Campbell River Water Use Plan

Monitoring Program Terms of Reference

- **JHTMON-15 Elk Canyon Smolt and Spawner Abundance Assessment**

September 20, 2013

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1 Program Rationale

1.1 Background

The value of Elk Canyon[1] as fish habitat was not fully appreciated until a base flow of 3.5 m^3/s was provided as part of an interim flow management strategy developed in 1997 (Campbell River Hydro/Fisheries Advisory Committee). Field investigations since the release has shown a dramatic increase in the use of the canyon as juvenile rearing and salmonid spawning habitat; all salmonids species appear to use the canyon for at least part of their life history. Despite this noticeable increase in canyon use, there was a general belief among fish biologists that further habitat increases were possible with additional flow releases. Evidence for this however, was largely anecdotal.

Unfortunately, there were insufficient resources during the Water Use Plan (WUP) process to further explore the relationship of habitat availability versus flow. As a result, rather than using flow habitat relationships to aid decision making as in other parts of the watershed, a flow prescription was developed based on the professional opinion of several biologists (all members of the Fish Technical Subcommittee or FTC) following a number of site visits and snorkel swims at the site. Recognizing that the release of water to the canyon reach comes at considerable cost in terms of lost generation, the FTC recommended that the flow prescription be the start of a long term ‘titration’ study with the aim of modifying the prescription at regular intervals (i.e., WUP Review intervals) based on the results of the preceding interval’s monitoring program (i.e., this monitor is structured as a passive adaptive management study).

From the swim-based anecdotal observations and general experience in the watershed, the FTC identified three critical areas believed to be constraining the canyon’s full potential as a critical spawning and rearing area. These were:

1) A minimum base flow for egg incubation and juvenile rearing;

   Though a base flow of 3.5 m^3/s appeared to provide considerable new usable rearing habitat, there was a general belief that additional flows would further increases fish habitat given the area of dry channel at this flow.

2) Flow pulses to attract spawning fish to move up the canyon in search of spawning habitat, and;

   Snorkel observations suggest that, downstream of Elk Falls, there are no barriers to upstream migration at base flow levels. However, several FTC members believed that a constant base flow would not be sufficient to trigger the movement of spawning fish up the canyon in search of suitable spawning habitat, and that higher flows would be required, particularly those that mimic stream responses to storm events. Though there was some evidence in support of this hypothesis from a video camera study carried out during the WUP, the results were far from conclusive (Bruce et. al 2003).

[1] Elk Canyon lies immediately downstream of John Hart Dam and forms part of the spillway facility.

3) Higher base flows during the spawning period to maximize the area of suitably wetted substrate.

   Though much of the canyon bottom was wetted at the base flow, anecdotal observations indicated that there were a number of suitable gravel deposits at the channel margins that were either above the water line or were not sufficiently covered with water to be usable. Higher flows would be required to mitigate the issue and hence increase the area of spawning habitat. Total area of spawning habitat in the canyon reach is not considered to be very high, so the addition of the dry areas would add greatly to the spawning potential of the reach. Since the WUP process, there have been several additions of gravel to the canyon reach in attempt to further increase available spawning habitat.

Based on the available information at the time, the FTC recommended that the following flow prescription be implemented as an attempt to maximize fish use in the canyon;

1) Provide a minimum base flow of 4 m^3/s.

   This is only 0.5 m^3/s greater than the pre-WUP release, but was deemed to be adequate as further increases were believed to increase average stream velocity more than water depth.

2) Provide 2-day pulse flows of 10 m^3/s every two weeks in spring (February 15 to March 15) as an attraction flow primarily for spawning steelhead (though other spring spawners may benefit from this).

   The choice of 10 m^3/s as the peak magnitude and the timing of these pulses were based solely on professional judgment. The video survey work of Bruce et al. (2003) was done in the fall and therefore is only applicable to fall spawners. Whether the prescription is suitable for spring spawners is unknown.

3) Provide a two week spawning minimum flow of 7 m^3/s starting April 1-15.

   Whether 7m^3/s is sufficient to maximize spawning in the canyon is unknown as its selection was based primarily on professional judgment in light of high cost of delivering such flows. An additional constraint was the need to keep fish from spawning high on the banks which would be dewatered when the normal base flow of 4 m^3/s is resumed.

4) Provide 2-day pulse minimum flows of 7 m^3/s every week in the fall (September 15 to November 15) as an attraction flow for all fall spawners that could potentially use this reach.

   The choice of 7 m^3/s as a peak flow was based on the video survey work of Bruce et al. (2003). The timing of these pulse flow events was based solely on professional judgment. No spawning flows are to be provided in order to keep fish from spawning on banks that would be dewatered with the resumption of minimum base flows.

The prescription above was considered by the FTC as a starting point in a 'titration' type study that would progressively change the flow regime as new information is gathered; alterations are only to be considered during WUP reviews when trade-offs with other values in the system can be examined. In order to successfully follow through with this 'titration' approach to flow setting, it is essential that a monitoring program be developed and implemented to track the success or failure of the flow prescription in meeting its management objectives, as well as use the outcome of the monitor to increase the knowledge and understanding of flow relationships in the canyon reach.

1.2 Management Questions

This monitor is designed to address the following management questions based on the rationale used to derive the Elk Canyon flow prescription:

1) Is the prescribed 4 m^3/s base flow sufficient to increase juvenile rearing habitat to near maximum values? If not, by how much should the base release increase (or decrease) and what would be the expected gain in habitat area?
2) Does the 2-day, 10 m^3/s pulse release every two weeks trigger the upstream migration of spring spawners as expected? If not, is this the result of inadequate pulse magnitude, duration or some combination of both attributes? Or conversely, is the pulse attraction release unnecessary?
3) Is the 2-week long 7 m^3/s spawning flow effective at increasing available spawning habitat to spring spawners? If not, by how much should the spawning release increase (or decrease) and what would be the expected gain in habitat area?
4) Does the resumption of base flows following the spawning release keep redds adequately wetted throughout the egg incubation period as expected? If not, what should the spawning release be to ensure all redds are wetted at the base flow?
5) Does the 2-day, 7 m^3/s pulse release every week trigger the upstream migration of fall spawners as expected? If not, is this the result of inadequate pulse magnitude, duration or some combination of both attributes? Or conversely, is the pulsed attraction release unnecessary?

In addition to the hypothesis based questions above, the following management question concerning the general success of the flow prescription is also addressed:

1) Following implementation of the WUP flow prescription to the Elk Canyon reach, has the general fish productivity of the reach increased as expected? If a change is apparent, whether positive or negative, can it be attributed to WUP operations? Conversely, if no change is apparent, are some or all elements of the flow prescription still necessary?

   This management question will be difficult to address directly as there will be no pre-WUP data for comparison. Rather, it will have to be addressed indirectly from the outcomes of Questions 1 through 5, as well as the results of other monitors that focus sampling effort on lower Campbell River downstream of the John Hart facility.

1.3 Summary of Impact Hypotheses

There were several logistical constraints to overcome when designing the terms of reference for this monitor; all stemming from the fact that all sampling is to take place in a steep canyon environment that is part of the spillway route for the facility. Because it is part of a spillway, it is subject to flooding that can at times be very sudden, putting stationary sampling equipment at considerable risk of flood damage.

For crews working in the canyon, there will be no escape if there is a sudden change in release, making the work potentially hazardous should there be a communications failure. The canyon walls are for the most part steep and unscalable except when using specialized equipment. Historically, fish surveys in the reach have been done by snorkel only; either walking up from the entrance or being dropped off by helicopter several kilometres upstream of the canyon mouth. For the purposes of this Monitor, reliance on helicopters landings in the canyon should be minimized. Detecting relative amounts of spawner migration up the canyon around pulse flow will be completed using underwater videography (i.e., Didson or Blueview cameras), or resistivity counters followed by verification using an independent method such as observations using overflight photography or direct observation. The only easily accessible part of the canyon is the first 100 m or so upstream of the canyon entrance.

The ability to carry out habitat studies is also made more complex because of the canyon environment. Though safety and access are issues, particularly at higher flows, the main concern is the high level of channel complexity that makes it very difficult to consistently measure and model habitat suitability over a broad range of flows. For example, survey pin installation to mark the location of transects for repeated measurement would require specialized equipment to get through the bedrock and large boulders that make up much of the channel margin, particularly at elevations higher than the maximum flow of interest. More sophisticated survey techniques would have to be employed to establish pin elevations and traverse coordinates. Furthermore, because of the rough terrain that must be traversed, all but the simplest equipment will be subject to considerable risk of water or mechanical damage.

Management Question 1 concerning the magnitude of the base flow and its impact on available habitat will be addressed through test of the following impact hypothesis:

$H_0$1: Carrying capacity of the Elk Canyon reach, as measured by annual smolt outmigrant counts does not vary as a function of discharge.

Assessing smolt production of two target species, steelhead and chinook, will be done to draw conclusions about the overall effectiveness of pulse flows for adult migration, spawning and rearing. For steelhead, there is potential for confusion in the results to be generated by over-wintering immigrants to the canyon. To provide greater clarity, counts of steelhead redds will be used in combination with smolt outmigration data to determine if pulse flows are having an effect on Elk Canyon capacity.

The chinook using the canyon reach are ocean-type, meaning their fry will spend 2-5 months in freshwater after emergence, and then move into the estuary. Because the in-river rearing period for these chinook is relatively short and their first migration takes them to the estuary (McPhail, 2007), there is little risk of outmigrant counts collected in the canyon to include over-wintering immigrants.

It is important to note that to test this hypothesis, carrying capacity estimates will have to be collected at several different discharges. At the time of the flow prescription was developed, the general belief among the FTC was that a WUP review would occur every five years, allowing different discharges to be tested following each review; as in a ‘titration’ type study. However, during the last WUP meeting, there was consensus among the Consultative Committee (CC) to extend the review to ten years. This has implications on the present study in that there would be no opportunity to examine the effect of alternative flows for at least ten years. Collection of data at the same flow for the duration of the monitor could be a waste of sampling effort as carrying capacity can be estimated with reasonable degree of precision in as little as three years; assuming that the reach is fully 'seeded' each year. It is strongly recommended that alternative base flow releases be considered such that the average base flow for the duration of the monitor approaches 4 m^3/s. An example may be three years at 3 m^3/s, four years at 4 m^3/s, and another three years at 5 m^3/s if adequate seeding is reasonably certain. This concept is discussed further in Section 2.1.

Carrying capacity in the present context can be viewed as containing two components; the first consisting of fish that complete their life cycle from egg to smolt within the reach (here referred to as rearing residents, but which also over-winter in the reach) and the other consisting of immigrant juveniles that enter the reach only to over-winter (over-wintering immigrants)

The second testable hypothesis is:

$H_0$2: The number of rearing residents deemed likely to smolt the following spring, as measured during late summer, is not significantly different from the abundance estimate obtained in late winter just prior to the onset of their out-migration.

As alluded to above, the test of $H_0$1 can only be valid if the available habitat is fully seeded following emergence. This requirement leads to another set of hypotheses, which now pertain to Management Questions 2 and 5. The first hypothesis of these is concerned with the pulse flow operation;

$H_0$3: The rate of spawning salmonid in-migration (No./day) during the 2-day pulse flow release operation is not significantly different from that during the base flow operation.

This hypothesis is to be tested separately for steelhead during the spring operation when the pulse flow operation consists of a 2-day, 10 m^3/s release every two weeks, and for chinook during the fall when the operation consists of a weekly 2-day, 7 m^3/s release.

$H_0$4: The rate of spawning salmonid in-migration (No./day) during the first day of the pulse flow release operation is not significantly different from that during the second day.

This hypotheses would be tested separately during both the spring and fall implementation of the pulse flow regime. The aim of the spring pulse release would be to stimulate summer-run steelhead to move up the canyon. The fall pulse would likely stimulate all salmon species holding in the canyon; hence this test would look at this assemblage as a whole. This test will provide the information necessary to determine whether the 2-day pulse duration is necessary or whether an extension should be considered.

The preliminary work done by Bruce et al. (2003) showed that the fall spawners that migrated into the canyon during a pulse release did not necessarily stay in the reach following the resumption of base flow operations. The reason for this is uncertain, and it is unknown whether the response would be similar among spring spawners. This leads to the next hypothesis:

$H_0$5: The estimated number of spawning salmonids following pulse flow release operation is not significantly different from that just prior to the release.

Hypothesis $H_0$5, is to be tested during the spring implementation period to determine whether the response of spring spawners is similar to that observed among the fall spawners. In the fall, test of this hypothesis will determine whether the preliminary observations of Bruce et al. (2003) persist throughout the spawning period.

The next two hypotheses are concerned with the spawning capability of the reach for steelhead as it relates to the 2-week, 7 m^3/s spawning release, i.e., Management Question 3:

$H_0$6: The estimated number of spawning steelhead during the 2-week, 7 m^3/s spawning release period in spring is not significantly different from that observed just prior to the operation.

Hypothesis $H_0$6 will test whether sustained higher flows would attract and retain a greater number of steelhead than the previous six weeks at the base flow with the pulse releases.

Though Hypothesis $H_0$6 may be considered as one indicator of spawning capability, a more definitive test would be based on the number of observed redds. There is however, some uncertainty as to steelhead redds in the system will be easily identifiable. For the purposes of TOR development it is assumed that it is, leading to the next hypothesis:

$H_0$7: The number of redds found above the base flow water level (minus a nominal depth to take into account that steelhead will not spawn in very shallow water, e.g. 10 cm) following the 2-week spawning release is not considered significantly different when compared to the total number of redds in the reach.

Critical to the test of Hypothesis $H_0$7 is the development of what can be termed a significance threshold. In the absence of developing such a threshold, individual investigators will have to draw their own conclusions based on the data provided.

The next hypothesis deals with Management Question 4 and follows the same format as Hypothesis $H_0$7, but with a different water line threshold:

$H_0$8: Following resumption of base flow operations, the number of steelhead redds found above the water line and therefore at risk of egg mortality from stranding is not considered significant compared to the total number of redds in the reach.

As in Hypothesis $H_0$7, this hypothesis will be difficult to test, the main problem being the concept of establishing a significance threshold. In the absence of developing such a threshold, individual investigators will have to draw their own conclusions based on the data provided.

The last hypothesis is a final check to make sure that the assumption of ‘full seeding’ needed to test Hypothesis $H_0$1 is satisfied. Note that the hypothesis is concerned only with that portion of the total smolt count that has spent their entire freshwater lifecycle in the reach. Over-wintering carrying capacity is considered to be a separate entity. It too requires an assumption of full seeding. A test of this assumption however is not considered necessary at this time as the population of smolts downstream of the canyon is believed to be considerably larger than the number of individuals that over-winter in the reach. The last hypothesis is as follows:

$H_0$9: Annual abundance of 'resident' smolts is not correlated with an index of steelhead spawner abundance.

This hypothesis is to be tested separately for each species. Tests within each flow trial as well as across all flow trials can be combined into a single analysis using ANCOVA techniques, provided that all statistical assumptions are met. Because there are few steelhead using the canyon for spawning, there will likely be a need for using data analyses which are alternatives to traditional parametric statistical approaches.

1.4 Key Water Use Decision

Because of insufficient information, the FTC had to rely mainly on professional opinion as the primary means of estimating the flow requirements of the Elk Canyon reach. Other than a general belief that the canyon required more flow to maximize habitat availability for both juvenile and spawning salmonids and that attraction flows were necessary to get fish to migrate into the area and fully seed it, there was little empirical data that went into the design of the flow prescription. As a result, there is a significant chance that some aspects of the prescription may be inadequate to achieve the intended objective, or that it may be unnecessary because of a misperceived need.

The cost of either error can be significant. From the fish habitat perspective, it may hinder the capability of the reach to fully realize its productivity potential, particularly for steelhead trout which are experiencing a general decline in population. It may also apply to the river spawning sockeye salmon that appear each year in low numbers to spawn in the mainstem (including the Elk Canyon reach). Conversely, each 1 m^3/s released per day through the spillway is considered to be very valuable, thus the cost of unnecessary releases can quickly amount to significant generation losses per year.

Recognizing the risk involved, the CC recommended the flow prescription with the intent to treat it as a starting point in a 'titration' style experiment. The information gathered by the monitor will be used to gauge the success or failure of each component of the flow prescription in how it achieves its intended objective and in turn, develops the knowledge base to alter the prescription as necessary to make it more effective and cost efficient during the next WUP review period.

2 Program Proposal

2.1 Objective and Scope

The objective of this Monitor is to address the management questions presented in Section 1.2 by collecting data necessary to test the impact hypotheses outlined in Section 1.3. The following aspects define the scope of the study:

1) The study area will consist of the Elk Canyon reach of the Lower Campbell River from its entrance by the John Hart generating station (at the first riffle above the pedestrian bridge) to the Elk Falls.
2) The species of primary concern include steelhead trout, chinook salmon and coho salmon, though other salmonid species known to use the system are not to

be ignored if encountered. Steelhead and chinook have been chosen as index species in this study, primarily because steelhead are the only spring spawners in the system, and chinook as an indicator of fall spawner response while having minimal interaction with rearing, immigrant smolts. It is assumed that management action concerning the index species will provide ancillary benefits to the other species as well. All stages of the fresh water cycle are to be considered in this monitoring study.

3) The Monitor will be carried out annually until the next WUP review period (5 and 10 years following WUP implementation).
4) Sampling will be carried out in a standardized manner and follow a specified schedule to ensure consistency among years in data quality and collection procedures.
5) A data report will be prepared annually, summarizing the year's findings. All data will be archived into a standard format in consultation with BC Hydro staff.
6) A summary report will be prepared in Year 5 summarizing the data collected to date, discussing inferences and presenting conclusions.
7) A final report will be prepared at the end of the Monitor that summarizes the results of the entire Monitor, discusses inferences that can be drawn pertaining to the impacts of the WUP over time, and presents conclusions concerning the management question in Section 1.2 and the impact hypotheses in Section 1.3.

2.2 Approach

The Elk Canyon smolt and spawner abundance monitor will be carried out as a series of interconnected parts, each focused on addressing a specific hypothesis and with different durations over the course of the monitor. The two main sampling techniques to be employed in the monitor are snorkel swim counts and rotary screw trap enumerations. Under water video will also be employed as described by Bruce et al. (2003). The approach to the monitor is summarized in Table 15-1.

Table 15-1 Summary of approach to the Elk Canyon smolt and spawner abundance monitor

Study Component	Impact Hypothesis	Management Questions	Sampling Approach	Duration
Smolt Enumeration	H_01	1	Rotary screw trap enumeration of salmonid smolts during out-migration period	Annually
Over-wintering assessment	H_02	1	Snorkel survey of salmonid juvenile in late summer and just before onset of seaward migration	Annually
In-Migration Pulse flow Assessment	H_03, H_04, H_05, H_06	2, 5	1. Underwater videography surveillance/index or resistivity counter output for migrating spawners at canyon entrance. Done both in spring and fall. 2. Overflights or other independent method to verify spawners did not move back down after pulse ended.	Annually for 3 years
Steelhead Spawning Release	H_06, H_07, H_08	3, 4	Snorkel and redd count before and immediately following the release. Comparison to stage-discharge curve.	Annually for 3 years
Spawner Enumeration	H_09	1	Area under the curve spawner abundance index calculated from spawner count data. May require additional swims outside the spawning periods as defined in the flow prescription. Following initial three years of data collection, counts will continue, but not necessarily with the same frequency.	Annually

2.3 Methods

2.3.1 Data Capture

This monitor has been designed to minimize use of helicopters to ferry crews into the upper canyon. Year 1 of data collection is considered to be effectively a baseline study to verify the proposed methods. In February of Year 1, the contractor would access the upper canyon via helicopter and establish permanent benchmarks and flow transect locations under base flow conditions. The benchmarks would be used to gauge the water surface elevation in areas around steelhead redds under base flows as well as pulse flows. The contractor will record the location of any steelhead redds observed during this trip for future reference during pulse flows. Canyon sections should be marked in the field so that they are readily recognizable when carrying out the habitat surveys, spawner counts and redd searches. This reconnaissance exercise should include the marking of all potential hazards on the river.

Once steelhead spawning locations have been identified, flow transects should be completed to produce a stage-discharge curve. The stage-discharge curve will help determine flow releases required to accommodate steelhead spawning.

The use of underwater videography or resistivity counters for providing an index of fish moving up the canyon needs to be tested and troubleshooted in Year 1. Mounts for the cameras must be set up on the canyon banks so they can be removed should notice of an imminent spill be announced. The camera angle, height and specific location must be verified to be effective in detecting fish that are moving past the camera. Once the underwater counts have been successfully obtained, there will be a need to test and verify the estimates of spawner movements.

2.3.1.1 Smolt Enumeration

Trapping Methodology

Smolt enumeration will be carried out using a single 1.8 m rotary screw trap (RST) located at a suitable location within the first 200 m upstream of the canyon entrance. The RST installation should employ anchors and rigging of sufficient strength and flexibility that the trap can be moved as required to ensure effective fishing over the full range of test flows, including the pulse flows. Because the trap will be located in a relatively confined section of canyon and will always be under threat of sudden spills (up to 1,680 m^3/s), a mechanism should be in place to be able to move the trap out of harm's way for the duration of such events. Should the trap break free of the rigging, a failsafe mechanism should be in place that would allow easy recovery. A rigging expert should be employed to plan and implement the installation process. Training should be given to the operators to ensure that they are fully versed in the rigging's operation, and are therefore capable of responding to all eventualities.

Where necessary, installation is to include the appropriate use of sand bags to improve volume and direction of flow to the trap over the range of operational flows. It will be fished continuously from the last week of February to the end of June which is typically the period of smolt out-migration for the primary species of interest (to be confirmed with local fish agency staff).

Sampling will be carried out by a two-person crew, who will need to ferry to and from the site by a 'car-top' boat equipped with an outboard motor. A sampling platform/shelter should be installed in a safe area to facilitate the processing of fish. If necessary, rigging should be installed to move the platform/shelter out of harm's way in the event of a spill. It will be up to the contractor, in consultation with the BC Hydro facility staff and an expert rigger, to determine the necessity and feasibility for such a structure.

The traps will be maintained and adjusted as required to ensure consistent trapping conditions through time. Gear efficiency will be determined twice weekly for both fry (0+ fish < 70 mm FL) and smolts (fish > 70 mm FL that have over-wintered at least one year). Separate estimates will be obtained for each critical discharge of the flow prescription. Fry will be marked using Bismark Brown dye (1-2 hour immersion in 10 ppm solution) while smolts will be caudal fin clipped. The marked fry and smolts will be released at a location accessible by foot upstream of the trap; the farther upstream the better as this will increase the likelihood of complete mixing among the unmarked population. If possible, the frequency of measurement will be reduced to once a week if it is determined that precision and accuracy will not be compromised by the action.

Captured fish will be sub-sampled for measurement of fork length (mm FL) and wet weight (g). Sub-sampling will be done daily to ensure an even distribution of effort through time. Intensity of sub-sampling will be at the discretion of the crew (e.g., a minimum of 10 individuals) but must be based on a standard sub-sampling protocol (e.g., every x^{th} individual or be evenly distributed among the catch) and be consistent through time to minimize error.

Study Design

As previously described in Section 1.1, the current WUP only prescribes a single base flow for the duration of the WUP implementation period. At the time of the WUP process, much of the discussion on monitoring was based on the assumption that the implementation period would only last five years, leading to the general notion of carrying out the monitor as a ‘titration’ study. Data would be collected for the 5-year period after which a review would be carried out and an alternative would be proposed for additional study following a full WUP trade off assessment. With the present WUP, the implementation period was extended to 10 years. Though one could proceed with the original intended study design and just extend it into a 10-year program, this would not be the best use of sampling effort unless it was known that the habitat is not fully seeded each year. Alternative designs are possible that would provide greater amounts of information at the end of the 10-year implementation. These designs however, would require that the assumption of full seeding be met each year. One example of such a design would be to be estimate carrying capacity for three years at 3 m^3/s, four years at 4 m^3/s, and another three years at 5 m^3/s.

Because the degree to which the Elk Canyon reach is seeded each year is unknown, the best approach to the present monitor would likely be to reserve judgment on which design to use until at least four years of data have been collected. At this time, there should be sufficient information to determine the likelihood of full seeding and in turn decide the best design approach. If escapement and smolt abundance are found to be correlated and appear to follow a Beverton-Holt relationship, the study would continue unchanged until the end of the implementation period in order to better characterize the relationship. If on the other hand escapement and smolt abundance are found to be uncorrelated and smolt abundance tends to be consistent through time, then alternative designs such as the one described above should be considered as this would dramatically increase the available information for use at the next WUP review.

2.3.1.2 Over-wintering Assessment

Over-wintering assessments will consist of snorkel swim counts of parr during the latter part of the summer growing season (late September to early October) and of smolts just before the onset of smolt out-migration (early February). The focus will be on steelhead and coho; the two larger smolt species.

The snorkel counts will be carried out by a crew of two swimmers swimming in tandem with a third crew member acting as a recorder of all observations. A total of three snorkel counts will be made per sampling session (i.e., late summer and in winter). The counts are to take place on successive days when possible and are to be carried out by the same crew on each occasion. Crew roles should be rotated on each occasion in order to evenly spread out observer bias. As indicated above, the crew is to start at the same location on each occasion to ensure that the same distance of river is covered for each estimate. The sampling procedure is to be repeated by the same crew in winter as in the late summer period to ensure that consistent crew bias between sampling sessions.

For the purposes of this study it is assumed that over-wintering survival in the canyon reach is the same for both resident and immigrant smolts, though that may not necessarily be the case. Test of this assumption is considered to be outside the scope of the present study.

2.3.1.3 Pulse Flow Assessment

To assess the effect of increased flows in the canyon on upstream migration by spawners, pulse flows will be assessed in terms of the corresponding changes to fish location. The pulse flow assessment methodology is expected to use underwater videography (e.g., a Didson camera) and/or a resistivity counter, as well as an independent method to verify the net movement of salmonid spawners to areas further upstream in the reach.

Underwater Counts

Spawner movement during the spring and fall pulse flow events will be recorded by continuously recording underwater videography or a resistivity counter. The surveillance procedure is to begin on the day before the pulse flow event in order to get a baseline rate of net movement (number of immigrating individuals – the number of out migrating individuals). The daily recording of net movement continues over the course of the two-day pulse flow event and is then followed by one more day of baseline data collection. Counting methods which are effective in day or night conditions are expected to provide the most representative record of fish migration. The spawner-counting technology solution proposed will have to consider the power and memory requirements of the suggested approach, and recognize that there is no power source in the canyon and limited, if any, potential for supplementation through solar panels. Changing camera batteries and media storage units during spring pulse flows is expected to coincide with daily RST checks; however the fall recording sessions may require dedicated trips to the site to maintain the video equipment. Because of the required lock-out procedures and time needed for travel to the site, plans should be made to optimize the camera power and memory requirements and/or capacity.

During the first year of the Monitor, extra attention and effort will be needed to ensure the underwater counting method is effective and minimizes ambiguity in the results generated. Contractor teams should demonstrate prior experience in successful use in the proposed methodology and address the potential pitfalls of working in remote, underwater locations.

At the conclusion of each pulse flow event, or as time allows, the crew will be tasked with analyzing the count data records for evidence of fish movement; time of the event and direction of movement where possible. If enumeration of recorded fish becomes an automated process, project teams will need to provide assurance that generated counts are consistent with manual counts. The consultant's team would also need to include a contingency item for efforts needed to remove the counting equipment in the event of a planned spill release through the canyon. Low flows in the canyon would be provided during install and removal of counter pads or cameras and several days of notice would be provided ahead of a spill event.

Snorkel Swim Counts

Snorkel swim counts will be carried out every week starting two weeks before the pulse flow regime is to begin. This applies to both the spring and fall spawning periods. The counts are to continue until one week after the spawning release operation in spring and two weeks (if necessary) after the pulse flow operation in the fall. Where possible, the crew should strive to maintain a consistent interval between swims, though it is recognized that this may not always be possible. The counts should be focused on the species of primary concern, steelhead trout in the spring, and chinook and coho salmon in the fall. Though data on other species should be recorded, there will be no provision for subsequent analyses.

The swim counts are to be carried out by a three-person crew that will walk to the top of the accessible portion of the reach for each swim. Two crew members will be assigned the role of 'counters' and will be expected to swim in tandem counting spawners as they move downstream. The third person will act as the recorder of observations and act as back-up for safety purposes. As noted above, the canyon reach is to be broken down into short sections so that crews can regroup and communicate their observations to the recorder on a regular basis. This will ensure consistent data recording as well as provide a distribution map of spawners. To minimize the effect of observer bias, the crew should rotate their roles per trip.

It should be noted that the swim counts during the fall period will unlikely provide useful information on their own as there will be no contrasting treatments to highlight possible effects. During the spring counts, two weeks separate the pulse flow operation allowing one to group the weekly counts into those during which had a flow pulse and those that did not. This is not the case during fall when the pulse flows are provided every week. Rather than abandon the fall weekly counts, which are still needed for the spawner enumeration component of the monitor, it is strongly recommended that at least one (preferably two) pulse flow interval be extended to two weeks; preferably around the peak spawning period when in-migration 'pressure' can be considered constant. If done at other times, it will likely be too difficult to ascertain whether an observed difference is due to a treatment effect or simply reflects the natural periodicity of the migration event. The extended pulse flow interval would provide at least some contrast during the fall spawning period to test whether the pulse flow operation increases the spawning capability of the reach.

2.3.1.4 Steelhead Spawning Flow

The Steelhead spawning flow component of the monitor will comprise of two parts; the first being the collection of spawner abundance data by snorkel count before and after the spawning flow; and the other consisting of a redd count and assessment following the flow with particular attention on the distribution and elevation of redds relative to the river stage elevation.

Following the spring pulse flow (2-week, 7 m^3/s spawning release) treatment, the snorkel team will enter the upper canyon to evaluate the number of redds as well as to measure the elevation of the redds in relation to permanent benchmarks. The water depth and elevation of redds in relation to installed survey benchmarks will provide critical information on water flows best suited for spawning. While redds are being assessed, adult steelhead observations will also be recorded as well as notes on behaviour and condition.

The contractor is to complete a hydrological transect at each spawning site in areas of the canyon where steelhead spawn. If the sub-reach conditions of several spawning sites are considered to be represented by a single transect, then the number of transects can be reduced. The transect(s) will be used in conjunction with the discharge data from the John Hart Dam operation to produce a spawning-site-specific stage/discharge curve. The curve will need several data points, including 3.5, 5 and 7 m/s^3. The contractor will work with BC Hydro staff to coordinate transect surveys and operational flows to produce the stage/discharge curve. This curve may be completed over several years of the monitor. Once complete, the stage/discharge curve should allow resource managers better address the question of spawning flow effects for steelhead redds.

Snorkel Swim Counts

Before the two-week steelhead spawning flow release, a snorkel swim will be carried out to count the number of steelhead spawners in the system. Once the pulse flows have ceased, the snorkel team will repeat the snorkel survey. The counts are to be carried out by a three-person crew, two of which will be swimming in tandem counting steelhead spawners, and the other serving as a recorder of observations and as back up for safety reasons.

Redd Counts

A redd count survey will be carried out concurrent with the post-flow snorkel survey. The survey will be carried out by a three-person snorkelling crew. As in previous surveys, the crew will start at the same location for every swim. The crew will then swim and walk the channel in search of steelhead redds. As each redd is encountered, its location relative to water level will be recorded. Crew roles should be rotated per trip to distributed bias evenly.

The flow transects and subsequent stage-discharge curve for each spawning area will be compared to the redd elevations. Using biostandards data for preferred steelhead spawning depth(s) and the stage-discharge curve, the contractor will determine the corresponding flow release needed to provide sufficient stage elevation for steelhead spawning in the canyon.

2.3.1.5 Spawner Enumeration

The spawner enumeration component of the study will largely be a meta-analysis exercise of all of the verified, videography count data collected during each of the October-November and February-April sampling sessions. The meta-analysis, consisting mainly of area-under-the-curve analyses, will be carried out separately for both sampling sessions. If the trend data indicate that the spawning period still has not come to an end, additional swims counts may be required (to be determined in consultation with BC Hydro and DFO hatchery staff). Up to two extra snorkel swim counts have been included in this terms of reference. The same snorkelling methodologies should be used as in the previous surveys to ensure consistency in the counts.

2.3.2 Safety Concerns

A safety plan will have to be developed for all aspects of the study in accordance with WorkSafe BC and BC Hydro OSH standards and procedures and guidelines. It is important to note that, because of the confined nature of the study area and the roughness of the terrain, all field work must be carried out by a minimum two-person crew and that all appropriate check-in and checkout procedures must be followed. The crew will be required to lock-out the JHT spillway gates for any work in the canyon and all access to the canyon must therefore be coordinated through BC Hydro. For canyon work crews, members should be physically fit, highly experienced with snorkel surveys and work in a canyon setting. The use of neoprene dry suits, whitewater kayaking/rafting helmets, and felt-soled wading boots should help reduce the risk of slip/trip hazards for crews walking up the canyon.

2.3.3 Data Analysis

All data will be entered into a common database in a BC Hydro standard format for subsequent analysis. This will ensure that data collected over the years are compatible and can be extracted and compared without concern regarding differences in file format. BC Hydro will provide direction on data entry and file formats. At the conclusion of the Monitor, the contractor will carry out power analyses to assess the detectable limits of the Monitor, e.g., the magnitude of change in smolt abundance that is necessary to considerate it a statistically significant response to a change in some treatment factor. Some adjustment may be required to presentation formats and analyses suggested below, following collection and review of data. Contractors and BC Hydro are expected to make adjustments to ensure that the best methods are used for analysis and presentation.

It should be stressed that the analyses described below are to be repeated for each species of interest. In addition, the assumptions of homoscedasticity, normality and independence are to be evaluated to the extent possible and where required, either an appropriate transformation algorithm is applied to the data set or an alternative equivalent, non-parametric statistic is used.

2.3.3.1 Smolt Enumeration

The smolt abundance data collected by RST will be analyzed using both pooled and stratified Peterson approaches to population estimation (Ricker 1975, Schwarz and Taylor 1998):

$$N = \frac{(M+1)\cdot(C+1)}{(R+1)} + Mortalities$$

Where,

N = population estimate
C = total catch
R = number of marked fish recaptured
M = number of marked fish released

Standard error of the population estimate, and hence confidence intervals, will be calculated using the Chapman hypergeometric model as described in Seber (1982). The maximum likelihood Darroch estimator should be considered when assessing stratification strategies and their consequence on bias (Seber 1982).

Analysis of the smolt population estimates to test hypothesis H_01 will depend on the results of the spawner enumeration component of the monitor. If smolt abundance is found to be independent of escapement index (estimated spawner population) and two or more flows are tested over the course of the monitor, the relationship between discharge and carrying capacity will be assessed using ANOVA techniques (a t-test in the case of a two treatment study). If smolt abundance and escapement are not independent, and there is sufficient data to adequately characterize a linear relationship (with appropriate transformations if necessary) for two or more flow treatments, then ANCOVA techniques will be used to look for significant differences, though these differences would not be expressed in terms of carrying capacity as when the data are independent. Rather, it would more likely be an indication of density independent egg to smolt survival. If there are no flow treatments, i.e., the base flow remains the same for the duration of the experiment, the analyses described above would not apply.

The analyses above should be carried out separately for each species, and more importantly, on the 'resident' smolts rather than just the over-wintering individuals (see the next section).

2.3.3.2 Over-wintering Assessment

In the absence of alternative access to the upper canyon, direct measurement data of over-winter juvenile survival is not anticipated. The following description is provided in the event an alternative for late summer and late winter juvenile counts in the upper canyon becomes available. Data analysis for the over-wintering assessment will consist simply of a t-test comparing juvenile fish counts in late summer with that of smolt counts in late winter. This will be a direct test of hypothesis $H_0$2. Because of the small sample size (three for each count), power of the test will be low, thus only large differences will be detectable. The contractor will be expected to include power analysis as part of the data analysis work in order to identify what these detectable limits are. This will aid in the interpretation of study results.

The test will be carried out annually for the duration of the study. In addition to the annual test of $H_0$2, the data will be analyzed for temporal differences in a two factor ANOVA with time (year) as another treatment factor. The lack of a significant temporal trend would allow the annual count data to be pooled and thus lead to a more robust test of the hypothesis. Rejection of the ANOVA test would indicted that some other environmental factor may affect the over-wintering behaviour of Campbell River smolts. Though the contractor is encouraged to explore possible causal links for the temporal trend, no formal analysis will be expected.

2.3.3.3 Pulse Flow Assessment

The verified counts from underwater count data are to be analyzed using a one way within subjects ANOVA of the following design where flow events are considered to be experimental units that are measured repeatedly on different occasions; in this case, days that bound the flow event:

Flow Event	**Before**	**Pulse Flow**		**After**
		Day 1	**Day 2**	
1				
2				
:				
:				
N				

In order to proceed with testing, it is imperative that the null hypothesis of no difference between the four trial days that bound each pulse flow event be rejected. If not, it may be concluded that there was insufficient variability in the data between trial days to indicate any kind of migratory response to the pulse flow operation and in turn, that both hypotheses $H_0$3 and $H_0$4 cannot be rejected. If however the ANOVA null hypothesis is rejected, then there is sufficient between-day variability to warrant a series of multiple comparisons the specifically test hypotheses $H_0$3 and $H_0$4. The multiple comparisons should follow the approach of Tabachnick and Fidell (1983) where weights are used to generate various multiple comparison tests with the condition that the sum of weights sum to zero and that at least two of the weights are assigned non-zero values. Some of the tests to consider include;

1, 0, 0, -1	Test of whether before and after observations are significantly different. If not, then these data can be pooled
0, 1, -1, 0	Test of whether observations during day-1 and day-2 of the pulse flow are significantly different (i.e., test of $H_0 4$). If not, then these data can be pooled
½, -½, -½, ½	Test of whether pooled observations during the pulse flow is significantly different from the pooled non-pulse flow period (i.e., one test of $H_0 3$). The comparison can only be carried out if both comparisons above are rejected.
½, -1, 0, ½	Test of whether observations during the first day of the pulse flow is significantly different from the pooled non-pulse flow period (i.e., another test of $H_0 3$). The comparison can only be carried out if the before/after comparison above is rejected, but that of the two days of the pulse flow are not.

It should be evident that other multiple comparison tests are possible, and that the choice of which ones to pursue will be dependent of the data itself and the need to test the hypotheses of interest.

Each comparison will be evaluated using an F test where a calculated F value will be compared to a critical F value (F_c). Because the comparisons are post hoc, the critical F value (F') will be equal to:

$$F' = (a\text{-}1)\ F_c$$

Where '*a*' is the number of treatment categories (in this case four days). The calculated F value is determined as follows:

$$F = \frac{n_c \left(\sum w_j \bar{Y}_j\right)^2 / \sum w_j^{\ 2}}{MS_{error}}$$

Where n_c is the number of scores in each of the means to be compared, w_j is the assigned weight for treatment j and $\bar{Y}_j$ is the mean of treatment j. Because this is considered to be a within-subjects ANOVA test, separate MS_{error} terms must be calculated for each comparison.

It should be noted that this analysis is to be carried out separately for each species of interest as well as for each year of the study.

The spawner count data will be examined for treatment effects by comparing counts during which there were no pulse flows to those of the previous and following weeks when there was a pulse flow. At present, this can only be done for the spring counts where two weeks separate the pulse flow operation. In this case, the weekly counts are split into two groups, those which follow a pulse flow event and those that do not. To test for an effect, the weekly count data will be arranged in a time series for trend analysis using the LOWESS procedure (Cleveland and Devlin 1988). The LOWESS trending/smoothing procedure is much like regression analysis, except that there is no *a priori* expectation of a particular trend shape; the data itself guides the development of trend lines. For each weekly count, the LOWESS procedure calculates a trended or smoothed value that can be used to calculated a residual value (i.e., Residual = Observation – Trend value). These residuals are then divided into the two aforementioned groups and tested for a significant difference using a simple t-test (i.e., this is a direct test of H_05 for Steelhead).

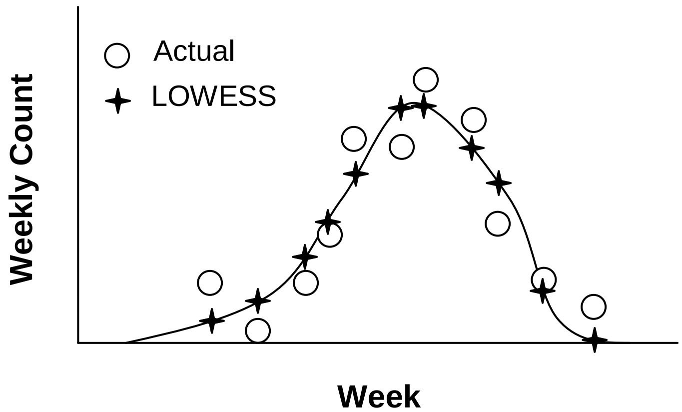

Figure 15a-1: Illustration of the weekly spawner count data analysis where LOWESS is used to approximate the underlying trend in the data which is then compared to actual observations to yield residual data. The residuals are then divided into pulse/no-pulse groups and tested for a significant difference in their respective means using a simple t-test.

With the current WUP operation, there is no provision for a contrasting treatment effect in the fall spawner counts. Thus, in the present state, no analyses regarding the impact of pulse flows are possible. However, should the Monitoring Advisory Committee and BC Hydro Operations agree to an extension of at least one pulse interval from the current one week period to two weeks, then the LOWESS technique described above can be applied as well. However, rather than grouping the residuals in preparation for a t-test, the one week of ‘no pulse’ data will be compared to the rest of the residuals using a simple z-test (Zar 1974).

2.3.3.4 Steelhead Spawning Release

Evaluating the effectiveness of the steelhead spawning release flows will focus on the stage elevation and the elevation of observed steelhead redds. The absolute accuracy of each elevation is not important, however the precision of the relative elevation differences will be critical in determining the importance of flow treatments on the redd habitats of the canyon.

The analysis will begin with plotting the water surface elevation at base flow and pulse flow with the observed redd elevations. The plots will consider the optimal depth required for spawning as well as minimum flows needed to ensure redds remain wetted. Over the initial three years of the monitor, the contractor will work with BC Hydro representatives to specify treatment flows releases needed, if any, to obtain data points needed for reduced uncertainty around flows needed for spawning and egg-fry survival. Input from the Fisheries Technical Committee may provide further clarity on depth for optimal spawning that may further refined these plots.

2.3.3.5 Spawner Enumeration

Spawner enumeration will consist mainly of Area-Under-the-Curve (AUC) analyses of the spawner counts. Where run timing over species is clearly distinct from others, counts may be separated by species; however, it is acknowledged that once migrations become mixed that all spawners may be grouped together. All of the count data for a given species and mixed species periods will be arranged in a time series after a trapezoidal approximation technique will be used to calculate AUC (English et al. 1992). At a minimum, the estimated spawning escapement '$\hat{E}$' in Elk Canyon will be estimated using the following equation:

$$\hat{E} = \frac{AUC}{s} v$$

Where 'v' is a correction for observer efficiency and 's' is the survey life, a measure of the mean number of days a spawner is thought to spend in the survey area. Because absolute counts of fish are not necessary for this monitor, observer efficiency can be ignored unless each year there is reason to believe that observer bias can fluctuate dramatically. If a camera is used to count the fish then the observer efficiency should be corrected.

The contractor will be expected to consult local biologists to determine a likely value for survey life. To aid the discussion, the contractor will also be expected to review the possible range of such values for a given species, or at the very least consult Perrin and Irvine (1990) where they provide some of this information. Uncertainty should be incorporated into the analysis where possible, following procedures such as those described in Parken et al. (2003).

Hypothesis testing should begin by plotting the 'resident' smolt abundance data as a function of escapement, which will be used as an initial subjective assessment whether the smolt data appear to be independent. Independence is considered to be an indication of a full seeding condition. Hypothesis testing will consist of simple correlation analysis, which will be done separately for each flow condition if allowed to vary over the course of the monitor. Where warranted, the data will be transformed to ensure that the assumptions of normality and linearity are satisfied. The plot should consider resident and over-wintering fish separately, as well as the population as a whole. These abundance estimates will be calculated by multiplying the smolt abundance data by the estimated ratio of resident to over-wintering juveniles (Section 2.3.1.2).

More complex model fitting can be done with this data set, but it is considered unnecessary for the present application.

The general approach to the monitor will be to collect a minimum of four years of escapement and smolt abundance data before the analysis above is first carried out. Based on the outcome of this analysis, a decision will be made as to whether the study should continue at the same base flow, or whether a new 'treatment flow should be tested. If the data are independent of one another, and the smolt abundance data is constant though time, it may be worthwhile to consider an alternative base flow regime to maximize flow habitat information for the next WUP review period. However, if the data are not independent, and there is a lot of variability in the smolt abundance data, additional data should be collected to better define the spawner smolt recruitment relationship. Data collection should continue until there is sufficient confidence in the shape parameters of the relationship, up until the end of the 10-year WUP review period.

2.3.4 Reporting

In general, project reporting will consist of annual data reports, a summary report in Year 5, and a final report at the conclusion of the Monitor.

Annual data reports will summarize the year's findings and include a short discussion of how the year's data compare to that collected in previous years. It will include a brief description of methods, present the data collected that year, and report on the results of all analyses.

The CC have requested that a summary report be prepared in Year 5 that collates all the data collected to date, summarizes all the analyses and presents a discussion of results as they pertain to the impact hypotheses in Section 1.3, and more importantly, to the management questions in Section 1.2. This will provide an early assessment of WUP operations in the study reach, though the implementation interval may be too short to determine with certainty whether the WUP was successful in meeting the intended fish benefits.

At the conclusion of the Monitor, a final comprehensive report will be prepared from all of the data and/or annual reports written to date that:

1) Re-iterates the objective and scope of the Monitor,
2) Presents the methods of data collection and analysis,
3) Describes the compiled data set and presents the results of all analyses,
4) Presents the result of all impact hypothesis testing and their consequence in terms of addressing the management questions in Section 1.2, and
5) Discusses the consequences of these results as they pertain to the current BC Hydro operations, and the necessity and/or possibility for future change.

Each year the final report will be due in spring of the year following the data collection period.

2.4 Interpretation of Results

2.4.1 Base Flows

The key hypothesis pertaining to the value of the base flow operations is H_01 which test whether carrying capacity of the reach changes as a function of discharge. Successful test of the hypothesis requires that several criterions be met. The most important of these is that carrying capacity is measured at a minimum of two different base discharges so that comparisons can be made. Over the ten-year time frame of the monitor, this can only occur if one can confidently determine whether the reach is fully seeded with eggs each year such that smolt abundance is relatively constant regardless of the number of spawners. Confirmation of this assumption is done through test of hypothesis H_09. If after four years testing of H_09 finds that smolt abundance is not correlated with escapement, the Monitoring Advisory Committee will be tasked with the decision of whether or not to recommend changes in the base flow operation, the magnitude of that change, and the likely duration of that change. It is entirely possible that the spawner abundance and smolt count data are indeed related and that, if no change in flow treatment is made over the course of the monitoring period, the hypothesis H_01 cannot be tested and will remain unresolved.

The test of hypothesis H_01 is not only relevant to fish that have spent their freshwater life in the reach. During the WUP the question was raised as to whether the fish numbers observed in the reach were due to in-migrants looking for suitable over-wintering habitat. If indeed the majority of fish in the reach are there simply to over winter, then the carrying capacity concept would only pertain to that part of the life cycle, and not necessarily to summer rearing conditions. Such a conclusion would call into question the value of the base flow discharge during the summer, but not necessarily in the winter.

In general, failure to reject H_01 would suggest that the proposed operational changes within the range of flows tested would have no measurable impact on carrying capacity of the Canyon reach. There may be a number of reasons for such a result:

1) There was only a minimal response to the treatments used,
2) The resolution of the Monitor was too low to detect a change (too small a sample size),
3) The change in base flow operations was too small to illicit a measurable ecological response (too small a treatment effects),
4) There is some other limiting factor that either that masks the ecological response to operational change, or
5) Some combination of the above.

The statistical resolution of the Monitor will be determined through power analysis at the conclusion of the Monitor when estimates of sampling error can be made. Results of the analysis will indicate the limits of detection for a change in fish population response and will put the results of the Monitor into the proper statistical context.

2.4.2 Pulse Flows

Hypotheses H_03 to H_05 pertain to the expected benefits of the pulse flow release operation. Failure to reject H_03 would indicate that the pulse flows do not appear to significantly affect the migratory behaviour of the salmonid species of interest. Rejection of H_03, but failure to reject H_05 would suggest that although a pulse flow seems to trigger a migratory response, it has no net effect on the number of spawners in the reach. In either case, including failure to reject both hypotheses, the value of the pulse flow is called into question.

Hypothesis H_04 is a test of whether a migratory response, if one is observed, is persistent during the full duration of the pulse event or is only evident in a portion of it. Rejection of H_04 would suggest that a pulse event of shorter duration would be as effective as the prescribed two-day event. It should be noted that test of H_04 is only of value if hypothesis H_03 is rejected.

In general, failure to reject any of the pulse flow related hypotheses would suggest that the prescribed WUP operation would have no measurable impact on the migratory response of salmonid spawners in the Elk Canyon reach. There may be a number of reasons for such a result:

1) There was only a minimal response to the pulse flow treatment used,

2) The resolution of the Monitor was too low to detect a change (too small a sample size),
3) The pulse flow operation was insufficient to illicit a measurable ecological response (too small a treatment effect),
4) There is some other operational aspect that is a limiting factor,
5) There is some other limiting factor(s) that mask the ecological response to operational change, or
6) Some combination of the above.

The statistical resolution of the Monitor will be determined through power analysis at the conclusion of the Monitor when estimates of sampling error can be made. Results of the analysis will indicate the limits of detection for a change in fish population response and will put the results of the Monitor into the proper statistical context.

2.4.3 Steelhead Spawning Flow

Rejection of hypothesis $H_0$2 would indicate that a persistent high flow release (in this case 7 m^3/s for two weeks) has a greater impact on the in-migration of spawning steelhead than the flow conditions prior to the spawning release operation. Interpretation of the results however, should be done with considerable care as changes in the number of spawners in the reach could simply be due to the inherent timing of the spawning/migration life phase, could be the result of a direct impact of the flow release on the migration behaviour of fish, or alternatively be due to an increase spawning habitat area, and hence potentially the capability of the system. Test of $H_0$2 should not be interpreted in isolation of other impact hypotheses.

A more definitive assessment of the spawning flow on the spawning capability of the reach would be tests of $H_0$7 and $H_0$8. Both are done on redd data rather than spawning escapement data, and a change in distribution of redds would be a more direct indicator of change in spawning habitat availability. However, testing will have to be done on a subjective basis as there is no *a priori* consensus on an ‘acceptable threshold of redd loss’ resulting from stranding. Similarly, consensus on optimal depth for initiating spawning will need to be found to further evaluate the effect of the two week pulse flows. Either a consensus is reached among interested parties during the monitor, say for example in a short workshop setting, or individual investigators are left to draw their own conclusions based on the raw data and a literature review.

As indicated in the sections above, failure to reject any of the spawning release related hypotheses would suggest that the prescribed WUP operation has no measurable impact on the migratory response or spawning capability of steelhead spawners in the Elk Canyon reach. There may be a number of reasons for such a result:

1) There was only a minimal response to the steelhead spawning release treatment used,
2) The resolution of the Monitor was too low to detect a change (too small a sample size),
3) The steelhead spawning release operation was insufficient to illicit a measurable ecological response (too small a treatment effect),

4) There is some other limiting factor(s) that masks the ecological response to the operational change, or

5) Some combination of the above.

The statistical resolution of the Monitor will be determined through power analysis at the conclusion of the Monitor when estimates of sampling error can be made. Results of the analysis will indicate the limits of detection for a change in fish population response and will put the results of the Monitor into the proper statistical context. Because statistical testing is not done for H_07 and H_08, no power analyses are necessary for these hypotheses.

2.4.4 General

Impact hypotheses related to pulse flows and the steelhead spawning flow are budgeted to be tested for only three years. After this time frame, the Monitoring Advisory Committee may decide to continue the test should the data prove highly variable, making it difficult to reach conclusions. Such a request will be judged as a change in scope, which will require formal approval from the Comptroller of Water Rights, before implementation.

The advisory committee may also request abandonment of the pulse flow and/or steelhead spawning release operations should the data show that they have no measurable impact on spawning capability of the reach or potential reproductive success. Because of the high power generation related costs involved, the unknown risk to flood control and other safety related issues, requests for increases in discharge will not be entertained until the next WUP review period where appropriate modeling and formal trade-off analyses can be carried out. Abandonment of the pulse flow or steelhead spawning release operations is allowed to be considered prior to the next WUP review because the impacts on these other values in the river are far more certain.

The only exception to this will be when WUP operations are purposely varied with the intent of providing some variability in flow treatments, and hence gain some insight on causal relationships. This includes consideration of variable base flows with the intent of maintaining the WUP prescribed 4 m^3/s as an average for the duration of the monitor (Section 2.3.1.1) and varying the time interval of flow pulses in the fall (Section 2.3.1.3).

2.5 Schedule

The smolt enumeration and spawner counts are to be carried out annually for the duration of the monitoring period (10 years following implementation of the WUP). The pulse flow and the steelhead spawning flow assessments are to be carried out annually for three years with the first year for work tentatively scheduled for Year 2 of the overall study.

Trend analyses on the abundance data will be done annually as well, but the level of effort should be kept to a minimum until the conclusion of the monitor when sample size would be sufficient to warrant more intensive exploratory analyses. The only exception would be in Year 5 when an interim report is to be prepared on the data collected to date and an early indication of potential trends is expected. As noted above, annual data reports are due each fall in the year following data collection.

The annual data collection cycle will commence with the collection of the fall/adult data and will be completed with the collection of out-migration data. This will allow reports to provide a more complete picture of out migration results relative to the previous fall's adult returns and flow conditions.

Two major reports are to be prepared as part of this monitor. The first is due in Year 5 (i.e., spring of Year 6) of the monitor, which is a summary report of all data collected and analyses done to date that provides an early assessment of WUP operations in each stream. The second is a final report due at the conclusion of the monitor in Year 10, as per Section 2.3.5. A summary of the monitor schedule can be found in Table 15-2, however this schedule is subject to change pending the commission and construction works associated with the John Hart generating station upgrade project.

It should be noted that the schedule presented here is different from that presented in the Campbell River WUP CC report. In the CC report, the duration of the monitor was fixed to five years on the assumption that the WUP would be reviewed within that time frame. However, the CC decided to extend the WUP review period to 10 years during the last meeting, and recommended that the monitoring program be similarly extended. This increase in duration is considered beneficial to the monitor as it provides a longer time trend from which to assess WUP impacts, and hence improve the monitor's statistical power. Given that the monitoring study conceived during the WUP was based on the premise of a 'titration' design, the extended WUP review period should also be viewed as a potential opportunity to examine the fish impacts of alternative base flow regimes provided that the net change in base flow over the 10-year period is negligible. The decision to explore alternative base flows should be based on whether the data collected to date indicate that the population is fully seeded or not and should be considered when a minimum of four years of data has been collected. It will be the responsibility of the Monitoring Advisory Committee to recommend the best course of action.

2.6 Budget

The total cost of the 10 year Elk Canyon smolt and spawner abundance assessment monitor is estimated to be $2,038,937.

3 References

Anon. 2004. Campbell River Water Use Plan: Consultative Committee Report. Prepared on behalf of the Consultative Committee for the Campbell River Water Use Plan. 132 pp. + App.

Bruce, J.A., A.C. Leake and J. MacNair. 2003. Use of pulse flows to attract spawning migrants into canyon habitats [In Progress]. Prepared for BC Hydro Water Use Plans, Burnaby, B.C.

Campbell River Hydro/Fisheries Advisory Committee. 1997. Campbell River Interim Flow Management Strategy. Edited by A. Eade, Alopex Consulting, Victoria, BC

Cleveland, W.S. and S. J. Devlin. 1988. Locally-Weighted Regression: An Approach to Regression Analysis by Local Fitting. Journal of the American Statistical Association, 83: 596–610.

English, K.K., R.C. Bocking and J.R. Irvine. 1992. A robust procedure for estimating salmon escapement based on the area-under-the-curve method. Can. J. Fish. Aquat. Sci. 49:1982

Link, W.A. and J.R. Sauer. 1997. Estimation of population trajectories from count data. Biometrics 53: 488-497.

McCulloch, M., A. McLean, T. Andrews. February 21, 2006. Snorkey Survey Report, Campbell River. BC Ministry of Environment, File #34560-20.

McPhail, J.D. 2007. The freshwater fishes of British Columbia. University of Alberta Press, Edmonton, AB. 620 p.

Parkin, C.K., R.E. Baily and J.R Irvine. 2003. Incorporating uncertainty into area-under-the-curve and peak count escapement estimation. N. Amer. J. Fish. Man. 23:78-90.

Perin, C.J. and J.R. Irvine. 1990. A review of survey life estimates as they apply to the area-under-the-curve method for estimating the spawning escapement of Pacific salmon. Can. Tech. Rep. Fish. Aquat. Sci. No. 1733.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Bd. Can. 191:382 p.

Schwarz, C.J. and C.G. Taylor. 1998. Use of the stratified-Petersen estimator in fisheries management: estimating the number of pink salmon (*Oncorhynchus gorbuscha*) spawners in the Fraser River. Can. J. Fish. Aquat. Sci. 55:281-296.

Seber, G.A.F. 1982. The estimation of animal abundance and related parameters. Blackburn Press, New Jersey, USA. 654 p.

Tabachnick, B.G. and L.S. Fidell. 1983. Using Multivariate Statistics. Harper and Row, Publishers, N.Y. 509 p.

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