each day of the spawning period, while also considering the typical spawning pattern over time (i.e., gradual increase to peak, then gradual decline). Then estimate what percentage of all spawning redds are likely to be stranded due to reductions in flows/wetted areas during the sensitive part of the incubation period (i.e., after the eyed stage).
Q3. What PMs should be used to assess the relative impact of each operating alternative on the ability of each species to successfully spawn and incubate eggs?	A3. The annual *effective spawning area (m^2)* is the area with the appropriate conditions for spawning at the time of spawning that remains wetted throughout the sensitive period of egg incubation. This index is converted into a PM by computing its median values over 32 years, together with its 10th to 90th percentiles. It is compared to range of spawning areas required in past years, using escapement estimates and literature estimates of the area required per spawning female (see CC Meeting Update for July 3 and 4 CC meeting). This comparison shows that only chum spawning habitat is likely to be limiting.

A4.3.4 Summary of Methods for Fish Food / Benthic Biomass PM

Questions	Methods used by FTC to find answers
Q1. How does the amount of fish food change with flow and other variables? [Impact Hypothesis 3]	A1. Cages were placed in the Cheakamus River for 8-week periods, during each of the 4 seasons in 1996, 1999 and 2000. Growth of periphyton (attached algae) and the biomass of benthic invertebrates (fish food) was monitored during each 8-week period, along with other potential explanatory factors. The data were then analysed to determine which factors influence the amount of fish food (Figure A4.4). The statistical models so developed were then modified to be applicable to operational alternatives in the Cheakamus WUP.
Q2. What PMs should be used to assess the relative impact of each operating alternative on the amount of food available for fish?	A2. A seasonal index of fish food is computed during an 8-week period of each season of each year, corresponding to the periods for which data were actually collected. The PM is computed using statistical models developed by Chris Perrin from the data he collected. The amount of fish food depends on both the benthic biomass / area and the total wetted area in riffles (Figure A4.4). The benthic biomass / area is primarily affected by the mean flow and the variability in flow during the preceding 8-week period (Figure A4.4). The PM is the median of the spring and summer indices of fish food over 32 years, and is computed for both representative anadromous reaches and representative resident reach. We also describe the variability in the indices.

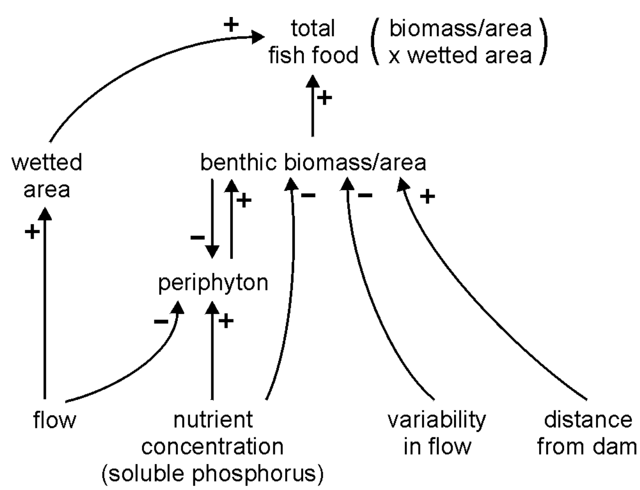


Figure A4.4: Factors shown to influence the abundance of fish food. "+" = positive relationship (factor at end of arrow increases with factor at start of arrow); "-" = negative relationship (factor at end of arrow decreases with factor at start of arrow). While benthic biomass/area (observed on sampling cages over an 8-week period) decreases at higher flows due to lower periphyton, this effect is offset by the fact that wetted area increases with flow.

A4.3.5 Summary of Methods for Migration Flow PM

Questions		Methods used by FTC to find answers	
Q1.	At what low flow levels are returning spawners negatively affected? [Impact Hypothesis 4]	A1.	There are various cues affecting the rate of in-migration of spawners, including temperature, barometric pressure and flow. To answer this question directly we need data on spawner distribution and movement in the Cheakamus River during low flows. We weren't able to gather such data in 1999 and 2000 since the detailed FTC work on spawning (i.e., spawner counts, radio-tagging) took place during periods of favourable fish flows. Therefore we must rely on anecdotal observations. There were no apparent access problems for spawning chinook during the low flows in fall 2000, nor for steelhead during the 1960s and 1970s when dam releases were lower. Other observations suggest steelhead may however be delayed at the Squamish-Cheakamus confluence when flows are below 10 m^3/sec. We may learn more in 2001 as flows are very likely to be lower than in 1999 and 2000.
Q2.	What PMs should be used to assess the relative impact of each operating alternative on spawner access?	A2.	Based on comparisons with other systems, and using rough estimates based on mean annual flow, the FTC agreed that there would not be any access problems when the flow at Brackendale is greater than 10 m^3/sec. We therefore decided to count the # days that Brackendale flows are less than 10 m^3/sec over the 32 water years simulated for each operating alternative. Higher values are worse.

A4.3.5 Why the FTC Feels It Is Not Appropriate to Have a Riparian Ecosystem PM

Background

The February 2001 report by Robertson Environmental Services Ltd., entitled Cheakamus Floodplain Ecosystem and Wildlife Overview, identified three types of floodplain ecosystems:

1. low bench floodplain ecosystems and gravel bars, which are flooded for at least one month every year;
2. medium bench floodplain ecosystems on fluvial benches that are flooded once every 5 years; and
3. high bench floodplain ecosystems that flood only once every 10 to 20 years.

The Robertson Environmental report (pg. 17) recommended that the "current flow regime be maintained", arguing that "these flows are maintaining healthy floodplain ecosystems and allowing the natural floodplain to evolve".

FTC Discussions of Possible Riparian Ecosystem Performance Measures

The FTC believes that existing dykes along most of the Cheakamus River prevent the evolution of the natural floodplain. After some discussion, the FTC developed a possible approach for a riparian ecosystem PM: use the Pass All Inflows operating alternative as a 'natural baseline' from which to assess the flows required to maintain riparian vegetation. The rationale for using the Pass All Inflows alternative is that it would approximate the flooding regime to which riparian ecosystems were originally adapted. We considered making riparian PMs that examined the relative magnitude of 30-day flows to support low bench vegetation (i.e., relative to Pass All Inflows), and the relative frequency of 5 and 10-year flooding flows to support medium and high bench vegetation, (about 350 and 500 cms, respectively). The idea of this PM would be that lower 30-day flows would be worse for low bench ecosystems, and lower flooding frequencies would be worse for medium and high bench ecosystems.

Here's an illustration of how such riparian PMs could work. Under Pass All Inflows flows of 120 to 200 cms are maintained for 30 days during the freshet. By contrast, the Power Optimal alternative would maintain only about 80 to 150 cms for 30 days. Therefore the Power Optimal alternative would have 30-day flows that were only 0.6-0.7 of the Pass All Inflows scenario, and the low bench PM would be assigned a value of about 0.65, where 1.0 is the maximum possible. Similarly, an operating alternative with 0 days of flows >= 500 cms would be judged to be inferior to one which had such flows 3 days out the 32 year period (roughly once every 10 years).

Upon further reflection, the FTC felt that these riparian PMs were misleading: with so much of the Cheakamus channel either naturally confined or dyked, higher flows will not improve riparian vegetation in most reaches, since this water will not reach the original floodplain. To make a serious effort at improving floodplain vegetation, one would need to first remove some dykes and then consider increasing flows. If the CC should decide to explore removal of dykes in some areas, then it may be relevant to generate riparian PMs. Until then, however, it seems less relevant. Furthermore, the flooding PMs indicate that the frequency of moderately high to high flows seems pretty well unaffected by operating alternatives in the Cheakamus River; they are driven mostly by year to year climatic variability.

Would lower dam releases than those in the past few decades negatively affect the riparian ecosystem by allowing vegetation to further encroach on the river channel? While the flow is lower than what it would be in the absence of the diversion to turbines, the channel has also narrowed, so that the flow is concentrated in a narrower width. Northwest Hydraulic Consultants (2000, pg. 34) estimated that flows of 250 to 350 m^3/s (for unknown duration) would be required at the Brackendale gauge to prevent establishment of pioneer vegetation on gravel bar surfaces. This is considerably greater than the maximum diversion to the turbines of 60 m^3/s, suggesting that there may be only a limited ability of dam operating procedures to affect vegetation establishment on gravel bars. The NHC report also suggested that flows of much more than 250-350 m^3/s would be required to remove existing pioneer vegetation, and that is would be simpler and more effective to remove such vegetation mechanically.

In light of all this, the FTC feels that the primary constraint on riparian ecosystems are dykes, not flows. Further evaluation by geomorphic and vegetation specialists would be required to assess more precisely the degree to which dam operating procedures can significantly affect riparian ecosystems. Monitoring of vegetation responses during natural variations in flows (both vegetation establishment during low flows and vegetation scouring from gravel bars during high flows) would also be informative.

Reference

1. Northwest Hydraulic Consultants. 2000. Analysis of Channel Morphology and Sediment Transport Characteristics of the Cheakamus River. Report prepared for BC Hydro. November 20, 2000. 37 pp. + tables, figures and appendices.
2. Robertson Environmental Services Ltd. 2001. Cheakamus Floodplain Ecosystem and Wildlife Overview. February 13, 2001. Report prepared for BC Hydro. 27 pp.

A4.3.6 Why more water isn't always better for fish

MEMORANDUM

TO: Cheakamus Consultative Committee
FROM: Cheakamus Fisheries Technical Committee
DATE: June 5, 2001
SUBJECT: Why more water isn't always better for fish

Reason for this memorandum

During the last CC meeting [May 28/29th], several CC members expressed surprise at the lack of sensitivity of fish PMs to operating alternatives. Indeed, it is surprising that in the Cheakamus River more water doesn't necessarily result in better conditions for fish. This result is counter to our previous intuition.

Some CC members were understandably sceptical of models, which generate such a counter-intuitive result. This scepticism is healthy, as all models contain assumptions that are limited by available information. That is why the Water Use Plan developed by the CC should also be accompanied by monitoring, to ensure that in the future we can detect any changes in the river or errors in our understanding of the system. Also, the FTC appreciates that the CC has not had nearly as much time as the FTC to explore the behaviour of the FTC models, test them, and check the results. The FTC therefore felt that it was important to provide the CC with more information explaining these results.

Summary

There are two primary reasons for the lack of sensitivity of fish PMs to flow, except at very low dam releases:

1) Inputs to the Cheakamus River from tributaries such as Rubble, Culliton and Cheekeye increase the flow in the mainstem, and offset the effects of low spills from the dam. Without input from these tributaries, the fish PMs are much more sensitive to flow alternatives.

2) Most of the length of the Cheakamus River is either naturally confined or confined by dykes (see presentation to the CC by Dr. Bob Newbury on February 7, 2000). This means that in most reaches higher flows increase the depths and velocities of water within the confined area, but do not spread out into a floodplain and side channels as would occur in a less confined river. The addition of dykes has significantly changed the river (see Figure 1, attached). The net result is that while more water creates new habitats along the margins of the river that are favourable to the rearing and spawning of fish species, other areas now contain velocities and depths which are less preferred. The net result is little change in the overall usable area for spawning and rearing, or even a decrease in some cases. This pattern of change is well illustrated by output from the River 2D model, which was presented to the CC by Barry Chilibeck on April 30th, 2001.

If there is interest, some of the above results can be briefly reviewed at the next CC meeting.

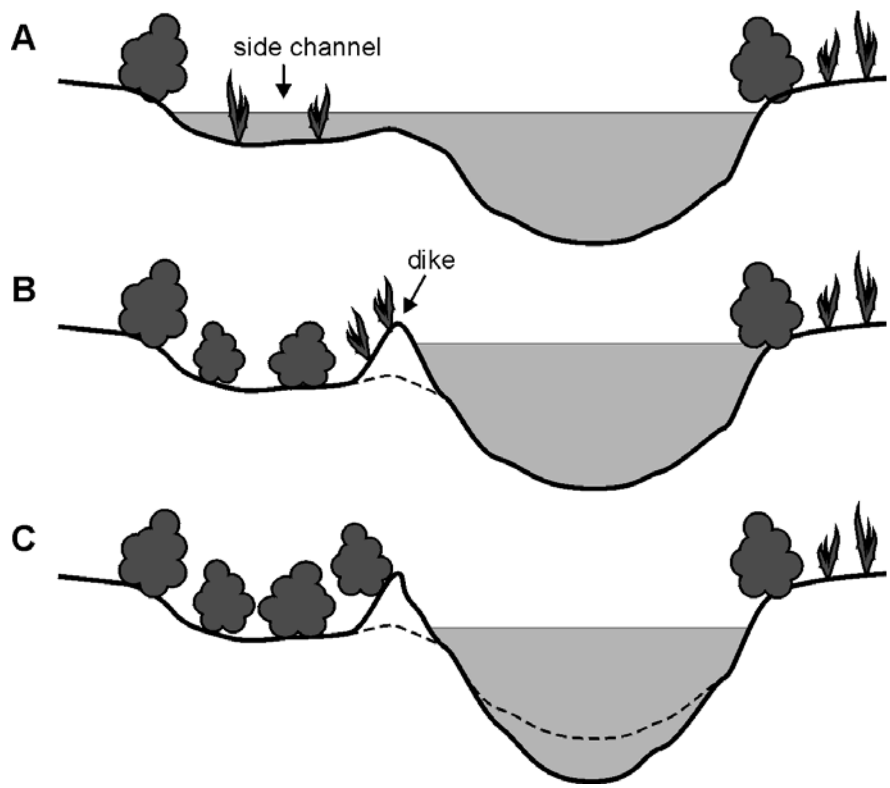


Figure 1. Example of changes over time in a river cross-section as it becomes confined by dykes. The sequence of changes is as follows:

a) original river with natural floodplain and side channel;
b) side channel cut off by dyke and covered by new vegetation; velocities increase in main channel;
c) higher velocity water causes further down-cutting of channel, increasing depth and reducing amount of suitable spawning and rearing habitat.

A4.3.7 Rationale for Excluding Pink Salmon from Habitat-Flow Analysis, Cheakamus River (Brent Lister, SFN FTC)

Date: October 2, 2001

At the September 7 2001 Consultative Committee Meeting I was asked to prepare a written explanation of FTC's reasons for not including pink salmon in their detailed analyses of habitat-flow relationships in the Cheakamus River. This memorandum provides background and reasoning for that decision.

Population Abundance Patterns

DFO spawning escapement estimates, commencing in 1951, indicate that the Cheakamus pink spawning population increased in the late 1950's and early 1960's to reach a peak of 550,000 fish in 1963 (Figure 1 attached). From that point, the population declined to a relatively low level from which it has yet to recover. Up to the late 1980's the Cheakamus pink abundance pattern was similar to that observed at Mamquam and Indian (Burrard Inlet) rivers, which also support populations with early adult migration and spawning timing. Since the late 1980's, however, the Mamquam and Indian River populations have recovered to some extent.

It should be noted that 1963 escapements were the largest on record for the Squamish watershed and Burrard Inlet streams.[1]

River Habitat Change

Physical character of the Cheakamus River has changed considerably since the hydro project began operation in 1957. In Reaches 3 and 4, for example, active channel width declined by 53% between 1957 and 1996 (based on air photos). Channel character in those reaches changed, from a braided pattern (with numerous secondary channels) to a sinuous, single-thread channel.[2] Most free-flowing side channels are now isolated from the mainstem by flood protection dykes. Flood plain constriction by dyking results in higher main channel velocities, which have probably led to some lowering of the channel and to coarsening of river bed material.[2] Limited sampling by Northwest Hydraulic Consultants during 2000 revealed median diameters of river bar material (mainly gravel and cobble) in the range of 9.5 - 16.0 cm.

Effects of Habitat Change

DFO studies in 1955 showed that 67% of pink salmon spawners utilised surface-fed side channels connected to the Cheakamus mainstem.[3] Isolation of those side channels behind dykes has forced pink salmon to spawn in the main channel where conditions appear to have become less favourable over time.

Of particular importance is probable coarsening of spawning substrates in the main channel. Pink salmon select relatively small gravels (less than 5 cm diameter) for spawning. They spawn in much finer gravels than generally selected by chum salmon, for example.[4] It is likely that suitable spawning substrate has therefore become less available to pinks over the last 3-4 decades.

As pink spawners are relatively small (less than half the size of chum salmon on average), they can be expected to dig shallow redds or spawning nests with eggs buried as little as 10-15 cm below the bed surface.[5] This makes pink eggs more susceptible than other salmon species to the gravel scouring effects of fall-winter flood events. Support for this hypothesis comes from the observed poor survival of Cheakamus pink broods subjected to relatively high flood events during spawning and incubation.[6]

Conclusions

1. Air photo analysis indicates that the Cheakamus River maintained a braided channel pattern, with side channels for pink spawning in Reach 4 (a major spawning reach) until at least 1964.[1] The

river also sustained high levels of pink production into the mid-1960's (Figure 1). This information suggests that the prevailing river flow regime was not, in itself, a major constraint on pink salmon survival and production.

2. Between the mid-1960's and late 1980's channel character (in key reaches) changed from braided to a single-channel pattern without the surface-fed side channels preferred by pinks. Main channel constriction by dyking also appears to have affected pink salmon adversely by: 1) causing a coarsening of the river bed and thereby reducing available spawning habitat; and 2) exposing pink salmon eggs to higher than normal risk of scouring due to flood events.
3. Based on conclusions (1) and (2), recovery of the Cheakamus pink run appears to depend mainly on restoring suitable spawning and incubation habitats, rather than major changes in river flow regime.
4. Increased minimum flows during fall-winter, which are a key feature of flow options now under consideration, should benefit pink salmon survival by reducing the likelihood of redd stranding.

I trust that this memo fairly characterises the FTC's reasoning for not conducting flow-habitat analyses for Cheakamus pink salmon.

Brent Lister
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References

1. **Farwell, M.K., N.D. Schubert, K.H. Wilson, and C.R. Harrison**. 1987. Salmon escapements to streams entering Statistical Areas 28 and 29, 1951 to 1986. Can. Data Rep. Fish. Aquat. Sci. 601.
2. **Northwest Hydraulic Consultants**. 2001. Analysis of channel morphology and sediment transport characteristics of the Cheakamus River. Prepared for BC Hydro, Burnaby. 40 pp. + appendices.
3. **Department of Fisheries, Canada**. 1957. A report on the fisheries problems related to the power development of the Cheakamus River system. Vancouver, BC. 39 pp. + appendices.
4. **Kondolf, G.M. and M.G. Wolman**. 1993. The sizes of salmonid spawning gravels. Water Resources Research 29: 2275-2285.
5. **van den Berghe, E.P., and M.R. Gross**. 1984. Female size and nest depth in coho salmon. Can. J. Fish. Aquat. Sci. 41: 204-206.
6. **Lewis, A.J., and B.T. Guy**. 1996. Cheakamus River fisheries study, 1991-1993. Prepared by Triton Environmental Consultants for BC Hydro, Burnaby. 154 pp + appendices.

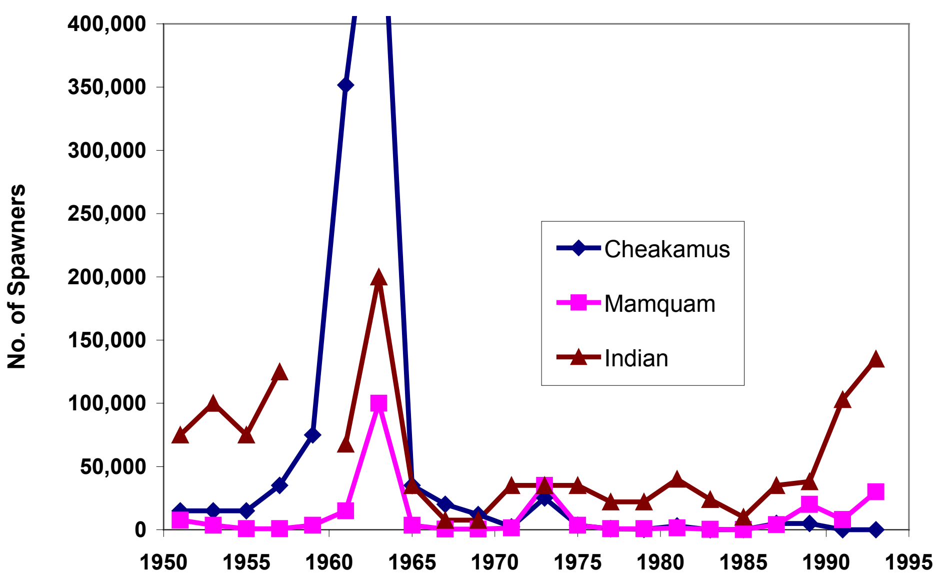

Figure 1. Pink salmon spawning escapements to the Cheakamus, Mamquam and Indian rivers, 1951 - 1993. Dept. of Fisheries and Oceans data.

Appendix 5: Alternative Screening – Summary of Performance Measures

(Full Objectives by Alternatives Matrix)

A5.1 Consequence Table for All Alternatives Considered during Evaluation

Fundamental Objectives	Performance Measures	Alternatives																								
		Power Optimal	FER	10Min	3Dam	15Min	15Min3Dam	5Dam	15Min5Dam	15_20Min3_7DamA	15_20Min3_5_7Dam	7Dam	15Min3_10Dam	15Min7Dam	20Min	15Min5_10Dam	Int22.5%	20Min3Dam	15_20min3_7DamB	20Min7Dam	20Min7_10Dam	10Dam	25Min	30Min	Int45%	Pass All Inflows
1. Maximize economic returns from power generation.	Average power revenue ($M/yr)	38.5		38.3	36.8	36.4	35.6	35.6	34.8	34.3	34.0	33.9	33.9	33.8	33.6	33.5	33.3	33.1	33.0	32.3	32.0	31.8	30.7	28.0	26.9	0.0
	Power production (GWh)	828		820	792	781	767	762	751	736	731	731	728	728	724	719	710	717	713	699	691	684	664	608	556	0
	Greenhouse Gas emission reductions (Ktonnes/yr)	253		251	242	239	235	233	230	225	224	224	223	223	222	220	217	219	218	214	212	209	203	186	170	0
2. Protect integrity of SFN heritage sites and cultural values.		Addressed by flood PMs and other studies.																								
3. Maximize physical conditions / access for recreation (kayaking, rafting, sportfishing).	Rafting (Avg. #days/yr)	61	63	62	62	61	62	62	62	61	62	64	62	64	61	63	73	61	63	63	63	67	60	59	100	121
	Kayaking (Avg. #days/yr)	112	118	112	124	112	124	138	138	200	202	158	181	158	242	186	171	242	222	242	242	204	237	232	199	226
	Sportfishing (Avg. #days/yr)	47	47	42	58	41	58	48	72	83	142	93	114	93	163	97	84	163	125	193	193	122	160	186	131	134
4. Minimize adverse effects of flood events.	Flooding (# flood days >450cms)	No alternative except Pass All Inflows exceeds 450cms at Brackendale																								
5. Maximize wild fish populations																										
RUA Anadromous Habitat Availability (x 10^3 m^2)	Chinook	104.1	104.3	105.1	105.1	105.1	105.1	105.1	105.1	105.1	105.1	105.1	105.1	105.1	105.1	105.1	105.3	105.1	105.1	105.1	105.1	105.1	105.1	105.1	104.2	100.4
	Coho	66.1	66.1	68.7	67.9	70.2	68.9	68.7	68.8	68.7	68.7	68.7	69.0	68.7	70.2	69.0	69.6	68.9	68.7	68.7	89.0	69.0	69.4	76.5	70.8	72.6
	Steelhead Fry	130.9	130.9	134.6	137.3	143.2	144.1	141.4	144.3	143.8	143.8	142.8	142.7	143.9	144.8	142.7	141.8	144.9	143.8	143.8	142.7	142.7	144.5	154.6	142.5	144.3
	Steelhead Parr	91.5	91.5	95.0	96.6	100.9	101.2	99.9	101.4	101.7	101.7	101.2	102.4	101.7	101.2	102.4	100.3	101.2	101.7	101.7	102.4	102.4	101.0	100.8	102.8	104.0
WUA Anadromous Habitat Availability (x 10^3 m^2)	Chinook	98.6	98.6	98.6	98.6	98.6	98.6	98.4	98.6	98.6	98.6	98.6	98.6	98.6	98.4	98.6	98.3	98.6	98.6	98.6	98.6	98.6	98.6	98.6	97.3	96.7
	Coho	104.1	104.1	104.1	104.1	104.1	104.1	104.1	104.1	104.1	104.1	104.1	104.1	104.1	104.1	104.1	104.1	104.1	104.1	104.1	104.1	104.1	104.1	104.1	104.1	102.8
	Steelhead Fry	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	69.0
	Steelhead Parr	116.0	116.0	116.0	116.0	116.0	116.0	116.0	116.0	116.0	116.0	116.0	116.0	116.0	116.0	116.0	116.0	116.0	116.0	116.0	116.0	116.0	116.0	116.0	116.0	115.0
RUA Resident Habitat Availability (x 10^3 m^2)	Rainbow Fry	7.1	7.1	7.2	7.7	7.6	8.0	8.6	9.5	13.0	13.0	11.1	14.8	11.5	8.2	14.8	8.7	10.0	13.0	13.0	14.8	14.8	10.7	13.9	12.1	19.6
	Rainbow Parr	32.0	32.0	32.5	34.4	34.0	35.8	36.4	37.7	42.5	42.5	39.9	45.2	40.4	35.9	45.2	36.7	38.1	42.5	42.5	45.2	45.2	38.5	41.4	41.4	50.2
Effective Spawning Area (x 10^3 m^2)	Chinook	37.8	36.9	40.2	42.4	46.0	46.8	46.5	48.7	53.2	53.6	50.0	53.4	51.1	52.9	53.8	49.6	53.6	53.5	54.1	54.0	53.0	54.7	55.1	49.6	43.5
	Coho	44.1	44.0	49.2	45.9	49.2	48.5	46.1	48.4	48.5	49.5	45.5	48.5	47.0	44.7	48.4	44.5	45.4	48.0	44.2	44.2	43.9	38.5	32.8	40.0	29.1
	Chum	8.0	7.8	10.2	7.9	10.2	9.8	8.0	9.2	9.7	9.7	7.5	9.6	8.3	7.9	9.0	7.3	7.5	9.5	7.3	7.3	6.5	5.5	3.8	5.5	2.8
	Steelhead	37.0	36.5	37.1	35.6	37.1	35.9	34.2	34.6	32.9	32.9	32.8	31.2	32.8	33.7	31.1	31.0	33.8	32.9	32.9	31.1	31.1	30.2	27.7	28.2	26.6
Adult Migration	Chinook	6.8	6.8	0.0	1.5	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Coho	31.9	31.8	0.0	11.8	0.0	0.0	1.6	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.2
	Chum	14.6	14.5	0.0	5.9	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0
	Steelhead	35.7	35.6	0.0	6.8	0.2	0.2	0.4	0.0	0.2	0.2	0.0	0.2	0.2	0.3	0.2	0.4	0.3	0.2	0.3	0.3	0.3	0.5	0.7	0.3	0.7
6. Maximize area and integrity of aquatic and riparian ecosystem	Anadromous Riffle Benthic Biomass (g x 10^6)	12.3		12.3	12.3	12.7	12.4	12.4	12.4	10.7	10.7	12.1	11.0	12.1	10.6	11.0	9.1	10.7	11.0	10.7	11.0	11.0	9.6	11.6	8.0	4.3
	Resident Riffle Benthic Biomass (g x 10^6)	3.7		3.7	3.6	3.5	3.4	3.6	3.5	2.9	2.9	3.4	3.0	3.3	2.8	3.0	2.4	2.9	3.0	2.9	3.0	3.0	2.3	2.2	2.2	1.6

A5.2 Pros and Cons Tables from Each Meeting

Table A5.1: Summary of major differences among alternatives for the May 28th/29th 2001 Consultative Committee meeting. Different PMs shown in different colours.

Alternative	Pros	Intermediate	Cons
Power Optimal (PO)	- Power ($39.2m) - relatively high effective spawning area for coho (~45,000 m^2), chum (8,000), steelhead (~37,000)[1]		- larger floods (2 events >680 cms) - Rafting/Kayaking (87 days /yr) - potential migration problems for all species - relatively low effective spawning area for chinook (~38,000 m^2)[16] - relatively low rearing area for rainbow trout fry and parr
Flood Empty Reservoir (FER)	- Power ($36.6m) - relatively high effective spawning area for coho (~45,000 m^2), chum (~8,000), steelhead (~37,000)[1]		- Rafting/Kayaking (91 days /yr) - potential migration problems for all species - relatively low effective spawning area for chinook (~38,000 m^2)[1] - relatively low rearing area for rainbow trout fry and parr
10 cms Minimum Flow (10cms)	- Power ($37.4m) - no migration problems - relatively high effective spawning area for coho (~50,000 m^2) 1, chum (10,000), steelhead (~38,000)		- Rafting/Kayaking (88 days /yr) - relatively low effective spawning area for chinook (~40,000 m^2) [1] - relatively low rearing area for rainbow trout fry and parr
20 cms Minimum Flow (20cms)	- Rafting/Kayaking (152 days/yr) - no migration problems - relatively high effective spawning area for chinook (~52,000 m^2), coho (~45,000 m2), chum (8,000), steelhead (~34,000)[1]	- Power ($32.9m) - intermediate rearing area for rainbow trout fry and parr	
30 cms Minimum Flow (30cms)	- Rafting/Kayaking (146 days/yr) - no migration problems - relatively high effective spawning area for chinook (~55,000 m^2) [1] - relatively high rearing area for rainbow trout fry and parr		- Power ($27.2m) - relatively low effective spawning area for coho (~32,000), chum (~4,000 m^2) , steelhead[1]
Interim Flow Order (IF)	- Rafting/Kayaking (150 days/yr) - no migration problems - relatively high effective spawning area for chinook (~50,000 m^2) [1] - relatively high rearing for rainbow trout parr	- intermediate effective spawning area for coho (~40,000) - intermediate for rainbow trout fry	- Power ($27.5m) - relatively low effective spawning area for chum (~5,000 m^2), steelhead (~27,000)[1]
Pass Inflows (PI)	- Rafting/Kayaking (174 days/yr) - no migration problems - relatively high rearing area for rainbow trout fry and parr		- Power ($0m) - larger floods (2 events > 680 cms; 7 moderate events > 450 cms) - relatively low effective spawning area for chinook (~40,000 m^2), coho, chum (~3,000), steelhead ~26,000)[1]

[16] Spawning habitat does not appear to be currently limiting chinook, coho or steelhead, though there are uncertainties in defining appropriate thresholds. Chum spawning habitat is currently most likely to be limiting.

Table A5.2: Summary of major differences among alternatives for the July 3rd/4th 2002 Consultative Committee meeting. Different PMs shown in different colours.

Alternative	Pros	Intermediate	Cons
10 cms Minimum Flow **(10Min)**	- Power ($38.3m) - relatively high effective spawning area for coho (~49,000 m^2), chum (10,000), steelhead (~37,000)[1] - relatively high benthic biomass in both resident and anadromous reaches		- relatively low # access days for rafting, kayaking and sportfishing - relatively low effective spawning area for chinook (~40,000 m^2)[17] - relatively low rearing area for rainbow trout fry (~7,000 m^2) and parr (~32,000 m^2)
15 cms Minimum Flow **(15Min)**	- Power ($36.4m) - relatively high effective spawning area for coho (~49,000 m^2), chum (~10,000), steelhead (~37,000)[1] - relatively high benthic biomass in both resident and anadromous reaches	- intermediate effective spawning area for chinook (~46,000 m^2)[1]	- relatively low # access days for rafting, kayaking and sportfishing - relatively low rearing area for rainbow trout fry (~8,000 m^2) and parr (~34,000 m^2)
5 cms Minimum Dam Spill **(5Dam)**	- Power ($35.6m) - relatively high effective spawning area for coho (~46,000 m^2)[1], steelhead (~34,000) - relatively high benthic biomass in both resident and anadromous reaches	- intermediate # access days for kayaking - intermediate effective spawning area for chinook (~47,000 m^2) and chum (~8,000 m^2) [1] - intermediate rearing area for rainbow trout parr (~36,000 m^2)	- relatively low # access days for rafting and sportfishing - relatively low rearing area for rainbow trout fry (~9,000 m^2)
20 cms Minimum Flow **(20cms)**	- relatively high # access days for kayaking and sportfishing - relatively high effective spawning area for chinook (~53,000 m^2), coho (~45,000 m^2), steelhead (~34,000)[1] - relatively high benthic biomass in anadromous reaches	Power ($33.6m) - Intermediate effective spawning area for chum (8,000 m^2) - intermediate rearing area for rainbow trout parr (~36,000 m^2) - intermediate benthic biomass in resident reaches	- relatively low # access days for rafting - relatively low rearing area for rainbow trout fry (~8,000 m^2)
Interim Flow Order with 22.5% of inflows **(Int22.5%)**	- relatively high effective spawning area for chinook (~50,000 m^2), coho (~44,000 m2)	- Power ($33.3m) - intermediate # access days for kayaking and sportfishing - Intermediate effective spawning area for chum (7,000 m^2), steelhead (~31,000)[1] - intermediate rearing area for rainbow trout parr (~37,000 m^2)	- relatively low # access days for rafting - relatively low rearing area for rainbow trout fry (~9,000 m^2) - relatively low benthic biomass in both resident and anadromous reaches

[17] Spawning habitat does not appear to be currently limiting chinook, coho or steelhead, though there are uncertainties in defining appropriate thresholds. Chum spawning habitat is currently most likely to be limiting.

Alternative	Pros	Intermediate	Cons
10 cms Minimum Dam Spill **(10Dam)**	- relatively high # access days for kayaking - relatively high effective spawning area for chinook (~53,000 m^2), coho (~44,000 m^2) - relatively high rearing area for rainbow trout fry (~15,000 m^2) and parr (~45,000 m^2) - relatively high benthic biomass in anadromous reaches	- Power ($31.8m) - intermediate # access days for sportfishing - Intermediate effective spawning area for chum (6,000 m^2), steelhead (~31,000)[1] - intermediate benthic biomass in resident reaches	- relatively low # access days for rafting
25 cms Minimum Flow **(25cms)**	- relatively high # access days for kayaking and sportfishing - relatively high effective spawning area for chinook (~55,000 m^2)	- Intermediate effective spawning area steelhead (~30,000)[1] - intermediate rearing area for rainbow trout fry (~11,000 m^2) and parr (~38,000 m^2) - intermediate benthic biomass in anadromous reaches	- Power ($30.7m) - relatively low # access days for rafting - relatively low effective spawning area for coho (~38,000), chum (~4,000 m^2) - relatively low benthic biomass in resident reaches
30 cms Minimum Flow **(30cms)**	- relatively high # access days for kayaking and sportfishing - relatively high effective spawning area for chinook (~55,000 m^2) [1] - relatively high rearing area for rainbow trout fry (~14,000 m^2) and parr (~41,000) - relatively high benthic biomass in anadromous reaches		- Power ($28.0m) - relatively low # access days for rafting - relatively low effective spawning area for coho (~33,000), chum (~4,000 m^2), steelhead (~30,000)[1] - relatively low benthic biomass in resident reaches
Interim Flow Order with 45% of inflows **(Int45%)**	- relatively high # access days for kayaking and rafting - relatively high effective spawning area for chinook (~50,000 m^2)[1] - relatively high rearing area for rainbow trout fry (~12,000 m^2) and parr (~40,000)	- intermediate # access days for sportfishing - intermediate effective spawning area for coho (~40,000) and chum (~5,000 m^2) - intermediate for rainbow trout fry	- Power ($26.9m) - relatively low effective spawning area for steelhead (~28,000)[1] - relatively low benthic biomass in both anadromous and resident reaches

Table A5.3: Summary of major differences among alternatives for the September 7th 2001 Consultative Committee meeting. Different PMs shown in different colours.

Alternative	Pros	Intermediate	Cons
10 cms Minimum Flow **(10Min)**	- Power ($38.3m) - relatively high effective spawning area for chum (10,200),[1] - relatively high benthic biomass in resident reaches		- relatively low # access days for kayaking and sportfishing - relatively low effective spawning area for chinook (~40,200 m^2)[18] - relatively low rearing area for rainbow trout fry (~7,200 m^2) and parr (~32,400 m^2)
3 cms Minimum Dam Release **(3Dam)**	- Power ($36.8m) - relatively high benthic biomass in resident reaches	- intermediate effective spawning area for chum (7,900m^2)[1] - intermediate # access days for sportfishing	- relatively low # access days for kayaking - relatively low effective spawning area for chinook (~42,400 m^2)[1] - relatively low rearing area for rainbow trout fry (~7,700 m^2) and parr (~34,400 m^2)
15 cms Minimum Flow **(15Min)**	- Power ($36.4m) - relatively high effective spawning area for chum (~10,200),[1] - relatively high benthic biomass in resident reaches	- intermediate effective spawning area for chinook (~46,000 m^2)[1] - intermediate # access days for sportfishing	- relatively low # access days for kayaking - relatively low rearing area for rainbow trout fry (~7,600 m^2) and parr (~34,000 m^2)
15 cms Min. Flow & 3 cms Min. Dam Release (**15Min3Dam**)	- relatively high effective spawning area for chum (~9,800 m^2)[1] - relatively high benthic biomass in resident reaches	- Power ($35.6m) - Intermediate effective spawning area for chinook (~46,800 m^2)	- relatively low # access days for kayaking and sportsfishing - relatively low rearing area for rainbow trout fry (~8,000 m^2) and parr (~35,800 m^2)
5 cms Minimum Dam Release **(5Dam)**	- relatively high benthic biomass in resident reaches	- Power ($35.6m) - intermediate # access days for kayaking and sportfishing - Intermediate effective spawning area for chum (8,000 m^2), chinook (~46,500)[1] - intermediate rearing area for rainbow trout parr (~36,400 m^2)	- relatively low rearing area for rainbow trout fry (~8,600 m^2)
7 cms Minimum Dam Release (**7Dam**)	- relatively high effective spawning area for chinook (~50,000 m^2) - relatively high rearing area for rainbow trout parr (~39,000 m^2) - relatively high benthic biomass in resident reaches	- Power ($33.9m) - intermediate # access days for kayaking and sportfishing - intermediate rearing area for rainbow trout fry (~11,100 m^2)	- relatively low effective spawning area for chum (~7,500 m^2)
20 cms Minimum Flow **(20cms)**	- relatively high # access days for kayaking and sportfishing - relatively high effective spawning area for chinook (~52,900 m^2)	- intermediate effective spawning area for chum (~7,900 m^2) - relatively low benthic biomass in resident reaches	- Power ($33.6m) - relatively low rearing area for rainbow trout fry (~8,200 m^2) and parr (~35,900 m^2)

[18] Spawning habitat does not appear to be currently limiting chinook, coho or steelhead, though there are uncertainties in defining appropriate thresholds. Chum spawning habitat is currently most likely to be limiting.

Alternative	Pros	Intermediate	Cons
20 cms Min. Flow and 7 cms Min. Dam Release (**20Min7Dam**)	- relatively high # access days for kayaking and sportfishing - relatively high effective spawning area for chinook (~54,000 m^2) [1] - relatively high rearing area for rainbow trout fry (~13,000 m^2) and parr (~42,500)	- relatively high benthic biomass in resident reaches	- Power ($32.3m) - relatively low effective spawning area for chum (~7,300 m^2)[1]
10 cms Minimum Dam Spill **(10Dam)**	- relatively high # access days for kayaking and sportfishing - relatively high effective spawning area for chinook (~53,000 m^2)[1] - relatively high rearing area for rainbow trout fry (~14,800 m^2) and parr (~45,100)	- intermediate for rainbow trout fry	- Power ($31.8m) - relatively low effective spawning area for chum ~6,500 m^2)[1] - intermediate benthic biomass in resident reaches

Table A5.4: Summary of major differences among alternatives for the October 4th 2002 Consultative Committee meeting. Different PMs are shown in different colours.

Alternative	Pros	Intermediate	Cons
15 cms Min. Flow & 3 cms Min. Dam Release **(15Min3Dam)**	- Power ($35.6m) -relatively high effective spawning area for chum (~9,800 m^2) - relatively high benthic biomass in resident reaches (3.4 x 10^6 g)		- relatively low # access days for kayaking (124) and sportfishing (58) - relatively low rearing area for rainbow trout fry (~8,000 m^2) and parr (~35,800 m^2)
5 cms Minimum Dam Release **(5Dam)**	- Power ($35.6m) - relatively high effective spawning area for chum (~8,000 m^2) - relatively high benthic biomass in resident reaches (3.6 x 10^6 g)	- intermediate rearing area for rainbow trout parr (~36,400 m^2)	- relatively low # access days for kayaking (138) and sportfishing (48) - relatively low rearing area for rainbow trout fry (~8,600 m^2)
15 cms Min. Flow & 5 cms Min. Dam Release **(15Min5Dam**	- Power ($34.8m) - relatively high effective spawning area for chum (~9,200 m^2) - relatively high benthic biomass in resident reaches (3.5 x 10^6 g)	- intermediate # access days for sportfishing (72) - intermediate rearing area for rainbow trout parr (~37,700 m^2)	- relatively low # access days for kayaking (138) - relatively low rearing area for rainbow trout fry (~9,500 m^2)
7 cms Minimum Dam Release **(7Dam)**		- Power ($33.9m) - intermediate # access days for kayaking (158) and sportfishing (93) - intermediate rearing area for rainbow trout fry (~11,100 m^2) and parr (~39,900 m^2) - intermediate benthic biomass in resident reaches (3.4 x 10^6 g)	- relatively low effective spawning area for chum (~7,500 m^2)
20 cms Minimum Flow **(20cms)**	- relatively high # access days for kayaking (242) and sportfishing (163) - relatively high effective spawning area for chum (~7,900 m^2)	- Power ($33.6m)	- relatively low rearing area for rainbow trout fry (~8,200 m^2) and parr (~35,900 m^2) - relatively low benthic biomass in resident reaches (2.8 x 10^6 g)
20 cms Min. Flow & 3 cms	- relatively high # access days for kayaking (242) and sportfishing	- Power ($33.1m) - intermediate rearing area for	- relatively low effective spawning area for chum

Alternative	Pros	Intermediate	Cons
Min. Dam Release **(20Min3Dam**	(163)	rainbow trout fry (~10,000 m^2) and parr (~38,100 m^2) - intermediate benthic biomass in resident reaches (2.9 x 10^6 g)	(~7,500 m^2)
20 cms Min. Flow and 7 cms Min. Dam Release (**20Min7Dam**)	- relatively high # access days for kayaking (242) and sportfishing (193) - relatively high rearing area for rainbow trout fry (~13,000 m^2)	- intermediate benthic biomass in resident reaches (2.9 x 10^6 g) - intermediate rearing area for rainbow trout parr (~42,500 m^2)	- Power ($32.3m) - relatively low effective spawning area for chum (~7,300 m^2)
10 cms Minimum Dam Spill **(10Dam)**	- relatively high # access days for kayaking (204) - relatively high rearing area for rainbow trout fry (~14,800 m^2) and parr (~45,100 m^2)	- intermediate # access days for sportfishing (122) - intermediate benthic biomass in resident reaches (3.0 x 10^6 g)	- Power ($31.8m) - relatively low effective spawning area for chum (~6,500 m^2)

Appendix 6:
Flow Information for Final Alternatives (January 11, 2002)

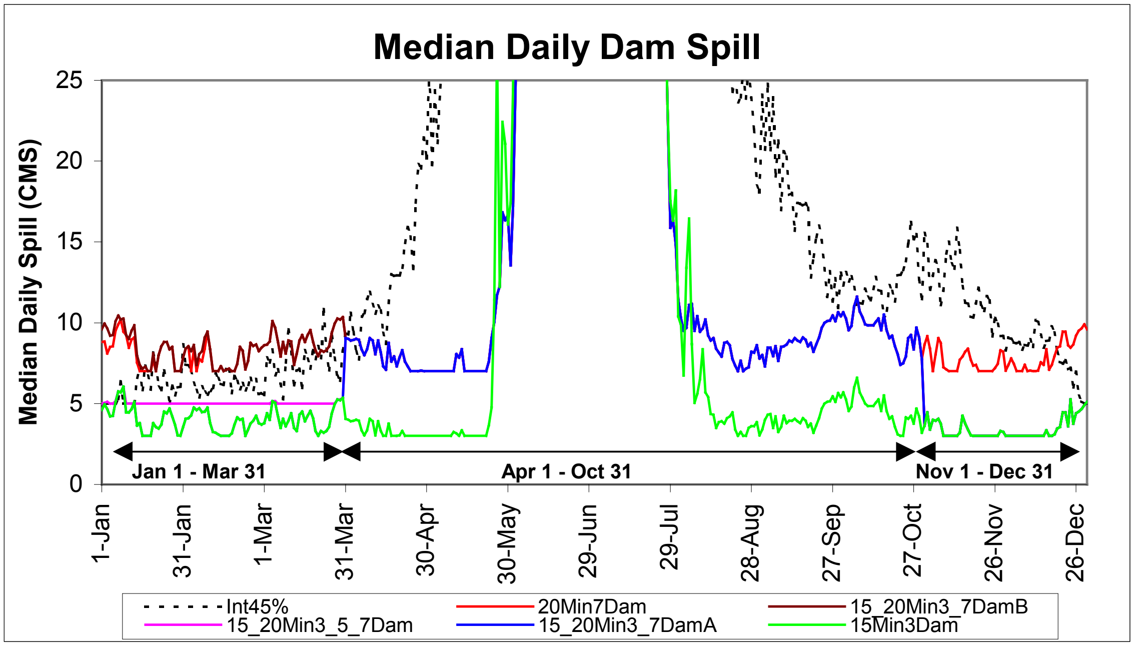

Figure A6.1: Median daily dam spill (cms) for the preferred alternatives at the final evaluation meeting (January 11th 2002).

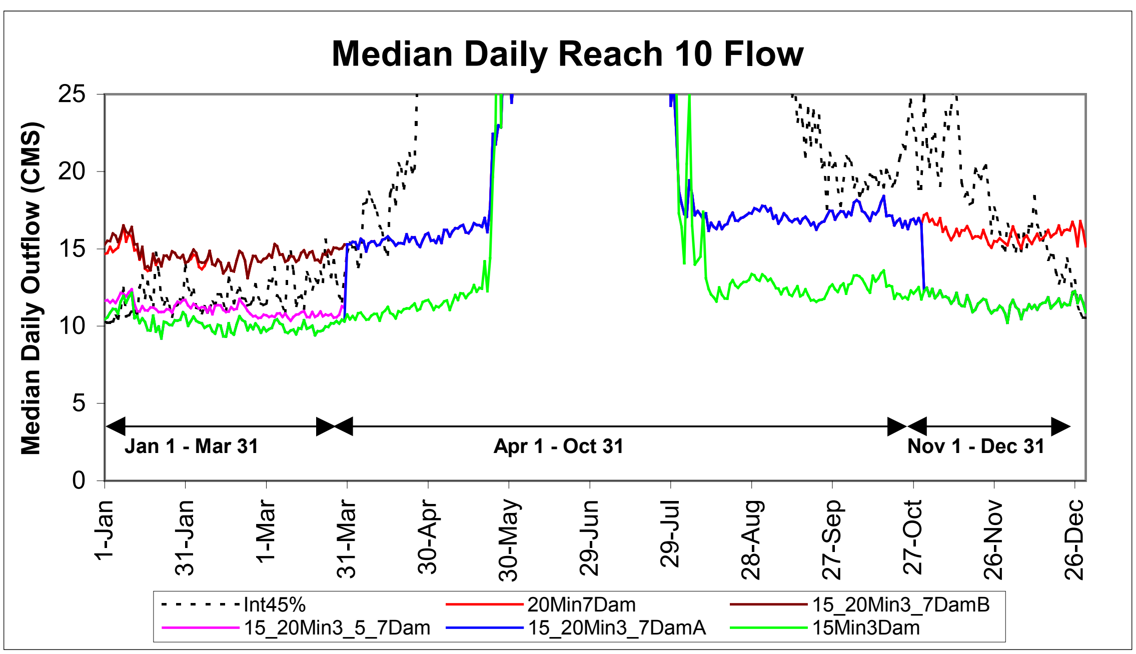

Figure A6.2: Median daily flow (cms) in Reach 10 (resident fish) for the preferred alternatives at the final evaluation meeting (January 11th 2002).

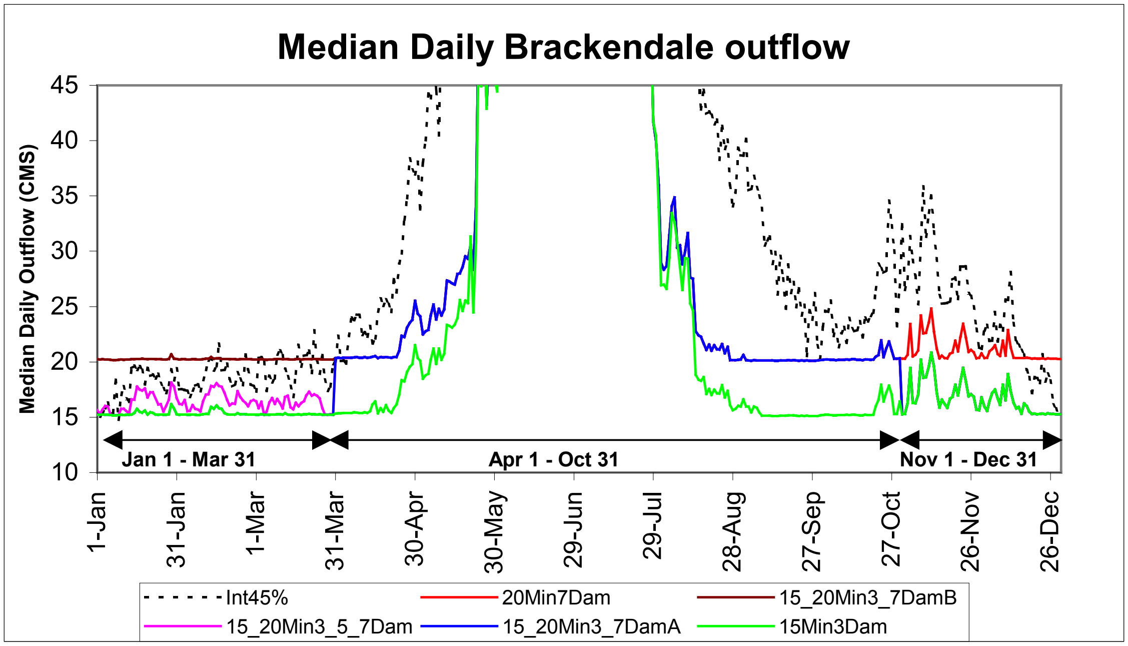

Figure A6.3: Median Brackendale outflow (cms) for the preferred alternatives at the final evaluation meeting (January 11th 2002). Note that the y-axis scale starts at 10 cms, not 0 cms as for Figures A6.1 and A6.2.

Figures A6.1, A6.2 and A6.3 show the median daily average flow at the dam, in Reach 10 and at the Brackendale gauge (Reach 3) respectively for the preferred alternatives from final evaluation meeting (January 11th 2002). The median daily flow is the flow that 50% of the flows are above and 50% are below for a particular day. The daily medians are calculated using the 32 years of AMPL output (1967-1998) for each alternative. The arrowhead lines below the median-flow curves show the periods used for defining hybrid alternatives (discussed below). Int45% represents the status quo Interim Flow Agreement, it was preferred by about half the CC on January 11th although the CC previously dropped it at the July 3rd/4th 2001 evaluation meeting. 15Min3Dam was preferred by one CC member, although it was not one of the two most preferred or acceptable alternatives from the penultimate evaluation meeting (October 24th 2001). The other four alternatives include the two most preferred alternatives from the penultimate meeting, the 15_20Min3_7DamA hybrid and the 20Min7Dam alternative, and two variations on these, the 15_20Min3_5_7Dam and 15_20Min3_7DamB hybrids. The hybrid alternatives were developed to address the trade-off between chum effective spawning area and rainbow trout parr rearing area and the concerns of some CC members about the potential impact of low winter flows on the quality of side channel habitat. The main text describes these issues in detail. Table A6.1 summarises the components of each alternative and the period of the year over which each of their components operates.

Table A6.1: Periodicity of the preferred alternatives' components. This table shows the components of the preferred alternatives and the period of the year over which they are implemented for modelling.

Alternative	**Period of year over which component operates**		
	Jan. 1 to Mar. 31	**Apr 1 to Oct. 31**	**Nov. 1 to Dec. 31**
15Min3Dam	15Min3Dam	15Min3Dam	15Min3Dam
15_20Min3_7DamA	15Min3Dam	20Min7Dam	15Min3Dam
15_20Min3_5_7Dam	15Min5Dam	20Min7Dam	15Min3Dam
15_20Min3_5DamB	20Min7Dam	20Min7Dam	15Min3Dam
20Min7Dam	20Min7Dam	20Min7Dam	20Min7Dam
Int45%	45% previous 7 days inflow, or a dam minimum release of 5 cms.		

Note that as Table A6.1 one indicates, the components for some alternatives are identical during some periods and their lines will overly one another in Figures A6.1 to A6.3. Thus, during the January 1 to March 31 period, only four lines are visible: Int45%, 15Min3Dam, 15Min5Dam and 20Min7Dam. During the April 1 to October 31 and the November 1 to December 31 periods, only three lines are visible: Int45%, 15Min3Dam and 20Min7Dam.

Figure A6.1 shows the differences between the six alternatives in terms of their minimum dam release components. Figure A6.2 shows the implication of the dam release constraint on flows in reach 10. The order of the lines is the same as in Figure A6.1, but the median flows are higher and less variable (except the 5 dam minimum during January 1 to March 31). This is due to the tributary inflows between the dam and Reach 10. Figure A6.3 shows the differences between the alternatives relative to their minimum Brackendale flow components. Again, the median flows are higher due to tributary inflows (not that the scale of the y-axis scale does not starts at zero as in Figures A6.1 and A6.2).

Note that under Int45% the "shoulders" of the freshet are broader than for the other alternatives and there is also more day-to-day variation in flow. Int45% also shows a larger range in flow over the year than the other alternatives ranging from less than the 20Min7Dam alternative from late-December to mid-March period, to flow greater than the other five alternatives from mid-March to late-December.

Appendix 7:
Final Meeting Supplementary Notes (January 11th 2002)

Appendix 7-A: Summary of Preferences at the Final Meeting

Appendix 7-B: Position of North Vancouver Outdoor School (distributed January 9, 2002)

Appendix 7-C: Maps of North Vancouver Outdoor School Side Channels

Appendix 7-A: Summary of Preferences at the Final Meeting

Table A7.1: Detailed summary of Ratings for Operating Alternatives January 11th, 2002. Alternative: A. Hybrid, B. Revised Hybrid "B", C. Revised Hybrid "C", D. 20Min7Dam. Preference: 1. Preferred, 2. More Acceptable, 3. Less Acceptable, 4. Not Part of Consensus if selected. The information in this table comes from rating sheets and/or written statements and submissions. Additional information comes from notes taken during the discussion after preference rating where CC members discussed their preferences.

Name of Participant	Alternative	Preference	Comments
Ross Neuman *WLAP*	A	*2/4	
	B	*2/4	
	C	*2/4	
	D	*2/4	
	Other		*My preferred alternative is an active adaptive management approach where **IFA** is monitored for 5 years followed by a switch to 15/3 which is also monitored for 5 years. I am prepared to accept any of these alternatives provided they are paired with an initial 5-year monitoring of the IFA. I will block any of these alternatives if presented without an initial 5-year monitoring of the IFA.
Denise Mullen-Dalmer *MEM*	A	2	See comments from Oct. Fair distribution of benefits across interests, but concerned about value for money
	B	2	Could be okay but what do we get for $300 K less VOE and will this satisfy the side channel concerns – rainbow trout issues.
	C	3	Not sure the decrease in the VOE is acceptable given reliability concerns – it is not the absolute value of the difference as much as the potential risks if the constraints are strict
	D	4	
	Other		
Rationale: (transcribed from hand written notes submitted with ratings) At this point, I feel as if the process and study results have been undermined – we are now negotiating positions. If, to date, we have accurately expressed and conveyed our values then logically the conclusion is that the current remaining 4 alternatives are representative of what may be possible and yields net benefits – if we have not expressed our values based on the information presented then the process has been undermined. In my view there has been no information presented since the elimination of the IFA as an alternative that provides evidence that it should come back on the table. However, assuming the process has given us good information both in science and values, and acknowledging uncertainty, then my choices are as stated above. In Alternatives C and D, I have issues around value for money. Fundamentally I have a problem with allowing people who have not participated in previous rounds of alternative "elimination" to participate in the final round of alternative refinement /voting/ elimination.			
Jas Michalski *District of Squamish*	A	2	
	B	2	
	C	2	
	D	2	
	Other		

<table>
<tr><th>Name of Participant</th><th>Alternative</th><th>Preference</th><th>Comments</th></tr>
<tr><td colspan="4">Rationale:

As the District of Squamish concerns regarding flooding are met in all alternatives, I am comfortable supporting any of the proposed alternatives. In particular, I support the results of the FTC work (i.e., Alternative “A”) although I caution that monitoring is critical to the long-term success and acceptance of any WUP for the Cheakamus.</td></tr>
<tr><td rowspan="5">Dave Brown
Whistler Angling Club
(submitted by Lyle Fenton)</td><td>A</td><td></td><td></td></tr>
<tr><td>B</td><td></td><td></td></tr>
<tr><td>C</td><td></td><td></td></tr>
<tr><td>D</td><td>3</td><td>See statement below</td></tr>
<tr><td>Other</td><td>1</td><td>IFA. See statement below.</td></tr>
<tr><td colspan="4">Rationale:

(transcribed from e-mail printout submitted by Lyle Fenton at Jan 11th meeting)

“I am writing you this e-mail so that you can act on my behalf at the meeting on Friday with regards to the Water Use Plan. I unable to attend the meeting at it is during the day and I cannot get the time off work. I represent the Whistler Angling Club and its 80 members at these meetings and have been given one of the seats on the committee for the sportfish community. I have been participating in the process from the very beginning and although I was not able to attend all meetings I have followed it closely by the minutes and conversations with other CC members.

To give you a bit of background on my knowledge of the Cheakamus I have fished it from Rubble Creek to the Canyon on the upper river below the dam and Butterfly Creek to the mouth in the lower stretch. I spend about 80 days a year on the river either walking it or floating it in a pontoon boat or raft. I was actively involved in the radio tagging program that was done for both Steelhead and Chinook. I also hold a seat on Sport Fish Advisory Committee. During the last ten years I have spent a great deal of time on the river. I have made many observations and drawn the following conclusions.

The river is [a lot] better off with the current IFA that it was previous to that. The Cheakamus starts to look like a real river. The fish have room to move around. As evidenced by this year’s Pink, Chinook, and Coho runs. The side channels have water increasing the amount of usable rearing and spawning habitat. Tenderfoot Hatchery has a record number of Coho returning to the creek this year with over 6000 adults the most ever. Many of the side channels are full of fish. These side channels play an important role. Without water in them we can lose as many as 15000 to 20000 Coho Salmon smolts. As evidenced by monitoring of fry escapement from these channels. We see more gravel recruitment. With the increased flows the fish don’t tend to concentrate in just the deeper pools and they’re spread [throughout] the river. This reduces exposure to both natural and man-made predators. These [flows] also provide more recreational opportunities for anglers, kayakers and rafters. This also benefits predators like Eagles, Otters, and Bears. The higher flows help fertilise the river [a lot] more by spreading the salmon carcasses out.

My choice would be to maintain the current IFA or go with 20-10 dam or 20-7 dam at the minimum. Please carry my vote forward.” (ratings submitted by Lyle Fenton)</td></tr>
<tr><td rowspan="5">John Werring
SLDF</td><td>A</td><td>4</td><td rowspan="2">In the absence of scientific certainty as to the impacts of lower flows during the winter months, (critical incubation / rearing periods). I would prefer that the precautionary principle prevails and we opt for higher water base flows which can possibly be reduced in time if monitoring indicates that a revision of hydro operations may be a viable option. I feel that if we start with lower base flows and monitoring indicates that more (greater) water releases may be warranted, it would be more difficult to have more water released than more water held back.</td></tr>
<tr><td>B</td><td>4</td></tr>
<tr><td>C</td><td>3</td><td></td></tr>
<tr><td>D</td><td>1</td><td>I continue to support higher recreation values – sport fishing / kayaking – in addition to increased fish production.</td></tr>
<tr><td>Other</td><td></td><td></td></tr>
</table>

Name of Participant	Alternative	Preference	Comments

Rationale:

On implementation, I would support keeping the IFA for another 3 years minimum (with monitoring) then, following a review of the monitoring data possibly implement 20Min7Dam for at least 5 years and monitor.

With IFA have large variation in flows, useful for exploring impacts of flow in off channel habitat, better than under a more "consistent" level of flow (that is less variable).

Start monitoring using the more comprehensive plan developed as part of this WUP rather than the basic one currently in place.

Name of Participant	Alternative	Preference	Comments
Carl Halvorson *NVOS*	A	4	
	B	4	
	C	4	
	D	3	
	Other	1	**IFA.** See rationale

Rationale:

(transcribed from typed statement submitted at the Jan. 11th meeting)

The goal of the Cheakamus WUP is to come to a consensus position that reflects the needs and desires of both BC Hydro and the community. Our Fish Technical Committee has done a lot of work at the request of the Cheakamus Water Use Planning Committee and has identified many things that we do not know.

We do not know the effects a change in flow regime will have on groundwater issues. We do not know if there will be adverse effects on groundwater levels, water chemistry, oxygenation or those changes on ecological function.

We do not know the connection between groundwater flows and fish production in off channel or main stem habitats.

We do not know the impact of changes in flow regime on hyporheic flows even the true importance of these flows in biological functions.

We do not know the impact of flow changes in river fed off channel rearing and spawning habitats. We don't even know the value of these habitats. They have been dismissed from consideration during this WUP.

We do not know the accuracy of our river modelling that drives most of our performance measures. There have been suggestions put forward that cast significant doubt whether the models can provide predictions that are useful for realistic evaluations.

We have been offered a comprehensive list of monitoring plans that might answer these questions and in time provide a base of information that could be used to make reasoned flow regime choices.

Under the current IFA we have had one of the finest salmonid returns in a long while. Pink salmon that had been dismissed as extinct in the system and unworthy of consideration entered the Cheakamus in good numbers and utilised both main stem and off channel habitats. We had a strong run of chinook, again utilising both main stem and off channel habitats. We have had an amazing run of coho utilising the full range of habitat. Chum runs have remained as strong as they have for years, making good use of off channel habitats.

We have had an incredible return in the Cheakamus under the IFA and with this in mind, I would suggest as a consensus position, that we continue the IFA for a period of 5 years, and establish an understanding of the aforementioned questions before making any decision to change flow regimes. This will provide the groundwork necessary for legitimate changes without endangering the conditions that DFO negotiated in good faith and appear to have benefited (at least the salmonid population) the Cheakamus River system.

The models have shown that BC Hydro can look forward to revenues of $26.9 million per year (in a median year). It is possible that the IFA can be optimised to increase these revenues by building some flexibility into the 45% rule, by allowing diversion of any flows through the turbine that are in excess of those required to maintain at least 60 cms at Brackendale. That is, as long as there is at least 60 cms flow measured at the Brackendale gauge, only an additional minimum flow would be required through the dam. Minimum year round flows at the dam should be increased to a minimum of 7 cms. This increase in flow reflects the broadly held view that flows need to be increased in the upper reaches of the river for resident fish populations.

Name of Participant	Alternative	Preference	Comments
Lyle Fenton *Cheakamus Residents*	A	4	Not enough flow for side channels and floodplain. Not likely to permit increase in flow later, so need to get highest flow possible now. Needs to be more consideration of natural river (ecosystem) I have made numerous points during meetings.
	B	4	
	C	4	
	D		Abstained from voting on this alternative
	Other	1	**IFA.** Need more time to monitor effects before final flow is decided
Rationale: Will submit written comments for report. "I fully recognise that I was part of the decision to drop the IFA initially, but I am changing my view now"			
Jim Schellenberg *CCG-DFO-NWPD*	A	3	
	B	3	
	C	3	
	D	2	The NWPD is looking for the most days available for recreational usage (i.e., kayakers).
	Other		
Rationale: Jim Schellenberg originally felt he should abstain because of his lack of involvement in the process, but John Werring asked that the Coast Guard go on the record.			
Dave Cattanach *BC Hydro*	A	1	Closest to supporting science, minimum risk of non-compliance and best VOE of the current 4 alternatives
	B	2	Some sacrifice in VOE over "A"
	C	3	Hidden costs associated with avoiding non-compliances for minimum flow in dry years
	D	4	Does not support the science, has significantly lower VOE and has hidden costs associated with avoiding potential non-compliances in the low water years.
	Other		
Rationale: Process perspective – CC decided fish important and formed the FTC. The FTC did good work and came up with conclusions contrary to previously held beliefs. I have observed the CC slipping into positions: accept science and process vs. not accept science, arguing from a position point of view. I believe in the process and the FTC. Order of preferences indicates strength of link to the science. I am a strong advocate of the monitoring plan to determine what the uncertainties are and move forward. {Lyle Fenton asked if the Facilitator considered it okay that side channels were left out. Dave Cattanach replied that the CC had spent the whole morning discussing that topic and had gone through a decision analyses diagram to explore ways to deal with uncertainty about side channels.}			
Randall W. Lewis *Squamish Nation, Elders, Chief & Council / Squamish Nation Membership*	A		No rating submitted
	B		
	C		
	D		
	Other	1	IFA (see statement below)

Name of Participant	Alternative	Preference	Comments
Rationale:			

Randall began by saying that he appreciated the work of the FTC. It had opened his eyes. He then went on to say that he had presented the WUP process to the Squamish Nation Council and that had not been easy as it had been a long process. He submitted the following written statement:

(transcribed from hand-written statement submitted at Jan. 11th meeting)

"To B.C. Water Act. Att: The Comptroller of Water Rights (the "Comptroller"). Evaluation of Alternative – Jan 11th 02 Cheakamus CC meeting.

I, representing the Squamish Nation, Elders, Chief & Council and the Squamish Nation Membership have been mandated to protect the ecological ecosystem of this Cheakamus Watershed with a perspective of traditional knowledge.

Subject to Section 35 of the Constitution of Canada, Delegamuukw, Supreme Court Cases, and in accordance with the International Convention of Biological Diversity, "in-situ".

Squamish Nation Aboriginal Rights & Title are alienated in this area of our territory when BC Lands & Assets Corp., when this other creature of the Crown is giving permits and tenure in this watershed that infringes on critical aboriginal rights.

The Dominion of the day the Provincial Government and BC Water Act and Comptroller of Water Rights (the "Comptroller") and other Respective Provincial Ministries such as: BC Lands and Assets Corporation are alienating Crown land through permit, tenures which infringe on aboriginal rights and title.

Please refer to The Water Use Plan Guidelines page 13, Important legal context, 3.4, Constitutionally protected treaty rights and aboriginal rights and title.

When the Squamish Nation looks at past representation in the documentation it is identified:

Protect integrity of Squamish First Nation (How?!) heritage sites and cultural values

Partly considered by Flood PMs, will be addressed – if necessary?! (**Not acceptable**)

The kayaking, sportfishing and other user groups have certainty of days of access on our historic river that we thrived off of for thousands of years!

The Squamish Nation has total uncertainty documented in this WUP process "**if necessary**". We will not sacrifice our aboriginal rights for trade-offs will impact on fishery constitutionally protected rights.

It is critical for this process to work with Squamish to develop and implement our Declaration of Intellectual Property Rights which include spiritual, culture, customs, and heritage. Subject to the binding commitments in the WUP Guidelines, page 13, 3.4, there is a fiduciary obligation to implement a Squamish Nation Declaration on Intellectual Property Rights.

The Squamish Nation has major concerns since the dam and diversion has been implemented (1957). The Squamish Nation has witnessed the prosperity of BC Hydro at the expense of fishery, fishery habitat, water quantity, water quality and ground water within the water shed. (The past water licence has over exceeded water volumes over the past 38 years).

Page 5 of Background Materials to Cheakamus CC Meeting, January 11th, 2002 states:

> "The CC has used all of this information to filter the alternatives and get to this point. **This is all the information the CC has to make a decision on their recommended operating alternative.** Remaining uncertainties exist, because even with all this effort our understanding is incomplete. This is commonly the case for environmental issues – information is always incomplete. The CC needs to make decisions under uncertainty with the information it now has, using adaptive management and monitoring to ensure that these decisions are re-evaluated over time and if necessary revised."

This uncertainty, incompleteness of what this process understands today makes it clear to stand with the existing Interim Flow Agreement. We need to understand the whole watershed and we have always maintained this position.

With the above mentioned in mind, we need to understand the whole water shed for positive / negative impacts on the Cheakamus Watershed.

Page 2, 3rd paragraph of the Draft Cheakamus WUP Monitoring Plan, must read:

> "Ecosystem and channel conditions could change in the future due to hydro operations, or due to other natural or human factors (e.g., floods, droughts, forestry, dykes). Without monitoring **["watershed approach"]** ecosystem components, it will be difficult to correctly diagnose the reasons for future changes in fish populations, and to make the right decisions about future changes to hydro operations."

At this point and time, the Squamish Nation strongly recommends to continue on with the Interim Flow Agreement until we have had an opportunity to assess, evaluate and monitor the Interim Flow Agreement that has been in place for the last 4 years. Along with our preferred alternative of IFA, it's essential to implement the Draft

Name of Participant	Alternative	Preference	Comments
Edith Tobe *SRWS – local environmental groups*	A	4	
	B	4	
	C	4	
	D	2	
	Other	1	IFA "would like to see 5-10 years further study to answer questions. That is, the IFA seems to be working, so why not continue to study it?"
Rationale: I do not feel confident in making a decision on any of these 4 scenarios based on the knowledge and science accumulated to date. I do feel the 20/7 scenario to be the most acceptable of the options given but is it better for the system than the existing IFA? This year we have unusually good salmon returns (pink, coho, chinook **and** chum) so why would we want to change this if we are basing our decisions on salmon returns. I would like 5 (or 10) more years of study and then see what the trends are so that we can know if a new scenario is more favourable or not and not just second guess. Also, I like the fact that IFA follows a natural hydrograph to some extent. Implementation of alternatives could also apply to the implementation of the monitoring plan for current conditions. I feel "pigeon holed" and want to re-evaluate, but dismiss all we've learned, just to look back and reassess. I don't feel it's inappropriate to look at the IFA again. If we can't, I don't feel comfortable with this committee. I disagree with Denise and want to be able to reassess. Now, under the IFA and taking this year's conditions into account and the gaps in our knowledge, the system seems to be functioning at present. I want to know more about how the system functions. I don't feel I have enough information now to make a decision. If I'm pushed, I would put 4 for A, B, and C; I am more comfortable with 20/7, I find it more acceptable. BUT my preferred alternative is the IFA. I think it should be monitored for another 5 years. When I originally dismissed the IFA, it seemed similar to other alternatives, although it fits the natural hydrograph better.			
Doug McDonald *SLRD*	A	3	
	B	3	
	C	2	
	D	1	
	Other		
Rationale: Still feel that higher initial flows should be put in place and at some time make it clear that flows may be reduced if Hydro does certain works (i.e., gravel from Roe Creek put back to main stem, reservoir debris back into main stem, civil works to improve or increase lower river habitat, placing dead spawners to attract eagles for better viewing, etc., artificial feeding). Monitoring results should determine what eventual minimum flow should be. In past dam constructors not required to ameliorate downstream results of construction as part of capital cost (initial). Any flow regime must give Hydro chance to pond higher flows.			
Ken Spafford *BC Hydro*	A	2	Question as to whether $1.3 million cost buys fish value relative to 15Min3Dam
	B	3	$300 K VOE cost is not justified by any improvements in fish PM's
	C	4	$1.3 million VOE cost does not buy any improvement in PM's, in fact conditions are slightly worse
	D	4	$2.0 million VOE cost buys a significant reduction in PM
	Other	1	15Min3Dam

<table>
<tr><th>Name of Participant</th><th>Alternative</th><th>Preference</th><th>Comments</th></tr>
<tr><td colspan="4">Rationale:
All comments are based primarily on VOE and Chum spawning PMs. Recreational PMs discounted due to lack of granularity. Preferred alternative is 15Min3Dam, acceptability of hybrid is to achieve consensus and small improvement in resident fish PM. Uncertainty of groundwater impacts should be addressed in monitoring program.</td></tr>
<tr><td rowspan="5">Steve Macfarlane
DFO</td><td>A</td><td>2</td><td>• Preferred option last meeting.
• Optimise mainstem spawning – chum
• Believe it will augment off channel over historic operations</td></tr>
<tr><td>B</td><td>1</td><td>• Provides increased flows in general without impacting chum spawning habitat
• Moderate power costs</td></tr>
<tr><td>C</td><td>3</td><td>• Moderate reduction in chum eff. sp. but to reach consensus this is acceptable.</td></tr>
<tr><td>D</td><td>4</td><td>• Significant impact on chum with little benefit for other interests including side channel flow
• Not based on PM’s</td></tr>
<tr><td>Other</td><td></td><td></td></tr>
<tr><td colspan="4">Rationale:
Acceptance of “A”, “B”, “C” implies that flow changes could be ramped over a period of time (e.g., 2 weeks)</td></tr>
<tr><td rowspan="5">Rob Way
ORC</td><td>A</td><td>4</td><td rowspan="2">Information implies 15Min3Dam may not be enough for fish during Jan-Mar. in the river system, not just the main channel</td></tr>
<tr><td>B</td><td>4</td></tr>
<tr><td>C</td><td>3</td><td rowspan="2">more water available to side channels</td></tr>
<tr><td>D</td><td>2</td></tr>
<tr><td>Other</td><td></td><td>IFA</td></tr>
<tr><td colspan="4">Rationale:
Any WUP = subject to monitoring and revision on ongoing basis, with aim of improving viability of river.
Re Alternatives: all subject to – continue IFA, but monitor for 3-5 years and reassess then.
I used to feel that a 15Min5Dam type of alternative would be okay. Now, after seeing the uncertainty, talking to biologists, and talking to others, I have changed my mind. The Outdoor Recreation Council takes an overall Cheakamus valley/holistic point of view and if the fish are happy that’s good for the valley’s recreational values. I’m leery of A and B if they are based only on the chum PM. What about other fish? Pinks appear to be thriving this year. It seems the existing flows are working. {Steve Macfarlane pointed out that the high return of Pink salmon to the Cheakamus was due to cut backs on fishing and that there were lots of pinks in other systems too.} I feel that we should use the IFA as a base for monitoring because any decision needs to be assessed over at least 3-5 years; the current river and fish conditions may only be a glitch. I feel that large flows will bring lots of water into traditional parts of the river and allow more water in other areas. We want to try to get back to more natural conditions. I am not as convinced now of the science as I was. Other biologists and people who use the river have opinions different from the FTC.
{Steve Macfarlane noted that coho, chum, and steelhead were not ignored by the FTC or the PMs, but under all flow scenarios, there was lots of habitat available.}</td></tr>
</table>

Name of Participant	Alternative	Preference	Comments
W.R. Dickinson Squamish Residents	A	3	
	B	3	
	C	3	
	D	1	
	Other	IFA	See comments below
Rationale: I would prefer for the IFA to continue for 3 or 4 more years, but if this is not possible, my preference is as above. I want the IFA for longer, it's good to have more water in the river for a lot of reasons. I don't want to be part of consensus, we're splitting hairs, Hydro is being sold off anyway and we live with whatever is accepted. I want more water down the Cheakamus river so less is diverted to the Squamish River. I think there is lots we have not considered with respect to the "big picture"; the wrong stuff is going into the computer models. For example, what about pollution in the Squamish River coming in with the diverted Cheakamus water? As more is water diverted into the Squamish River, more pollution is brought in and it also gets into the water table. What will be the impact of the Whistler Olympics? Less water to Squamish means less pollution for the Squamish Valley. {John Werring noted that with respect to sewage from Whistler, more water diverted to the Squamish River means more pollution in Bill's area of the river, since the Cheakamus flows into the Squamish downstream of that area.}			

Table A7.2: Summary of Consultative Committee ratings for the effect of monitoring component results on future decisions and relative importance of component for monitoring plan. Only those CC members attending the January 11th meeting contributed ratings. In the column under each component, the left cell shows the rating for likelihood and the right cell shows the rating for importance. H = high; M = medium; L = low. MC1 = Refine Statistical Methodology. MC2a = Do operations affect salmonid spawner abundance and smolt output? MC2b = How do operations affect rainbow trout habitat? MC2c = Do operations affect juvenile stranding below Squamish powerhouse? MC3 = What is the link between mainstem flows and groundwater in side channels at flows less than 20 cms at Brackendale? MC4 = Are Benthos/Periphyton/Nutrients affected by dam operations? MC5 = Is channel morphology affected by dam operation?

	Statistical Methods MC1	**Salmon MC2a**		**Trout MC2b**		**Squamish stranding MC2c**		**Ground water MC3**		**Benthos MC4**		**Channel Morph. MC5**		
CC Member	**Importance**	**Likelihood**	**Importance**	**Likelihood**	**Importance**	**Likelihood**	**Importance**	**Likelihood**	**Importance**	**Likelihood**	**Importance**	**Likelihood**	**Importance**	**Comments**
Dave Cattanach *BC Hydro*	H	H	H	M	M	L	M	H	H	L	M	L	L	MC4-Importance: agree to every 2nd year
W.R. Dickinson *Squamish Residents*	H	H	H	H	H	H	H	H	M	H	H	M	M	
Lyle Fenton *Cheakamus Residents*	H	H	H	H	H	H	H	?	H	M	M			? ambiguous, sheet has an M superimposed over an H, or vice versa.
Carl Halvorson *NVOS*	H	H	H	H	H	H	H	H	H	L	L	H	H	MC3-both: highest MC5-Likelihood: include proposed changes to improve main stem conditions (e.g., Robert Newberry's suggestion for groins, etc.) [this is really a recommendation] Add new Monitoring Component: Chemical analysis. change in pollutant loads – Importance = H?. important to have base information and a good forum to get it?
Randall W. Lewis *Squamish Nation*	H	H	H	H	H	H	H	H	H	H	H	H	H	
Steve Macfarlane *DFO*	H	H	H	H	M	M	M	H	H	L	L	M	M	
Doug McDonald *SLRD*	H	H	H	M	M	H	H	H	H	M	M	H	H	

CC Member	Statistical Methods MC1	Salmon MC2a		Trout MC2b		Squamish stranding MC2c		Ground water MC3		Benthos MC4		Channel Morph. MC5		Comments
	Importance	Likelihood	Importance	Likelihood	Importance	Likelihood	Importance	Likelihood	Importance	Likelihood	Importance	Likelihood	Importance	
Jas Michalski *Municipality of Squamish*	H	H	H	H	H	M	M	H	H	H	H	H	M	MC4-Importance = H!!
Denise Mullen-Dalmer *MEM*	H	H	H	M	M	L	L	M	M	L	L	L	L	
Ross Neuman *WLAP*	H	H	H	H	H	L	L	H	H	M	H	H	H	
Jim Schellenberg *Coast Guard*														Did not fill out form as didn't feel qualified or informed enough to be able to fill it out
Ken Spafford *BC Hydro*	H	H	H	M	M	M	H	H	H	L	L	L	L	
Edith Tobe *SWRS*	H	H	H	H	H	H	H	H	H	H	H	H	H	
Rob Way *ORC*	H		H		H		H		H		H		H	
John Werring *SLDF*	H	H	H	H	H	M	M	H	H	L	L	M	M	
Summary of Ratings														
High	14	13	14	9	9	6	8	11	12	4	6	6	6	
Medium				4	5	4	4	1	2	3	3	3	4	
Low						3	2			6	5	3	3	
No rating recorded		1		1		1		1		1		2	2	
Abstained	1	1	1	1	1	1	1	1	1	1	1	1	1	
Ambiguous rating								1						

Table A7.3: Summary of ratings for possible CC recommendations falling within the scope of the WUP. A = approve; I = indifferent; D = disapprove.

CC Member	Recommendation		Comment
	1	2	
Dave Cattanach *BC Hydro*	A	A	**Rec. 1:** Should be part of WUP!! Relates directly to operations. Would want to discuss whether 2-weeks is too long. **Rec. 2:** need to decide on a water management strategy.
W.R. Dickinson *Squamish Residents*	A	A	
Lyle Fenton *Cheakamus Residents*	A	A	
Carl Halvorson *NVOS*			No rating submitted
Randall W. Lewis *Squamish Nation*	A	A	**Rec. 1:** Ramping down changes to flow
Steve Macfarlane *DFO*	A	A	**Rec. 2:** Hydro to contact agencies when this becomes apparent.
Doug McDonald *SLRD*	A	A	
Jas Michalski *M. of Squamish*	A	A	
Denise Mullen-Dalmer *MEM*	A	A	**Rec. 2:** BC Hydro would have notification procedure.
Ross Neuman *WLAP*	A	A	**Rec. 1:** shorter period probably okay
Jim Schellenberg *Coast Guard*	A	A	**Rec. 2:** BC Hydro to contact agencies
Ken Spafford *BC Hydro*	A	A	**Rec. 2:** requires re-wording
Edith Tobe *SWRS*	A	A	
Rob Way *ORC*	A	A	**Rec. 2:** Add at end of last sentence: "and before Hydro's allocation"
John Werring *SLRD*	D	A	**Rec. 1:** Recommend no decrease in flow. Maintain 20Min7Day all year.
Summary of Ratings			
Approve	13	14	
Indifferent	0	0	
Disapprove	1	0	
No rating recorded	0	0	
No rating submitted	1	1	
Total	***15***	***15***	

Table A7.4: Summary of ratings for possible CC recommendations that fall outside the scope of the WUP. Ratings provided by CC members attending the January 11th meeting. A = approve; I = indifferent; D = disapprove.

	Recommendation								
CC Member	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Comment**
Dave Cattanach *BC Hydro*	A	I	A	A	A	I	I	I	**Rec. 1:** very close to January 11th Agenda package decision tree re: relationship between main stem flows and groundwater in channel. **Rec. 4:** Include gravel from Roe Creek. **Rec. 5:** There is a liability issue associated with log jam-induced flooding. In order for this to be acceptable to BCH, we would have to be directed to do this by the Water Comptroller. **Rec. 6 & 7:** I would rather not see these things happen but not strong enough to say "D".
W.R. Dickinson *Squamish Residents*	A	A	A	I	A	A	A	A	**Rec. 1:** "A" rating for both parts.
Lyle Fenton *Cheakamus Residents*	A	A	A	A	A	A	A	A	**Rec. 3:** Recognising the watershed has a carrying capacity use integrated approach. **Rec. 6:** Give it a "AA" rating. **General:** All parties, governments, etc. engage in watershed management rather than piecemeal development and its effects. *Recognising the watershed has a carrying capacity and agreeing not to manage the watershed to death.* Must not exceed carrying capacity.
Carl Halvorson *NVOS*									No rating submitted
Randall W. Lewis *Squamish Nation*	A	A	A	A	A	A	A	A	**Rec. 2:** Replace first sentence of the "Concern" statement with: Potential for using water from the power house to maintain water from Pilchuk channels to east side of upper Squamish River road historic channels that have been cut off by the road.
Steve Macfarlane *DFO*	A	A	A	A	D	A	A	A	**Rec. 4:** Subject to results of hydrology / morphology study. **Rec. 5:** Only following determination of appropriate flows – then I would support.

CC Member	Recommendation 1	2	3	4	5	6	7	8	Comment
Doug McDonald *SLRD*	A	A	A	A	A	A	I	A	**Rec. 3:** If Hydro took lead (and spent money) here they might divert more water to power. **Rec. 4:** There is no sediment lost from Rubble Creek. **Rec. 5:** Assuming it is a benefit. Could be done right at dam from debris they remove from reservoir. **Rec. 6:** Add under "Concern": Placing of rock in main stem to raise river bed to historic levels (groundwater).
Jas Michalski *Municipality of Squamish*	A	A	A	A	A	A	A	A	**Rec. 6:** Gave an "A!!" rating.
Denise Mullen-Dalmer *MEM*	I	I	A	A	I	I	I	A	**Rec. 4:** "A" but only if it doesn't negatively affect monitoring. **Rec. 5 & 6:** Confounding concerns.
Ross Neuman *WLAP*	A	?	A	A	D	A	A	A	**Rec. 2:** Not WUP – uncertain as to value. **Rec. 5:** Could confound monitoring. Should not be done until after monitoring program.
Jim Schellenberg *Coast Guard*	A	A	A	A	A	A	A	A	**Rec. 1:** "A" rating for both parts.
Ken Spafford *BC Hydro*	D	I	A		A				**Rec. 1:** Partially addressed in monitoring program and in selection of operating alternative. **Rec. 4:** Potential approval, depends on what may be allowed. **Rec. 5, 6, & 7:** No opinion
Edith Tobe *SWRS*	A	A	A		A	A	A	A	**Rec. 4:** Do not feel well enough informed to make a decision.
Rob Way *ORC*	A	A	A	A	A	A	A	A	**Rec. 4:** Or any other sources if being removed artificially.
John Werring *SLDF*	A	A	A	A	I	A	A	A	**Rec. 1:** Not beyond scope of WUP!
Summary of Ratings									
Approve	12	10	14	11	10	11	10	12	
Indifferent	1	3	0	1	2	2	3	1	
Disapprove	1	0	0	0	2	0	0	0	
No rating recorded	0	1	0	2	0	1	1	1	
No rating submitted	1	1	1	1	1	1	1	1	
Total	***15***	***15***	***15***	***15***	***15***	***15***	***15***	***15***	

Appendix 7-B: Position of North Vancouver Outdoor School (distributed January 9, 2002)

Submitted by Carl Halvorson, Consultative Committee Member representing North Vancouver Outdoor School January 9, 2002

I have been grappling with what amounts to the justification of my obstinance regarding flow scenarios in the Cheakamus. I believe we should send every spare drop of water down this system. I couldn't really find a way to explain it until very recently.

Every day I walk the Far Point system at North Vancouver Outdoor School. This year has been particularly rewarding for me with the abundant salmonid returns we have observed. In low flow situations Far Point is a rather placid place. It is kinda like "Mayberry" where life goes on but nothing really exciting happens. When we get high, elevated flows the place comes to life. Then it's really "downtown"! Instead of consistent, flatish water, there are ripples and swells and back eddies and pools. The water table rises and other "off-stream" areas re-wet and teem with activity. Fresh, beautiful spawners stream into the habitat. Dippers are bogyin' everywhere. Several days later, the flows have maybe dropped. The fish aren't active anymore. The water levels have dropped and areas that fish were spawning in are now too shallow. Spawners are hiding in deep holes, waiting. The "new" fish that do come up are "ratty looking" and listless. Then we get another slug of water and once again the place is hopping and dynamic. Far Point is a microcosm of the main stem. We can restrict it to Mayberry or allow it to be downtown.

The lifeblood of the Cheakamus River is water. It dips and dives, it rests in eddies, it seeps through the gravel deep under its cobbled bed. This complex interaction between surface and subsurface flows determine the integrity of all its connected biological functions.

I believe the Cheakamus Water Use Planning Committee is treating this river like a culvert. We have divorced the ecosystem from the mainstem and rebuilt the river with aerial photos and computer models into something that we can somehow limit and concisely define. I think we are wrong.

Our deliberations are intended to come to a consensus by first developing performance measures and testing their sensitivities to arbitrary flow scenarios. The first thing that was thrown out the window was the Interim Flow Agreement (IFA). It was implied that this was never really on the table because no one on the committee could support it. It has been implied that no one could support it because it demanded too much water from the system. The fact is that many people allowed it to be disregarded because they felt the IFA was too low a flow and they would be fighting for "more water for fish". I believe if you polled the original members of committee, many would reflect this belief. The Power Optimal (PO) scenario was also thrown of the table (as if to balance the loss of the IFA). The PO option was never a serious scenario anyway since it implied diversion of all usable inflows from Daisy Lake, other than those miniscule flows needed to run the onsite generator. (which runs the actual dam operations) This is basically what happened before the IFA was imposed. The flow arrangement most favored by BC Hydro mirrors this scenario, except for the additional of 2.5 cms from the dam. The flows in a 15 minimum at Brackendale / 3 minimum at the dam (15 / 3) scenario are almost always maintained by downstream tributary inflows. Even the blended scenarios offer very little new water. Most of these proposed flows would be in the river regardless of how much water went through the penstocks. If downstream tributary inflows are enough to maintain the viability of this river, why are we even having this discussion?

Several themes from this process are troubling.

The most exasperating is the focus on chum and at the same time the complete exclusion of its most productive habitat. 16500 m^2 of off channel spawning and rearing habitat has been arbitrarily excluded from all deliberations. This is some of the most productive, protected habitat in the entire system. I emphasize protected. This is very important in the Cheakamus system in particular because of its volatility. Fall and winter flood flows often carry vast amounts of silt and those eggs laid in the main stem are severely impacted. Because of this, these protected habitats are critical. Many times the very structures (dykes) that have afforded this protection are put forward as the biggest culprits in the downfall of the natural system. This notion completely disregards the fact that behind these dykes, off channel habitat has been restored past the carrying capacity of the river in its natural state. In response to having off channel habitat thrust on the table so many times we are now told "side channel chum production is less valuable ecologically than mainstem production". (Jan 11 2002 CC Agenda Background pg 7 table 2. So, we have two adult salmon, and they swim 5 km up Moody's Channel to Far Point and spawn in Cheakamus gravel surrounded by Cheakamus wood in a river water fed system and they are less valuable ecologically! Please show me the science!

This committee should have been looking at any and all habitat that is impacted by any change in river flows as a result of a change in dam operation. We acknowledge that changes in river elevation impact groundwater yet are willing to make flow decisions without any idea of what those impacts will be. I urge you to read the correspondence from Matt Foy included in this message. It is also ironic that the documentation supporting much of the monitoring focuses on the importance and value of the same off channel habitat that had been completely dismissed.

We are not focusing on those main stem fish most effected by "higher flow" scenarios. We are assured that there is no sensitivity to those flow scenarios modeled for chinook and steelhead. We were assured that it was all right to disregard pinks because they were basically extinct anyway. This year we had pinks and chinook in abundance, and using the afore mentioned protected off channel habitats.

We are saying there isn't any impediment to salmon migration with any flow over 10 cms. I have always felt this was simplistic. If we dig a ditch up the middle of the channel there would be a wet enough area for fish to swim in but that does not mean they will leave the estuary. What are the realistic flows that actually pull fish in? If there is not a strong enough flow do the fish instinctively know their preferred spawning habitat will not be accessible? Once again I urge you to read the correspondence from Rob Bell-Irving.

The notion that we should make this a smaller river to protect fish also disturbs me. What impact does this theory have for other watersheds? I look at those steep banked systems farther up in the mountains and wonder, "if we can only keep the bed of the stream or river wet, why do we need all that extra water?" That extra water is important for the diversity of that river and diversity is the absolute driving force.

If I can simplify my admittedly narrow position: The only water I don't want to see in that river is the stuff that comes over the dyke.

Carl

The following excerpts are from the draft monitoring plan:

2.6 Mainstem Flows and Off-channel Fish Production

At both rivers, significant chum and coho salmon production comes from flood-protected man-made side channels with relatively stable flows, generally dominated by groundwater. Because of the relatively stable environment, fish survival and production in these channels

Groundwater Monitoring

Groundwater fed side channels play an important role in Cheakamus River salmonid productivity (Cheakamus Water Use Plan Fisheries Technical Committee, 2001). Current research indicates that there is a close connection between flows of the Cheakamus River mainstem and shallow groundwater systems and side channel upwelling in the vicinity of the North Vancouver Outdoor School (NVOS

Background

Groundwater-surface water interactions control the extent and character of floodplain hyporheic zones (subsurface zones where groundwater and surface water mix), and play an important role in the function of riparian ecosystems (Harvey and Bencala, 1993; Winter *et al*., 1998; Bencala, 2001). These interactions can dominate stream physicochemical gradients, baseflow discharges, and stormflow response. Understanding stream and groundwater processes requires knowledge of the linkages between all of these interactions. This is particularly true in high-energy coastal watersheds, where highly permeable sediments and steep gradients encourage groundwater-surface water mixing (Edwards, 1998). The lower Cheakamus River Valley is a high-energy watershed in which effective future watershed management requires an understanding of Cheakamus River surface/groundwater interaction to minimize impacts on salmonid production.

The following messages are to Matt Foy and Rob Bell-Irving (DFO)

-----Original Message-----
From: Carl Halvorson
Sent: November 3, 2001 4:40 AM
To: Matthew Foy
Subject: Cheakamus WUP Questions

Matt,

I was wondering if you could comment on the following conclusions. They are an amalgamation of many conversations with lots of different people, research on the web and stumbling through reams of information from the WUP, offered with apologies to all those people not getting credit for their own contributions.

I noticed that in the draft report of year 2000 juvenile salmon migration in the Cheakamus River by Instream Consultants they state that the chum out migration peaked from April 2 and April 22, with April 18 appearing to be the peak. Pink out migration peaked April 8, basically overlapping, yet my understanding is that Pink spawning peaks around 2 months before chum. If both these species require the same amount of time to incubate how can they emerge at the same time? I have requested confirmation of spawning and emergence timing from Info@DFO-MPO.GC.CA

Our manual in the hatchery shows both species requiring about the same amount of thermal units to develop from egg to emergence. (actual #'s 900-1000 for chum and 900-950 for pink) The only logical solution is water temperature, and one obvious source of water temperature difference in the system would be upwelling groundwater.

I did a quick comparison of water temperatures and found about a 2 degree difference between the main stem and redds in Upper Paradise Channel. If they seek out upwelling groundwater in a static enhanced habitat, it could reasonably follow that they would seek upwelling flows in the main stem as well. This would account for the fact that chum and pink fry emerge at essentially the same time even though their spawning cycles are a couple of months apart.

If the viability of chum fry is dependent on upwelling groundwater, how can any computer model take this into account? I wonder how you could test the connection of upwelling water, temperature and emergence in the main stem? How do you differentiate between groundwater and "river water"?

During the Cheakamus WUP process I have continued to question the model used to determine "viable spawning habitat". I have based that on my belief that pictures taken from over flights and interpreted under a microscope are not accurate estimates of usable habitat. Just because habitat appears to have the same attributes, it doesn't mean a fish will use it. I have repeated several times that Upper Paradise, being an "old fashioned" constructed channel has consistent flows, consistent depth, consistent size of cobble, yet chum will pick little pockets here and there to spawn. It has always been explained to me that was because chum seek out upwelling groundwater.

Groundwater issues on the whole have not been properly considered in the WUP process either. Along with several other committee members, I have been pushing for higher based flows to address the observed connection between river elevations and groundwater levels. When Tenderfoot Creek Hatchery made presentation to the WUP it was pointed out they notice a direct connection between the levels in Tenderfoot Lake and creek and main stem flows. Tenderfoot Lake would almost dry up during winter low flow periods pre IFA.

It seems to make sense that if minimum flows are the standard, there will be a decrease in groundwater base levels. It also make sense that all upwelling water is not in a spawning channel or river. If Chum do in fact seek out upwelling flows in the mainstream, this could mean that some of the eggs laid during higher fall flood flows could be maintained by upwelling water alone as eggs? They might be dependent on elevated flows in the later alevin and emergent stages to survive though. I would think that the highest maintainable levels in the river during this time would be of significant importance.

It would follow that a natural hydrograph would be beneficial to "recharge" this groundwater aquifer. If flows were maintained at a minimum, the groundwater levels would draw down to a minimum level as well? Maybe I should ask Quinn Jordon-Knox his opinion of the theory? I know he has some definite ideas of why Outdoor School in particular has such an active artesian groundwater zone.

The only other performance measure that has been used to determine flows was benthic invertebrates. This has been shown to be insensitive over all scenarios. Can you think of any other biological function that we should be looking at?

Looking forward to your comments

Reply:
From: Matt Foy
Sent: November 5, 2001 16:12:11

Carl You have summarized the important questions and issues very well. I have always felt that any model that predicted chum production based exclusively on water velocity, depth, and substrate would be fatally flawed because of the fundamental dependence of Cheakamus River chum salmon production on upwelling groundwater sources whether in the mainstem or in sidechannels. You can not have a model which would predict that chum and pink could use much of the same gravel areas for spawning when in fact if this occurred you would have the chum salmon fry emerging in July up to 12 weeks later than the pink salmon fry. Without upwelling groundwater to increase winter incubation temperatures chum salmon will not produce viable fry due to their late emergence which is the key reason why measurements of water velocity, depth, and substrate must be irrelevant when predicting chum salmon production in the Cheakamus River. The three variables proposed measure the ability of surface water to perculate through a redd. In fact if surface water dominates a chum salmon redd as the model predicts it will mean that redd will not be viable due to a retarded emergence timing.

Chum salmon spawning in groundwater areas that may be exposed during periodic low flow periods will survive given adequate sub surface groundwater flow. Chum salmon that utilize groundwater will also spawn in deep water in pools along cutbanks and at low or zero surface flow velocities. The Cheakamus chum salmon are known as a late spawn timing chum population and this is due to their total reliance on upwelling groundwater areas. The models for chum would be better off focussing on how river flows affect valley groundwater flows. The groundwater studies undertaken to date at NVOS have shown the linkage between surface flows in the Cheakamus and groundwater recharge although I understand the studies have not looked at higher river flow regimes. I do know that chum fry production from Upper Paradise Channel in the spring of 1996 was 650,000 chum versus 380,000 in the spring of 1995. The winter of 1995 experienced some of the highest fall-winter flows seen in that decade and it appears high flows may have super charged the aquifer which in turn significantly increased the production of chum fry from groundwater dependant habitats such as Upper Paradise Channel. Presumably this would have also occurred in mainstem groundwater spawning areas. Again the chum model may be using the wrong data to generate its conclusions regarding chum production and how it is related to flow variation in the Cheakamus River. Perhaps the flow regime chosen should be the one that maximised the recharge in the valley aquifer. Caution is advised if the present chum model is being used exclusively to justify the final fall- winter flow regime. Matt

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From: Matt Foy, NOV.20.2001

Carl In terms of groundwater flow to incubating eggs it is important to remember the eggs need adequate water flow past the egg mass to successfully incubate. A higher water table increases upwelling water flow and velocity past the embryos. While we do not have a good data set on GW flows versus egg survival I did give you the fry outputs from Upper Paradise from 1995 and 1996 which showed a very significant difference that may have been attributed to the high river flow in the fall of 1995 which presumably increased groundwater flow and also egg survival and ultimately fry production from Upper Paradise. My feeling is that high flows in the main river increase overall groundwater flows in the near surface aquifer which in turn increases egg survival and fry production. A channel going dry is not the only indicator of low flow. A reduced total area of upwelling flow and lower intra gravel velocities are the two variables that likely result in a negative impact to chum fry production in a channel like Upper Paradise. Matt

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(the following message was not included in its entirety, cause it was really long. Carl)

To: Rob Bell-Irving
Sent: Sunday, Nov.18, 2001

Hi Rob,

Here are my questions and my request for comment regarding Cheakamus WUP issues.

1. Our Fish Technical Committee has determined that decreasing the flows to no lower than 10cms would not be an impediment to upstream migration of spawners. I always thought they sort of hung around the river mouth waiting for elevated flows?

Is there any information out there connecting flows and upstream migration?

Re: Cheakamus WUP Issues as requested by Carl Halvorson; North Vancouver Outdoor School
From: Rob Bell-Irving, Community Advisor, HEB – F&O
Squamish – Howe Sound – December 2001

1. "Flows and Upstream Migration" – On pink salmon rivers on which I've worked (notably the Quinsam and Puntledge on Vancouver Island) there are obvious connections between river flows, temperatures, and salmon migration including pinks. The dam(s) on the Puntledge have raised water temperatures and reduced flows to the point where returning pink adults would hang out in the estuary longer. In an increasingly stressed and ragged condition, and obviously, not interested in swimming back out to sea, the pinks over years became targets for seals who soon caught on to their plight. Thus, over the year's seal populations grew in the Puntledge estuary to the point where seal culling is necessary. There were and are, second and third generation seals teaching their young to acclimate to this unnatural, dam induced feeding opportunity. On the Quinsam, in years where there are higher summer flows in the Quinsam, we often would see significant numbers of pinks "at the fence" (counting fence) at the Quinsam Hatchery in mid-late July. However, in low water years, we would not see large numbers of pinks early in the run timing period. It seemed pretty common sense really.

   With chinooks, the issue of flows was important in the Campbell River because high flows would draw more chinook into the lower river while lower flows would keep them in the estuary longer. And unnatural dam induced heavy flows during juvenile emergence were blowing young fish out down to the estuary and likely beyond. The heavy late summer/autumn flows also affected Tyee Club catches in many years and made our F&O river swim inventory results difficult to evaluate accurately relative to predicting escapement size, even though we swam weekly during the escapement period. There was also a parallel issue of the best flows required for Campbell juvenile salmon and steelhead rearing and how the juvenile salmonid requirements meshed with the chinook escapement upstream migration. So a gradual flow sequencing system was worked out in order to accommodate both. I would encourage you to further pursue the background to this agreement by contacting Jim Van Tine F&O (250-287-9564) and Craig Wightman from the Provincial steelhead group (250-751-3100) who were the principal architects of this flow system.

2. Finally, it is well understood on the East Coast of Vancouver Island, that many small streams had strong pink runs (most documented is Nile Creek, 30,000 in cycle years – counting fences circa 1940-1950's, Ricker et al) and earlier timed coho runs (Black Creek, etc.) but these runs were

> destroyed entirely. Usually after increasing urban and agricultural water use, logging, highway construction, wetland filling and so on had altered stream flows and temperatures. So that essentially, creeks that I fished in August and September as a kid (late 1950's-early '60's), were now drying in June. Thus, over time, early returning (August – early Sept) pinks and even early returning coho (late Sept-mid Oct) were not finding the spawning or even upstream migrating conditions workable. Thus, these runs petered out leaving only the later returning fish. To this day, often Black Creek (a counting fence operated key stream) will get sudden "overnight" clumps of fish all at once, when water levels quickly rise after a heavy rain. Even numbering in the high hundreds or low thousands almost overnight. Simply because the water flow patterns have become so inconsistent with competing water use.

I can't really comment too much on your other questions as I've not been privy to the computer modeling. I don't find benthic invertebrates as particularly reliable measureables because they too are very dependent upon a whole set of conditions and variables. The amount of nutrients affects their abundance and distribution at any given time. And this past year for example, Streamkeeper groups in West and North Vancouver were initially alarmed and fooled into thinking that nutrient production had dropped in their study streams, because their bug surveys didn't find very many. But what happened is that the early season water temperatures were much cooler than in other study years and when they re-sampled a bit later, the abundance was there, in fact is was greater than in past years. So I never go much on "bug sampling," it's interesting but nothing to judge fish abundance or enhancement potential on because it is so fickle. So plankton blooms and other phenomenon are very fickle and subject to many variables including water flow changes, water temperatures, upper watershed land clearing, siltation loads and so on. To my way of thinking the very best indicators can be better determined by yearly data gathering, counting fences and other hands on enumeration, river swims, sampling over longer periods, past histories, habitat impact assessments and histories, reasonable historical anecdotal evidence, where fish used to spawn and rear, wildlife populations (bears, minks, otters, herons, kingfishers, eagles) and their various movements and so on all taken as a whole. I'm a firm believer in the inter-connectedness of ecosystems and tend to distrust uni-dimensional modeling simply because it's almost always wrong, and if not wrong, then its results and conclusions are very short term and do not at all consider the very broad perimeters of natural limits and boundaries which are seldom completely understood as it is. Also modeling can be easily mis-interpreted and even pre-determined or rigged to "discover" or determine essentially pre-ordained results and conclusions meant to support a certain specific agenda. Whereas the reality of actual field interactions and combined watershed evidence and past histories paints a much more accurate and broader picture relative to the effects of actual impacts upon it. And can't be so easily manipulated to achieve a pre-determined objective or agenda. Dams – gravel size, water flows – gravel size distribution, urban development – wetland filling, logging – flood/drought cycles, diking – lost side-channel habitats, estuary loss – poor ocean and early ocean survivals and adult spawning upstream access, etc., etc. And the impacts of all these impacts and others – on the entire ecosystem, fish, animals, and birds, fish distribution, etc.

I find the best strategy – is to try to save and restore (enhance) what's left, add what you can – and try to reproduce the water flows and other issues relative to what you think the original situation might have been – or at least as close to it as you reasonably can. At least this is what we strove to do in Campbell River and I understand that the Campbell had close to a record run of chinook back to it this fall, and 250,000 pinks – in an off-cycle pink year, so Jim and his crew must have been doing something right as these returns coincide exactly with the start of the Campbell Watershed Management Planning process, gravel placements, estuary reclamation, side and spawning channel construction, new flow regime and so on.

Hope this helps Carl – thanks for asking – Rob Bell-Irving

Appendix 7-C: Maps of North Vancouver Outdoor School Side Channels

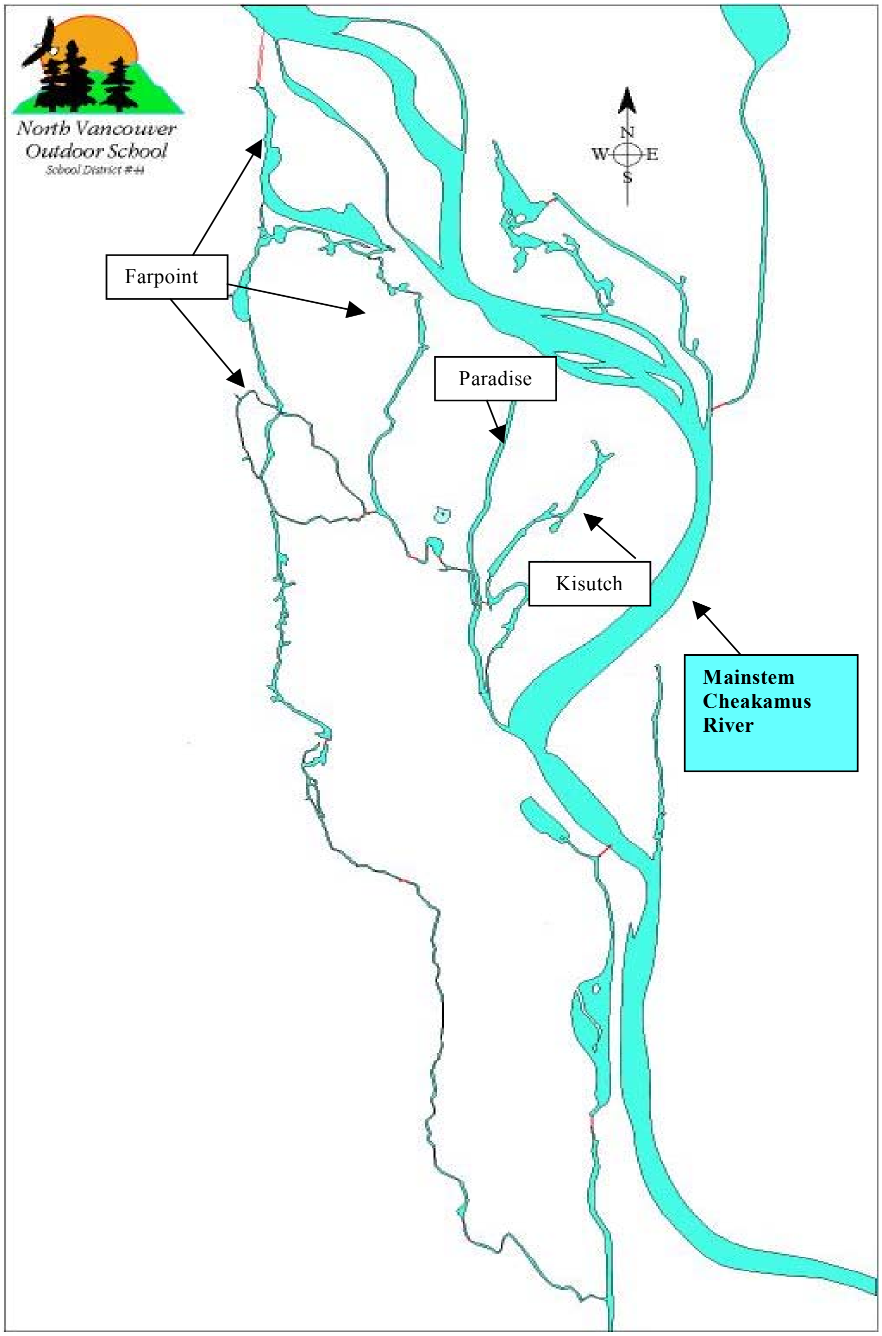

Figure A7-C1: Side Channels Near North Vancouver Outdoor School. Paradise and Kisutch are groundwater fed. Farpoint has a surface water intake from the Cheakamus River. *(Source: Carl Halvorson, NVOS)*

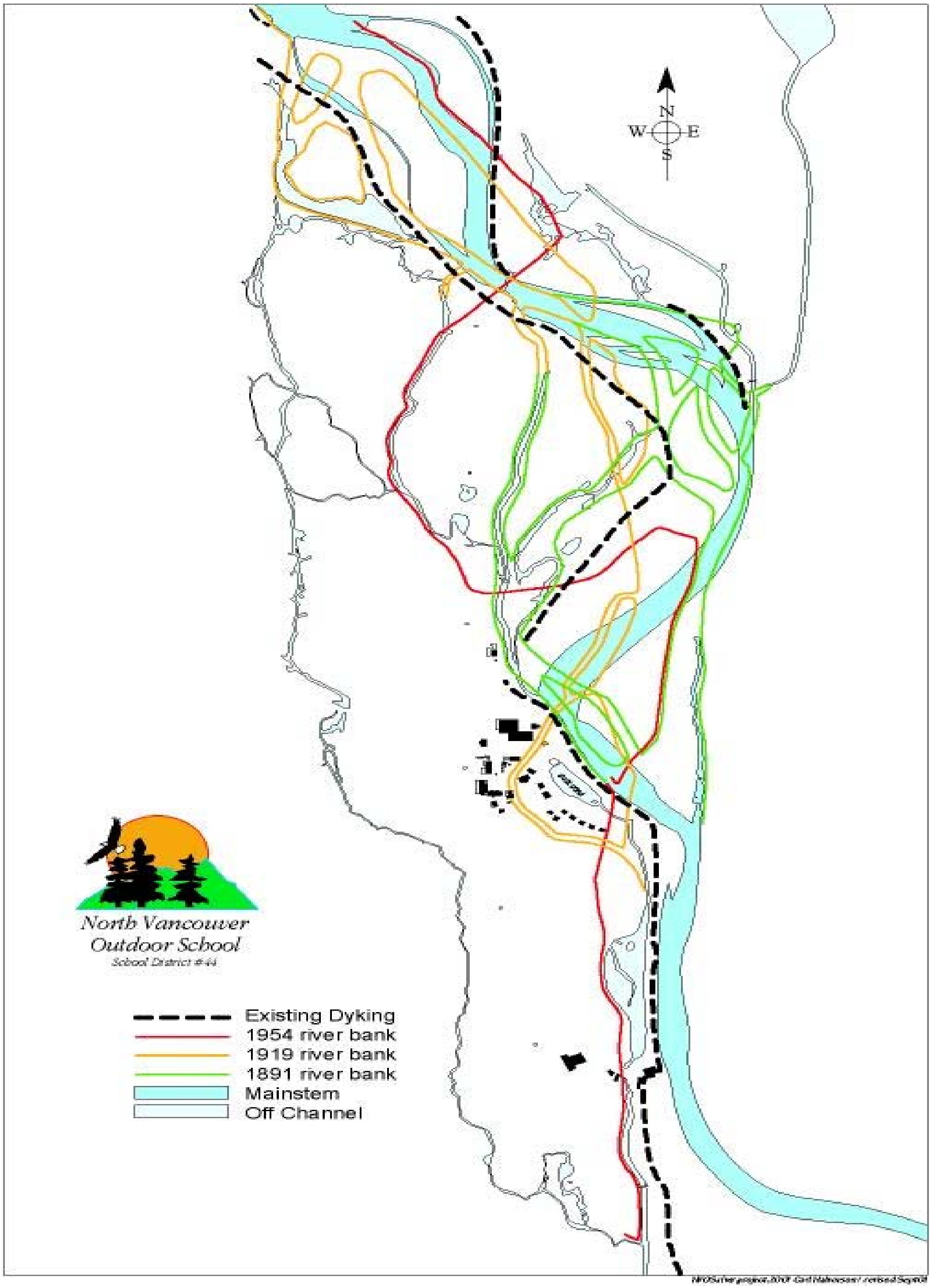

Figure A7-C.2: Relationship of NVOS channels to Historic River. (Source: Carl Halvorson, NVOS)

Appendix 8: CD-ROM Table of Contents

A8.1 Cheakamus Water Use Plan (WUP) Consultative Committee Documents on CD

Welcome to the compilation of Cheakamus Water Use Plan Documents on CD. This information supplements that presented in the Cheakamus Consultative Committee Report.[19] When you first open up the CD, you will see six directories, the Table of Contents (electronic copy of this file, "Table_of_Contents.pdf") and a copy of Adobe Acrobat Reader, a freeware program required to view and print the pdf documents on this CD.

1. Cheakamus Consultative Committee (CC) Reports and Products
2. Fisheries Technical Committee (FTC) Reports and Products
3. Hydro Operations and Power Studies Committee (HOPSC)
4. Draft WUP Monitoring Plan
5. Performance Measure (PM) models and database
6. Performance Measure Information Sheets

[19] **Marmorek, D.R. and I. Parnell.** 2002. Cheakamus River Water Use Plan - Report of the Consultative Committee. Prepared by ESSA Technologies Ltd., Vancouver, BC on behalf of the Cheakamus River Water Use Plan Consultative Committee, Vancouver, BC, 231 pp.

A8.2 Cheakamus WUP Reports – Table of Contents

A8.2.1 Directory 1: Consultative Committee (CC) Reports and Products

WUP Step	File Name	Description
	CC_Terms of Reference.pdf	Draft Final Cheakamus Water Use Plan Consultative Committee Mandate and Terms of Reference, June 28th, 1999.
	Table_Summary of CC Meetings.pdf	Summary table of Cheakamus Water Use Plan Consultative Committee meetings.
2	"SC2 Meeting Notes May 6, 1999.pdf"	Pre-announcement meeting of *ad hoc* "steering committee", preliminary definition of issues Draft CC Terms of Reference
3	"1_(&2)_CC Meeting Notes June 23 & 28, 1999.pdf"	June 23rd - Inaugural CC meeting: 1) Design and operation of CC; 2) Review of recent activities; 3) discuss summer work June 28th - 1) introduction to technical approach (decision analysis, resource valuation, adaptive management); 2) review of work program
4	"3_CC Meeting Notes September 15, 1999.pdf"	1) Review of summer activities; 2) Draft of CC "Master Plan"; 3) Overview of approach to developing and assessing alternatives (Smart Choices: "PrOACT"); 4) Begin selecting issues and defining objectives.
	"4_CC Meeting Notes October 4, 1999.pdf"	Issues and objectives
	"5_CC Meeting Notes October 18, 1999.pdf"	Issues and Objectives – focus on fisheries
	"6_CC Meeting Notes November 1, 1999.pdf"	Finalize list of objectives; develop performance measures
5	No meeting notes	Expert presentations on geography, hydrology, power studies, geodynamic and hydrodynamic process relevant to fish, FTC work
	"8_CC Meeting Notes November 29, 1999.pdf"	Review fundamental objectives, define means objective and performance measures, and mandate for FTC and HOPS.
	"9_CC Meeting Notes December 13, 1999.pdf"	Establish technical committees, determine supplemental data and information required, discuss draft FOs (7 of them), Draft FO text
	"10_CC Meeting Notes January 10, 2000.pdf"	Confirming a consensus on the fundamental objectives, a presentation concerning Cheakamus flooding
	"11_CC Meeting Notes January 24, 2000.pdf"	Flooding presentation, FTC update (IH workshops), HOPS update, constraints on operations
	"12_CC Meeting Notes February 7, 2000.pdf"	Fluvial geomorphology and fish habitat, tenderfoot hatchery, tour of NVOS hatchery
	"13_CC Meeting Notes March 20, 2000.pdf"	Introduce new CC members, HOPS report, SFN heritage and cultural values, fish and aquatic ecosystem presentation
	"14_CC Meeting Notes April 3, 2000.pdf"	Candidate PMs, subgroup discussions to develop PMs
	"15_CC Meeting Notes May 1, 2000.pdf"	BC Hydro Operations and Finances, Review list of PMs, Discussion Draft Fundamental Objectives and PMs
	"16_CC Meeting Notes May 29, 2000.pdf"	Presentation on Cheakamus Hydrology, Draft letter to FTC
	"17_CC Meeting Notes June 26, 2000.pdf"	Presentations by FTC: Impact hypotheses, studies and models, schedule, flow diagram of process, summary of relevance of CMS literature to fisheries
	\Educational Presentations BCHydroOperations.pdf	Overview of BC Hydro Operations and Finances and coordination of generating facilities presented by Ken Spafford dated February 1st, 2000.

WUP Step	File Name	Description
	\Educational Presentations ValuingWholesaleElectricityinBC.pdf	Presentation by Doug A. Robinson, Resource Management Power Supply on Valuing Wholesale Electricity in BC, January 15th, 2001.
	\Educational Presentations Hydrologic Input to the Cheakamus WUP BC Hydro.pdf	Eric Weiss' presentation regarding Hydrologic Input to the Cheakamus Water Use Plan, February 15, 2000.
	\Educational Presentations Hydrology in British Columbia BC Hydro.pdf	Eric Weiss' presentation regarding Hydrology in British Columbia, May 29, 2000.
	\Educational Presentations Inflow Computations BC Hydro.pdf	Eric Weiss' presentation regarding inflow computations, May 29, 2000
	\Educational Presentations Quality Control of Inflows for Water Use Planning BC Hydro.pdf	Eric Weiss' presentation regarding quality control of inflows for water use planning, May 10, 2000.
	\Educational Presentations ChrisPerrin LWMPpp97.pdf	Chris Perrin's presentation June 5th, 2001 regarding LWMP – phosphorus and periphyton.
	\Educational Presentations ChrisPerrinSummaryofKeySlides.pdf	Summary of key benthos slides.
6	"18_CC Meeting Notes October 23 2000.pdf"	Modelling water management alternatives, Methods for comparing alternatives, hands-on trade off analysis, developing alternatives
	"19_CC Meeting Notes April 30, 2001.pdf"	VOE, FTC-IH, Rearing RUA PM, Rearing WUA PM, Benthos PM, Spawning and Incubation PM, Fish PM example tradeoffs, Discussion of PMs for FOs 5-6, HOPS (flow, power, flooding, recreation), Discussion of PMs for FOs 1-4
	"CC_Prereading_May_28_29_2001_Final.pdf" "20_CC Meeting Notes May 28_29, 2001.pdf"	Scope of Consultative Report, Clarification of Alternatives, Review of performance measures, Features of alternative worth carrying forward, Which alternatives should be carried forward and which should be dropped, New alternatives to be examined, Schedule
	"CC_Prereading_July_3_4_2001_Final.pdf" "21_CC Meeting Notes July 3_4, 2001.pdf"	Review of items from the May28th-29th meeting, Update and review of results for current set of alternatives, Review of Performance Measures, Rating of alternatives, Decisions on Alternatives, Other CC Decisions Schedule
7	"CC_Prereading_September_7_2001_Final.pdf" "22_CC Meeting Notes September 7, 2001.pdf"	Review of items from the July 3rd and 4th meeting, Update and review of results for current set of alternatives, Review of Performance Measures, Rating of alternatives, Decisions on Alternatives, Other CC Decisions Schedule
	"CC_Prereading_October_4_2001_Final.pdf" "23_CC Meeting Notes October 4, 2001.pdf"	Review of items from the September 7th meeting, Update and review of results for current set of alternatives, Review of Performance Measures, Rating of alternatives, Decisions on Alternatives, Other CC Decisions Schedule

WUP Step	File Name	Description
	"24_CC Meeting Notes October 24, 2001.pdf"	Reviewed: • results and final 4 alternatives selected at October 4th meeting, • a consensus proposal from previous meeting, a table of concerns, and draft CC recommendations, • several hybrid alternatives within the range of the final four selected on October 4th, • conducted a preference rating exercise, consensus was not achieved, but defined two most preferred alternatives: 15-20Min3-7Dam, 20Min7Dam.
8	"25_CC Meeting Notes January 11, 2002.pdf	a) to develop final CC recommendations for an operating alternative, a monitoring plan and other activities; b) outline areas of agreement and disagreement with respect to these recommendations
	"Cheakamus River Water Use Plan - Report of the Consultative Committee.pdf"[1]	Final Cheakamus Consultative Committee report.

A8.2.2 Directory 2: Fisheries Technical Committee (FTC) Reports and Products

The FTC files are organized into the following directories:

- Impact Hypotheses
- Meeting notes over the performance measure development period (February to June 2001)
- Studies

Directory / File Name	Description
Root directory	
CMS_WUP_FTC_coverletter1.pdf	Fisheries Technical Committee cover letter to CMC WUP Consultative Committee, April 12th, 2001 from David Wilson, Chair of CMS WUP FTC accompanying first information package sent to the CC for the April 30 2001 CC meeting. (Impact hypothesis worksheets, summary of performance measures, draft benthic report).
CMS_WUP_FTC_coverletter2.pdf	Fisheries Technical Committee cover letter to CMC WUP Consultative Committee, April 12th, 2001 from David Wilson, Chair of CMS WUP FTC accompanying second information package sent to the CC for the April 30 2001 CC meeting. (Impact hypothesis table, performance measure information sheets for spawning/incubation, rearing and benthos).
FTC_Method_Summary.pdf	Summary of fish and aquatic ecosystem performance measures (PMs) by the Fisheries Technical Committee for the Cheakamus Water Use Plan.
Table_FTC_Deadlines_2001.pdf	Deadlines for FTC modelling work to meet the revised CCC schedule.
FTC_Memo_to_CC.pdf	Memo from the FTC to the CCC dated June 5, 2001 re: Why more water isn't always better for fish.

Directory / File Name	Description
Impact Hypotheses	
CMS_WUP_IHsummary.pdf	Summary table of Impact Hypotheses providing status, rationale, key uncertainties and recommendations.
FTC_IH_Synthesis_Report.pdf	Summary of progress on the Cheakamus River Impact Hypotheses, June 30th, 2000.
H1_Assessment.pdf	H1: Operations at the Cheakamus Facility affect the frequency, duration and magnitude of flows that cause changes in the geomorphology of the Cheakamus River mainstem. This in turn, affects the quantity and quality of fish habitat and hence, the numbers of wild fish sustained in freshwater habitats influenced by operations of BC Hydro's facility.
H2_Assessment.pdf	H2: Operations at Daisy Dam affect the frequency, duration and magnitude of moderate flows that directly affect the quantity and quality of mainstem rearing habitat for fry and parr, and of mainstem spawning habitat. Such changes to habitat can influence The production of seaward migrant fry or smolts and hence, the abundance of wild salmonid fish.
H3_Assessment.pdf	H3: Operations at Daisy Dam affect the frequency, duration and magnitude of moderate flows that directly affect fish food supply and hence, affect juvenile fish growth and survival. This in turn, will have an effect of the abundance of wild fish populations.
H4_Assessment.pdf	H4: Operations at Daisy Dam affect the frequency, duration and magnitude of moderate flows that affect upstream migration and spawning distribution of adult salmonids and outmigration timing of smolts. Changes to adult in-migration timing will affect spawning success while changes to smolt out-migration could affect smolt survival. Both will influence the abundance of wild fish.
H5_Assessment.pdf	H5: Operations at Daisy Dam affect the frequency, duration and magnitude of moderate flows that directly affect water temperatures and hence, emergence times of incubating salmonids, summer growing conditions, and over-wintering survival. All will influence the abundance of wild fish.
H6_Assessment.pdf	H6: Operations at Daisy Dam affect the frequency, duration and magnitude of moderate flows that directly affect vulnerability of juvenile fish to predators. High predation rates reduce egg to freshwater survival and hence affect the abundance of wild fish.
H7_Assessment.pdf	H7: Operations at Daisy Dam affect the frequency, duration and magnitude of flows that cause changes to the surface flow - groundwater interactions of the Cheakamus River mainstem. This in turn changes the upwelling characteristics of groundwater fed off-channels affecting the quantity and quality of spawning, rearing, and over-wintering fish habitat in these channels. This has a direct effect on the abundance of wild fish.

Directory / File Name	Description
H8_Assessment.pdf	H8: Operations of the Cheakamus River powerhouse on the banks of the Squamish River affect the frequency, duration and magnitude of water levels immediately downstream of the powerhouse canal confluence. Such changes to downstream water levels cause stranding of juvenile fish, and hence affect the abundance of wild fish in the Squamish River.
Meeting Notes	
\February 15 2001	
FTC Meeting Notes Feb 15, 2001.pdf	
\March 7 2001	
FTC Meeting Agenda Mar 7, 2001.pdf	
FTC Meeting Notes Mar 7, 2001.pdf	
FTC Meeting Notes Mar 7 Revised Schedule, 2001.pdf	FTC schedule of work over March and April, 2001. Revised at March 7th meeting.
\March 23 2001	
FTC Meeting Actions Mar 23, 2001.pdf	
FTC Meeting Agenda Mar 23, 2001.pdf	
FTC Meeting Notes Mar 23, 2001.pdf	
\April 3 2001	
FTC Meeting Agenda April 3, 2001.pdf	
FTC Meeting Notes April 3, 2001.pdf	
FTC Meeting Notes April 3 Conclusions, 2001.pdf	Conclusions from RUA Analyses for April 3, 2001 FTC Meeting.
\April 10 2001	
FTC Meeting Agenda April 10, 2001.pdf	
FTC Meeting Notes April 10, 2001.pdf	
FTC April 10, 2001 Meeting followup.pdf	Memo from ESSA Technologies regarding the RUA and WUA Analyses Requested by the FTC, dated April 16, 2002.
\April 20 2001	
FTC Meeting Notes April 20, 2001.pdf	
FTC Meeting Notes April 20 RUA Results April 5, 2001.pdf	
\May 10 2001	
FTC Meeting Agenda May 10, 2001.pdf	
FTC Meeting Notes May 10, 2001.pdf	
Sensitivity_Analysis_Short_May7, 2001.pdf	Initial RUA Results: Sensitivity of Rated Usable Area (RUA) Rearing Performance Measures to RUA% and Wetted Area calculation methods: Why do Methods B and H produce different results? Draft updated May 10, 2001.
Preliminary_WUA_Results_May 7, 2001.pdf	Initial Weighted Usable Area (WUA) Results. Draft May 10, 2001.

Directory / File Name	Description
Preliminary_WUA_RUA_Comparison_May 9, 2001.pdf	Comparison of RUA and WUA results. Draft May 10, 2001.
RUA_Additional_Wetted_Area_May 10, 2001.pdf	RUA using new WUA based Wetted Area curve to add points below 5CMS dam release flows. Draft May 10, 2001.
Initial_RUA_without_Reach_Flow_May 10, 2001.pdf	Initial RUA PMs calculated without Reach Inflows. Draft May 10, 2001.
RUA_for_Specific_Flow_Years.pdf	Sensitivity of Rated Usable Area (RUA) Rearing Performance Measures to RUA% and Wetted Area calculation methods: Results a wet and dry year. Incomplete Draft, May 11th, 2001.
FTC_RUA_WUA_Analyses_Summary.pdf	Overview of RUA and WUA analyses since April 20th, 2001 for the May 10th meeting.
\May 22 2001	
FTC Meeting Agenda May 22, 2001.pdf	
Spawning_Incubation_Results.pdf	Preliminary Spawning and Incubation Performance Measure results. Incomplete Draft, May 22, 2001.
Benthic_Performance_Measure_Results.pdf	Benthic Performance Measure Results Including Reach 11, May 23rd, 2001.
RUA_WUA_Comparison_Figures.pdf	RUA WUA Comparison Figures for May 22nd, 2001 Meeting.
\June 5 2001	
FTC Meeting Actions June 5, 2001.pdf	
FTC Meeting Agenda June 5, 2001.pdf	
FTC Meeting Notes June 5, 2001.pdf	
New_Habitat_Variability_PM.pdf	New Habitat Variability Performance Measure. Preliminary Draft, May 25th, 2001.
FTC Meeting June 5 Results.pdf	Analyses completed for June 5 Fisheries Technical Committee meeting. Draft, June 5th, 2001
\June 27 2001	
FTC Meeting Agenda June 27, 2001.pdf	
Riffle_Benthos_PM_Results_for_FTC.pdf	Summary Riffle Benthos PM Results. June 27th, 2001. Updated March 4, 2002 to include figures referenced in text.
\October 23 2001	
FTC Meeting Notes October 23, 2001.pdf	Review of CMS WUP Monitoring Plan, Draft CC Recommendations, and a Draft Memo to CC in rebuttal to Ross Neuman's email of WLAP's position on WUP flow alternatives and the FTC models.
Studies	
Cheakamus_Benthos_Report_Draft.pdf	Trophic Structure and Function in the Cheakamus River for Water Use Planning. Draft Report. By C. Perrin of Limnotek Research and Development Inc., March 22nd, 2001.
See Table 4.1 and Appendix 3 of the Consultative report[1] for a list of FTC studies and the executive summaries of those studies respectively.	

A8.2.3 Directory 3: Hydro Operations and Power Studies (HOPS)

Directory / File Name	Description
Cheakamus_WUP_AMPL_Model_DBM.pdf	BC Hydro Inter-office memo summarizing the AMPL Power Studies model developed for the Cheakamus Water Use Plan. In addition, this memo documents the checking and reviewing of the basic model configuration and inputs. Dated November 22nd, 2001.
Draft_HOPSC_ToR.pdf	Draft Hydro Operations and Power Studies Technical Committee (HOPSC) Terms of Reference, February 28th, 2000.
GHG_Memo.pdf	Greenhouse Gas performance indicators memo, June 15th 2001.

A8.2.4 Directory 4: Draft WUP Monitoring Plan

Directory / File Name	Description
CMSWUPMonitoringPlan030102.pdf	Draft, January 2002.

A8.2.5 Directory 5: Performance Measure (PM) Models and Database

The PM files are organized into the following four directories:

- Database (recreation, flooding, and adult migration performance measures)
- Input data spreadsheets (operational alternatives, reach inflows, RUA and WUA)
- Model spreadsheets (juvenile rearing area, effective spawning area, and benthic biomass performance measures)
- Results spreadsheets (hold results for juvenile rearing, effective spawning area, and benthic biomass)

Directory / File Name	Description
Description of PM Calculation Tools.pdf	READ ME! – Brief introduction to PM calculation tools. Not a User's Guide!
Database	
PerformanceMeasures.mdb	Database used to calculate recreational, flooding, and adult migration performance measures
Input data spreadsheets	
\Operating alternatives	
See Table 1 of "Description of PM Calculation Tools.pdf" for a list of the operating alternatives evaluated during the WUP process. See Table 5.1 of the consultative report for a description of each alternative.	

Directory / File Name	Description
\Reach Inflows	
Cheakamus River 10 Reach Inflows 1967-2000.xls	Cumulative Reach inflows data
\RUA and WUA	
Resident RUA Summary.xls	Resident RUA rearing model input data
WUA_Summary.xls	WUA rearing model input data
RUA_Summary.xls	RUA rearing model input data
Model spreadsheets	
Benthic Biomass PM Algorithm	For calculating the Benthos PM.
CHK_EffSpawnPMAlgorithm.xls	For calculating the effective spawning PMs.
RUA_Resident_Fish	For calculating resident RUA rearing habitat
RUA_WUA_Anadromous_Fish	For calculating the anadromous RUA and WUA.
Results spreadsheets	
CHK_EffSpawnPMResults	Holds summary output from the effective spawning algorithm, graphs are linked to output data.
CHK_EffSpawnPMResults_by Reach	Holds reach specific output from the effective spawning algorithm, graphs are linked to output data.
RUA_Resident_Output	Holds output from resident RUA algorithm
RUA_WUA_Anadromous_Output	Holds output from anadromous RUA and WUA algorithm
Summary Results Benthos	Holds results from the Benthic algorithm

A8.2.6 Directory 6: Performance Measure Information Sheets

Directory / File Name	Description
Adult Migration PM Infosheet.pdf	Description of the adult migration performance measure. Also in Appendix 2 of the Consultative Committee report.
Benthos PM Infosheet.pdf	Description of the benthic biomass performance measure. Also in Appendix 2 of the Consultative Committee report.
Greenhouse Gas PM Infosheet.pdf	Description of the greenhouse gas performance measure. Also in Appendix 2 of the Consultative Committee report.
Rearing PM Infosheet.pdf	Description of the anadromous and resident performance measures. Also in Appendix 2 of the Consultative Committee report.
Recreation PM Infosheet.pdf	Description of the recreational performance measures. Also in Appendix 2 of the Consultative Committee report.
Spawning Success PM Infosheet.pdf	Description of the effective spawning area performance measure. Also in Appendix 2 of the Consultative Committee report.
Squamish Nation PM Infosheet.pdf	The Squamish Nation privately evaluated a range of operating alternative to protect the integrity of their heritage sites and cultural values. The specific consideration that was evaluated for the WUP process was the flood risk to heritage sites and cultural values. Also in Appendix 2 of the Consultative Committee report.

Appendix 9: Clarifying Comments

A9.1 NVOS Comments on Side Channels, Channel Confinement, Groundwater and Chum

(extracted from Carl Halvorson's comments on the March 21 CCR Draft).

Performance Measures

The consultative committee agreed to a set of PMs based on the information and understandings they had at the time. As we moved forward, new issues and concerns came forward. Instead of developing PMs for these new issues (ie. groundwater linkages, off channel habitat and production, etc. it appeared that Essa (and the FTC) looked for ways to mitigate them (like a problem or hurdle) rather than address the issues seriously like you might with a PM linked concern.

Channel Confinement

The assertion that the river cannot spread out over a flood plain has always been overstated. In its 26 km length there is only 2100 metres of ripraped dyke. That is 2100 metres in 52 kms of riverbank. That is 2100 metres of dyke in the 34 kms of riverbank below the canyon. The river actually bears against this riprap for perhaps half this length. All berms constructed by DFO to protect salmonid habitat are well back from the river edge, providing significant flood plain. These berms do not get their "feet wet" until flows that reach well over 100 cm^3/s. The river is not artificially constrained to any significant degree until the middle of reach 4. Even in reach 3 and 4, there are constraints only on one bank at a time, except at the major choke point under the Bailey Bridge. This particular problem area was the work of BC Electric. During construction of the 128K transmission line through the valley, they constructed the dyke from Far Point to the Bailey Bridge and for a couple hundred meters upstream on the north side of the bridge. This was done at considerable expense to protect their transmission line towers. Construction of the right bank dyke at the bridge is clearly shown in the 1949 aerial photos. This cut off the natural side channels we now call the Far Point system and all the braided channels that now are called Dave's Pond and BCR Channel. Below the bridge they cut off the side channel we now call Upper Paradise and Kisutch. The new "pink channel" will also rewet old river swales cut off by this initial dyking. These changes are clearly identified in the nhc 2000 report, where they offer the rewetting of these same historic side channels as mitigation for the dykes in the area. Apparently nobody told them it has largely been done. In his May 28, 1999 correspondence to David Wilson, Brent Lister estimated that 70% of indicated spawning area occurred in side channels.

Chum

I am still confused by the explanation of why chum and coho spawning characteristics are not more closely linked and the continued focus on chum spawning requirements.

In fact I am confused by most of the fish data.

Concentration of fish into smaller and smaller areas (by artificially restricting the flow of the river) results in greater territorial behavior and therefore larger areas are needed per redds. Our documentation from the FTC shows chums needing a minimum of 2.3 m^2 per redd and coho 2.8 yet field observations show fish using half that space. This also discounts the fact that many of these redds overlap. Are not these numbers median values? For example in the document Quantitative Measures of Rearing and Spawning Habitat Characteristics For Stream-Dwelling Salmonids: Guidelines For Habitat Restoration by E.R. Keeley and P.A Slaney they show chinook utilizing anywhere from (less than) 3 to (almost) 20 m^2 per redd, yet our habitat numbers are based on 8.

This same report shows that the overlap for chum, coho, chinook and steelhead / rainbow preferred flows is in the 25 to 30 cms range yet we are optimizing the river to 15? In the same way, my comments directed to Brent Lister outlined my confusion over the apparent contradictions. On one hand, chum are identified as the most flexible of salmonids. They adapt well to flow and water temperature, they like higher flows at riffles, they gave been strongly associated with upwelling water sources, yet on the other hand we are told they are the most sensitive to the effects of increased flows and therefore must have low flows to survive. We decry the fact they do not have enough spawning habitats yet admit that we are not considering on non-mainstem habitat or reach one at all. I am further confused by the way Brent Lister's explanation has been presented. As it stands, it is implied that chum only rely on upwelling water when they are cut off from mainstem flows? Since their construction the side channels at NVOS have been some of the most productive habitat around. Various report indicate that chum seek out upwelling water. In fact this is what might attract them to fast flowing riffles. As was explained to me by James Bruce, because of the nature of these riffles there is actually significant water "upwelling" on the back side of one of these features. In many cases it may not be an upwelling groundwater that is attracting the fish, but plain old river water that has entered the gravel substrate just upstream of the riffle and is now upwelling on the downstream side. The chum can somehow sense this upwelling water and chose that area to spawn, knowing that it will increase the viability of their redds, particularly if flows decrease. This would be much the same reasoning behind their documented preference for upwelling groundwater sites.

Side Channels

This whole notion that habitat that happens to be behind a dyke or berm and has been impacted by man is now artificial, are less valuable or engineered or any other dismissive label is garbage. These are largely rewetted natural channels that are now permanently protected from devastating flood flows. At least 3 km of habitat on Outdoor School is completely natural. The Far Point system is the model of modern habitat reconstruction. These are not 1950's road race fish factories. It disgusts me that they are dismissed. It disgusts me that statements are made saying "they are engineered, and engineered during low flow regimes", so they cannot be influenced. They are influenced, they are negatively influenced. In so much as some of these habitats were designed, they were designed to "not be death traps" in low flows. Not to work optimally. During those lowest flow years there would be refuges. It is a sin they are dismissed as engineered or artificial or less ecologically important. "Wild" fish use them and use them very effectively. One of our major fundamental objectives was to maximize wild fish populations. The FTC noted that the operational definition of a "wild fish" refers to any fish hatched in a non-hatchery setting, regardless if one or more of the parents was from a hatchery. These are all wild fish and their habitat needs to be on the tally sheet.

Page 6: Ecological: An extreme oversimplification see previous notes re side channels and dykes etc. The access to side channels has not been cut off. The list of side channels that are <u>not</u> cut off include BCR Channel, BCR Mile 49, Lower Paradise, Upper Paradise, Moody's Channel, Emerald Forest, Far Point East Swale, Birth of a Stream North and South, and Kisutch. Many of these are natural, untouched habitat. The rest are rewatered side channels.

Many of the braids seen in historic photos are flood channels and not actual habitat. A comparison of wetted area for given flows shows very little change in actual habitat availability in the flows currently sustainable with the dam in place. Some of the earlier air photos in particular were just after the floods of record and before construction of the dam. With these extreme flows and without the dam's 15% attenuation, you would expect that the river changed dramatically. There are still lots of room in the river for significant changes, but not before we once again get flows in excess of 1000 cms.

NVOS perspective on relationship of mainstem flow to side channels is illustrated in the following 3 figures (figures not to scale, looking downstream).

figure 1a. NVOS Eagle Point:

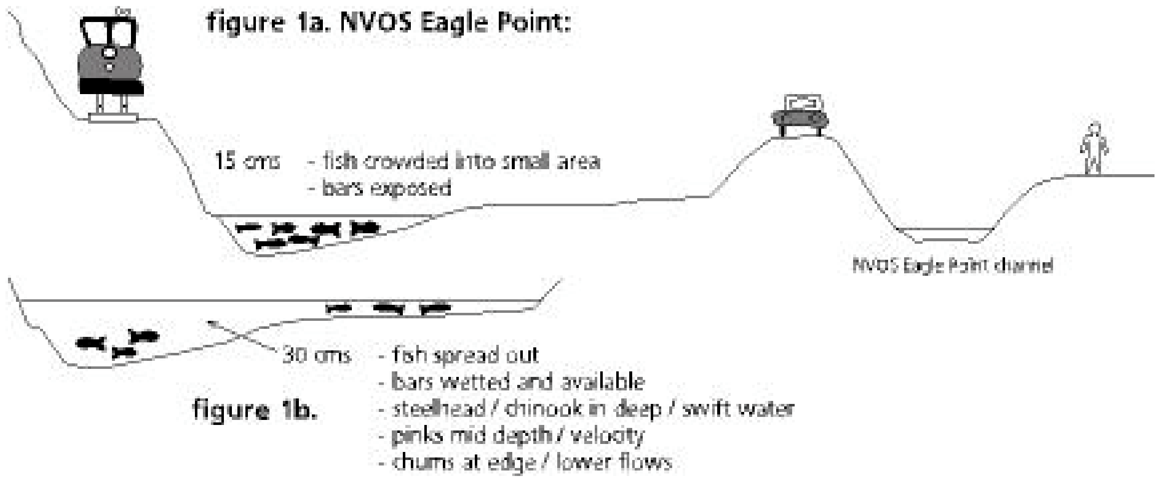

figure 1b.

figure 2. NVOS Canoe Pond: typical cross section

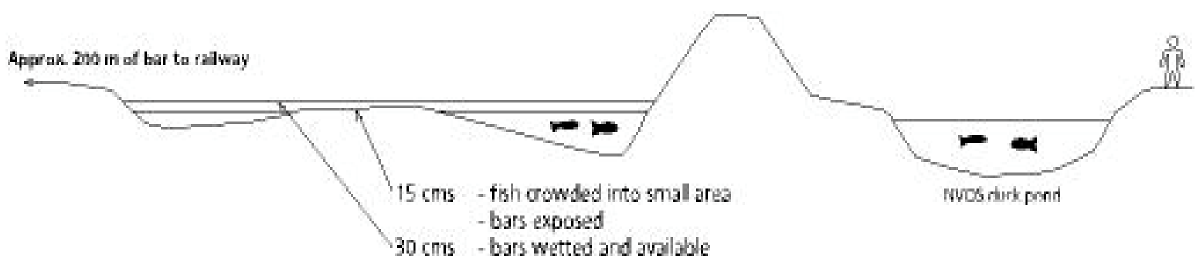

figure 3. NVOS Kisutch Refuge Channel / Upper Paradise Channel: typical cross section

The Cheakamus Water Use Plan Consultative Committee Documents CD-ROM

Here is the Cheakamus Water Use Plan Consultative Committee Documents CD-ROM. You need a computer equipped with a CD-ROM drive and Windows 95 (or more current) operating system to use it.

Appendix 8 of the consultative report contains further instructions and the Table of Contents, the Table of Contents is also in a file called "CD Table of Contents.pdf" in the root directory on the CD-ROM.

You will need Adobe Acrobat Reader (freeware, copy provided on CD-ROM), MS Access, MS Excel and MS Word to access all files.