Campbell River Water Use Plan

Monitoring Program Terms of Reference

- **JHTMON-3 Upper and Lower Campbell Lake Fish Spawning Success Assessment**

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1 Program Rationale

1.1 Background

Observations suggest that some resident rainbow trout and cutthroat trout spawn in tributaries and alluvial fans within the drawdown zone of Upper and Lower Campbell Lake Reservoirs (Lough 2000a). During the Campbell River Water Use Plan (WUP) development, it was hypothesized that rising reservoir water levels during spring freshet inundate and thereby kill incubating eggs, effectively limiting the area of functional spawning habitat for salmonids, and ultimately recruitment to Upper and Lower Campbell Lake Reservoirs. The main premise for the impact hypothesis is that these fish typically dig their redds during late winter when reservoir levels are low, and are then susceptible to inundation from rising reservoir levels during the freshet period (Anon. 2004). In the absence of groundwater upwelling, standing water above a redd is thought to kill incubating embryos in the pre-eyed stage because it prevents replenishment of oxygen at the egg-water interface.

During the Campbell River WUP an “Effective Spawning Habitat” (ESH) Performance Measure (PM) was devised for trout spawners in Upper and Lower Campbell Reservoirs, which calculated the amount of spawning habitat inundated during the spawning and incubation period of different salmonid species. During the WUP, the ESH PM was used to evaluate reservoir operations by assuming that more spawning habitat would result in greater recruitment to Campbell River reservoirs and their tributaries. In essence, this PM assumed that recruitment of trout in the reservoirs is limited by functional spawning habitat[1], an assumption that will be tested with this Monitor.

Implementation of the Campbell River WUP (Alternative T in Anon. 2004) is expected to increase effective spawning habitat for cutthroat trout by 167% and 67% for rainbow trout in Upper Campbell Lake Reservoir. In Lower Campbell Lake Reservoir, effective spawning habitat is expected to increase 117% for cutthroat and 20% for rainbow. Although the relative increases are substantial on a percentage basis, the actual area of effective spawning habitat within the drawdown zone remains small (Anon. 2004). Some (though not all) reservoir tributaries have abundant spawning habitat above the drawdown zone that could confound attempts to measure population level impacts. This Monitor will assess the extent of this spawning habitat both within and above the drawdown zone, evaluate its overall utilization and success, and determine whether there is sufficient habitat to allow the salmonid populations to fully seed the reservoirs.

1.2 Management Questions

The Campbell River WUP Fish Technical Committee (FTC) developed the ESH performance measure with the assumption that the trout populations in both Upper and Lower Campbell Reservoirs are severely limited by availability of functional

[1] The term ‘functional spawning habitat’ refers to spawning habitat that remains ‘suitable’ for the duration of the spawning and following incubation periods.

spawning habitat. It was hypothesized that operations that increase spawning habitat would result in greater recruitment and hence an increase in population size. If this assumption is correct, the expected increases in spawning habitat following WUP implementation should lead to a positive population response. However, given the number of uncertainties associated with the impact hypotheses and the associated calculations that lead to performance measure development, the Fish Technical Sub-Committee (FTC) recommended that this prediction be validated in the field to confirm the underlying rationale for accepting the consensus WUP decision. This leads to the following management question:

a) Following implementation of the Campbell River WUP, does the population of rainbow trout, cutthroat trout and Dolly Varden in Upper and Lower Campbell Reservoirs increase as a result of the expected gains in functional spawning habitat?

By corollary, the following management questions are also addressed:

b) Are the trout populations in Upper and Lower Campbell Reservoirs limited by the availability of functional spawning habitat?

c) Is the ESH performance measure a reliable measure of spawning habitat, and therefore useful in the present Monitor, as well as in future WUP investigations?

1.3 Summary of Impact Hypotheses

The monitoring study is designed to test the following set of four primary, null hypotheses:

$H_0$1: Following implementation of the Campbell River WUP:

a) The abundance of adult trout does not change in Upper Campbell Reservoir.

b) The abundance of adult trout does not change in Lower Campbell Reservoir.

In essence, $H_0$1 is a global hypothesis and does not relate to a specific causal mechanism. That is, the test simply asks whether salmonid adult abundance has changed in response to WUP implementation, and not why. Subsequent hypotheses test specific mechanisms related to WUP PMs. The impact hypothesis will be tested independently for each trout species of interest, rainbow trout, cutthroat trout and Dolly Varden

To determine whether changes in trout abundance are related to the availability of functional spawning habitat, a correlation test between these two parameters is necessary. The ESH performance measure will be used to measure spawning habitat availability because the PM was used during the WUP process, and it is the only variable at present that tracks functional spawning habitat. The Monitor will test the following set of null hypotheses:

$H_0$2: Following implementation of the Campbell River WUP:

a) Abundance of adult trout in Upper Campbell Reservoir is not correlated with ESH at the time of the cohort's emergence.

b) Abundance of adult trout in Lower Campbell Reservoir is not correlated with ESH at the time of the cohort's emergence.

Because rainbow trout, cutthroat trout and Dolly Varden are repeat spawners (iteroparous), the test of $H_0$2 will have to be carried out separately for each age class above the age at recruitment to the adult stage 't'. If possible, site-specific age-at-recruitment values will be determined for each trout species.

Reliably testing $H_0$2 will depend in part on the reliability of the ESH performance measure as an indicator of functional spawning habitat. The FTC identified a number of assumptions pertaining to the ESH PM that, if found invalid, could undermine its usefulness in its present form. Tests of these assumptions form a third group of null hypotheses:

$H_0$3: The proportion of mature adults that spawn in the drawdown zones of Upper and Lower Campbell Lake Reservoirs is not biologically significant.

The importance attached to the ESH performance measure stems from the assumption that a significant proportion of the spawning population spawn in the drawdown area and that the reproductive failure of these individuals significantly impacts recruitment to the reservoirs. Though there is some anecdotal evidence supporting this assumption, a formal test is necessary to validate the ESH performance measure. The test will compare intensity of spawning in the drawdown zone vs. spawning above the drawdown zone.

$H_0$4: There is insufficient groundwater movement in areas of the drawdown zone suitable for trout spawning to replenish local oxygen supply and flush away metabolic waste.

A key assumption of the ESH performance measure is that inundation causes cessation of water movement in the immediate vicinity of incubating eggs, which in turn causes local oxygen supply to fall below tolerance levels and for toxic metabolic wastes to accumulate. This assumption is only valid if there is no upwelling of groundwater in the area, a condition that has yet to be verified, though some anecdotal data has been collected to suggest that this may indeed be the case (Lough 2000a).

1.4 Key Water Use Decision

During development of the Campbell River WUP, evaluation of reservoir operations relied heavily on the ESH performance measure. Validation of PM predictions is required in order to evaluate the effectiveness of the Campbell River WUP, and to evaluate the reliability of the PM for future assessments of reservoir operations. The Campbell River generating project is complex and there are a number of constraints on reservoir management (e.g., fish, recreation, erosion, flood control), so the response of the ESH performance measure to changes in the WUP cannot be tied to a single operational constraint. Results of the Monitor will likely influence future reservoir operations, but only in relation to its effect on other systems values and the constraints brought on by system hydrology.

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 selected tributaries of Upper and Lower Campbell Lake Reservoir and the reservoirs.
2) The Monitor will be carried out annually until the next WUP review period (10 years following WUP implementation).
3) 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.
4) A data report will be prepared annually, summarizing the year's findings. All data will be archived according to BC Hydro protocols.
5) A summary report will be prepared every five years summarizing the data collected to date, discussing inferences and presenting conclusions.
6) 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 impact hypotheses and the management question in Section 1.2.

2.2 Approach

The approach adopted here is different from that described in the CC Report (Anon 2004). At the time of the WUP process, the CC recommended that Creel census data, supported by data collected from regular snorkel surveys at specific spawning sites, be used to assess the impacts of WUP operation on reservoir spawning success. Upon further reflection however, it was believed that creel survey approach is inadequate to satisfactorily address the management objectives of the monitor. Not only is the creel survey an unreliable estimator of population abundance (Guthrie et al 1991), but the approach proposed by the CC ignores the need to collect causal information that allows one to draw direct linkages between reservoir operations and population abundance.

We chose to adopt hydroacoustic surveys as the preferred means of population estimation, supported by data collected through regular snorkel surveys at specific spawning sites — this survey builds up on the historical spawning population assessment undertaken by Ministry of Environment (MOE) in the past. The rational for switching to hydroacoustic approach include the fact that hydroacoustic surveys typically completed within a very short period of time (weeks instead of months). Furthermore, hydroacoustic surveys are easily repeatable from year to year, which allows for accurate trend analysis through time. This latter feature of hydroacoustic survey methodology is considered critical when attempting to identify population changes. However, angler harvest data collected by MOE through the annual Vancouver Island Lakes Questionnaire (VILQ) program is available from the Ministry. These data and several additional studies that contrasted VILQ against field creel assessments will be used to look into historical fish population dynamics in the Upper Campbell reservoir.

The first year of the study will be considered a pilot year to test study approaches and methodologies. Based on the success of the pilot year, study approaches and methodologies could be fine-tuned for better effectiveness.

Also in this proposal, we include several studies to establish causal linkages between WUP operations and population abundance, including a protocol to assess the utility of the Effective Spawning Habitat (ESH) performance measure. Although these studies expand the scope of the monitor from what was originally conceived, they add considerable value to the success of the monitoring study, maximizing its utility for future decision-making processes.

This Monitor will be carried out in three parts: 1) annual (Years 1 - 9) hydroacoustic surveys of fish abundance and biomass in the reservoirs; 2) a two-year survey of spawning distribution in reservoir tributaries; and 3) and a two years detailed analysis of flow and incubation conditions within the drawdown zone of tributaries. This Terms-of-Reference provides a description of the studies as they are presently conceived, but contractors are free to suggest improvements, provided there is a good rationale for doing so, do not detract from the original intent of the monitor, and do not significantly impact the proposed budget.

2.2.1 Reservoir Fish Abundance Surveys

Given their large size, it is difficult to estimate population abundance accurately and repeatedly within the reservoirs. Abundance estimates will rely on state-of-the-art hydro-acoustic survey methods, supported by fish sampling with gill nets and minnow traps, and measurements of fish. Surveys will be conducted annually, in late summer or early fall. Nine years of hydroacoustic data, supplemented by gillnet and snorkel survey data, is expected to provide sufficient data set to assess impacts of reservoir operations on reservoir fish population.

2.2.2 Spawner Snorkel Surveys

This survey involves annual snorkel swims to assess salmonid spawner abundance in selected tributaries of Buttle Lake, Upper and Lower Campbell Lake reservoirs, and builds on MOE’s spawner survey program implemented over the last decade. The contractor is fully responsible for implementation of this snorkel survey but is expected liaise with MOE for additional or ancillary information collected by the Ministry and for site-specific local knowledge, especially during survey design. Data from the spawner abundance assessment will supplement the hydroacoustic data in assessing impacts of reservoir operations on reservoir fish. Surveys will be conducted annually, in early summer over the 10-year period. This survey is expected to be coordinated with the redd survey assessment both in terms of geographic overlap and finding some efficiencies, e.g., sharing resources.

2.2.3 Redd Survey

Surveys will be completed on selected tributaries of Upper and Lower Campbell reservoirs. These surveys will be conducted to assess the relative intensity of spawning within and above the drawdown zone. This survey will be conducted twice in successive years.

2.2.4 Incubation Conditions

Direct and indirect studies of incubation conditions will be conducted on site selected for the incubation cassette study, on tributaries of Upper and Lower Campbell reservoirs. These studies will assess embryo survival in relation to elevation, inter-gravel dissolved oxygen and temperature, water column DO and temperature, and flow conditions through gravel in relation to elevation. Indirect studies will use seepage meters to measure the rate of intra-gravel water flows, or seepage, and the oxygen content of seepage water. Syringes maybe used to sample inter-gravel water quality while minimizing sampling-induced error. The contractor is expected to propose tolerance levels of prevailing conditions via comparison to published values in the scientific literature. These studies will be coupled with direct measurements of incubation success in relation to elevation above and below the reservoir water level. This study will be conducted twice in successive years.

2.3 Methods

2.3.1 Data Capture

2.3.1.1 Reservoir Fish Abundance Surveys

Acoustic Surveys

This study is designed to test Impact Hypotheses $H_0 1$ and $H_0 2$ and will also be used to test hypotheses in other Monitors. Specifically we are interested in the extent to which reservoir salmonid abundance and biomass are related to BC Hydro operations, such as reservoir drawdown, fill rates and timing. Annual fish surveys, based on proper statistical considerations, will be used to develop an indicator of salmonid abundance in Campbell River reservoirs. The reservoirs of interest are Upper Campbell Reservoir and Lower Campbell Reservoir; results for Upper Campbell Reservoir will be used as an indicator of conditions in Buttle Lake. The species of interest are rainbow and cutthroat trout, although information will also be collected opportunistically for Dolly Varden. When designing the survey it will be important to remember that we are looking for a responsive and repeatable *indicator* of abundance and biomass, and not necessarily a precise estimate of each. This indicator will be used to assess whether and to what extent fish abundance in the reservoirs responds to BC Hydro operations. The precise design of the acoustic surveys should be finalized based on experience of the contractor, but the following describes approximate techniques and the main technical considerations.

Sampling will occur during late summer or early fall (ideally mid-September to mid-October) to: standardize timing of surveys, sample fish after they have attained most of their summer growth, and sample while thermal stratification is strong, which will promote maximum segregation of fish species. It is expected that night-time sampling will not be necessary as the reservoirs do not contain kokanee or other species that undertake extensive diel migrations. It may nevertheless be necessary to confirm this decision.

Survey methods will generally follow protocols described in standard fisheries acoustic texts (Thorne 1983, MacLennan and Simmonds 1992, Brandt 1996). Survey transects will be placed systematically to ensure adequate coverage of the water body. Nearness to shore will be determined in part by distribution of water hazards (e.g., trunks, submerged logs), but will extend from approximately the 2 m depth contour and thus include both pelagic and littoral habitats. Contractors will consider whether zigzag or parallel transects offer the best design for this program.

Acoustic sampling will be performed from a boat. Data will be collected using both downward and sideways-angled transducers to maximize coverage of the water column; contractors should consider costs when deciding whether this is best done simultaneously using a two-transducer system or with repeat passes using a single transducer system. Typically the echo sounding system will consist of a digital scientific echo sounder paired with a differential GPS. A computer is used to operate the echo sounder and monitor depths and echograms at the time of data collection, and also to log data. Digital data files of echoes are stored for post-processing in the lab with specialized software. Geographic coordinates from the DGPS are logged simultaneous to acoustic data.

Two temperature profiles of the water column will be recorded at the time of the acoustic surveys. Profiles will be made from deep water stations, from the lake surface to a depth of at least 50 m.

In areas where hydroacoustic sampling technique is deemed ineffective or unsafe a netting protocol may be integrate along with the hydroacoustic sampling techniques. A series of vertical nets with appropriate panel sizes may be employed with results integrated with the results of the standardized hydroacoustic approach.

Fish Surveys

In addition to acoustic surveys, a limited amount of fish data will be collected to aid the interpretation of the hydro-acoustic data, as well as the understanding of species-specific habitat use, growth rates, population structure, and diets. All fish collections will be completed under Province of BC scientific collection permits.

Sampling will be conducted at approximately the same time as acoustic surveys so that conditions are similar for both sampling events. Fish sampling will use gill nets and minnow traps. Sampling will occur in the same parts of the reservoir as the acoustic sampling. Minnow traps will be used in the shallow littoral zone (< 6 m depth), whereas gill nets will be used to sample littoral, profundal (> 6 m depth) and open water areas. To avoid loss of gear, trapping and gill-netting will not be done in areas with extensive debris. For at least the first year, both day and night sampling will be carried out to firmly establish the presence or absence of diel trends in fish distribution, primarily among the salmonid species. The need to continue day/night sampling will be assessed after this first year of data collection. It is possible that only day or night sampling would be required to obtain estimates of salmonid biomass for inter-annual comparison.

All gillnet sets will use standard floating and sinking, 6-panel, monofilament variable-mesh gillnets (RIC 1997: 25, 89, 51, 76, 38, and 64 mm mesh, 100 m × 2.4 m total dimension). Nets will be set perpendicular to the shore, so that sinking nets sample the littoral zone and floating nets sample the upper 2.4 meters of the water column. Mid-water sets will also be used as necessary to sample the pelagic zone. In the latter case, gillnets will be set horizontally to the bottom at a depth of 12 to 15 m within the thermocline where fish are observed on the echograms. It is assumed that two gillnetting stations per reservoir will be sufficient for this study. Set times may vary to ensure that excessive sampling of fish does not occur; an approximate target for fish samples is 50 to 150 fish per reservoir. Nets will be checked frequently to avoid excessive fish capture. Set and retrieval times, depth of the set, net orientation, weather, and geographic coordinates will be recorded for each set.

Standard Gee traps will be baited and set at the same time as the gill nets and in similar locations. It is assumed that two trapping stations per reservoir will be sufficient for this study, and that a minimum of 10 traps will be deployed per station. Depth, habitat descriptions (cover, substrate, etc.) and location of each trap will be recorded.

Spawner Snorkel Surveys

Snorkel surveys will be conducted in selected tributaries, perhaps twice a year. Tributary selection, including the number of reaches to be sampled and sampling frequency, will be determined in consultation with MOE local staff and will be detailed in the contract proposal.

The data collection methodology will be as per the standardized methodology implemented by MOE for over a decade (Mike McCulloch, pers. comm.). It will be the responsibility of the contractor to review existing methodology with MOE and prepare a detailed description of data collection methods, including the location of study/index sites in each river, the frequency and timing of sampling, an assessment of data consistency in sampling between years and an assessment of the overall quality of the data collected to date.

Fish Biometrics

All fish captured in all gear types will be identified to species, weighed, and measured to the nearest mm (fork length) in the field. Fish will be anaesthetized as necessary. Scales and otoliths will be taken from all salmonids. Scales will be taken to a maximum of 10 samples per 10 cm length interval in each reservoir to enable accurate aging. All live fish will be returned to the reservoir unharmed. Excised stomachs contents will be taken from already dead fish to a maximum of five fish per each species and age class. The excised stomachs will be preserved in 10% formalin for later analysis in the lab. Observations of sex and state of sexual maturity will be also recorded.

Scale Analysis

Only a subset of the scale samples, five samples per 10 cm length interval in each reservoir, will be subject to measurement. The remainder will be stored in case additional samples are required. Aging of fish will be done by experienced staff/lab, by examination of growth rings on scales and otoliths. To ensure accuracy, scale and otoliths analyses will proceed in an iterative fashion, beginning with a preliminary aging of each scale using the standard features to mark a year of growth. The results of this initial aging process will then be compared to corresponding length data as a screen to identify possible errors in scale interpretation. Where errors were identified, the scales will be re-examined in light of the fish length data and re-assigned an age accordingly. By convention, fish age should be reported as an ‘n+’ value to acknowledge that these fish were sampled during what is generally regarded as the peak growing season, and that they have yet to complete a full year of growth. If the aging of a fish remains unclear, the scale sample will be discarded and another will be taken from the subset set aside for storage.

Stomach Contents

Diets of fish will be ascertained through identification and enumeration of stomach contents of sampled fish (salmonids) taken every other year. This analysis is meant as descriptive supporting information and is not intended to be highly detailed. Stomach contents will be examined under a dissecting microscope and identified and enumerated, where possible, to lowest reasonable taxonomic order (usually family). This information will be useful in identifying or ruling out potential causal factors for any changes on population age/size structure and overall abundance observed through time in the hydroacoustic survey data.

2.3.1.2 Redd Survey

This study will concentrate on cutthroat trout. Evidence to date indicates that this is the species of greatest concern for risk of redd inundation because numerous cutthroat redds have been found within the drawdown zone at tributary confluences (Lough 2000a, b). To assess absolute and relative spawning intensity above and within the drawdown zone a redd enumeration survey will be conducted in selected tributaries of Campbell River reservoirs at the end of the cutthroat spawning season. This study is designed to test Impact Hypothesis $H_0 3$; the study will also provide useful background information for testing Impact Hypotheses $H_0 1$ and $H_0 2$.

This study will occur in each of two successive years. Redd surveys will be timed to coincide with the end of the cutthroat spawning season. Cutthroat spawning is typically the first of March through the end of April with a peak usually in the third week of March (Table 3-1 Anon. 2004). Other spawning salmonids are Dolly Varden, which spawn in mid to late fall, and rainbow trout, which spawn later than cutthroat, from mid-May to the end of July with a peak usually in the first week of June. Thus, if redd surveys are well-timed there should be less chance of miss-identifying redds.

Nine streams will be selected for an annual survey of redds, a target of three representative streams from each of the following reservoirs: Buttle Lake, Upper Campbell Reservoir and Lower Campbell Reservoir. These streams should have ample suitable habitat both within and above the drawdown zone. Surveys of tributary streams completed by Lough (2000b) should be used to select appropriate streams. In addition, Mike McCulloch, MOE, should be contacted to discuss suitable streams, as the MOE carries out annual spring spawner counts in six tributaries to Upper Campbell Reservoir. The final streams will be approved by the BC Hydro Representative and MOE.

Initial surveys must be completed to assess the availability of spawning habitats in the target streams within and above the drawdown zone, based on habitat suitability information in Hickman and Raleigh (1982). Suitable spawning habitat will be mapped and quantified to a level of detail sufficient to re-locate these habitats in future years and to track changes through time. It will be up to the contractor to determine the most cost effective means of collecting this data, the appropriate level of accuracy, scale of measurement and the level of detail to be recorded. Because selection of microhabitats is highly dependent on flow, and flow itself is highly variable, the quantification of suitable spawning habitat is expected to be somewhat subjective and not highly detailed. For this reason it will be necessary to use experienced field crew with appropriate training and experience. The assessment should be highly repeatable, but it will be more important to accurately assess *relative* habitat availability within and above the drawdown zone, than it is to quantify the available habitat with full precision and accuracy. Methods such as those used by Lough (2000b) are likely appropriate. Habitat surveys should be timed to reflect prevailing conditions during the cutthroat trout spawning season. When possible, habitat surveys in the drawdown zone should also coincide with typical reservoir low water periods.

Target streams will be visually surveyed for cutthroat redds over their full length of accessible, suitable habitat. For example, this may be all stream length downstream from the headwaters or all habitats downstream of an impassable barrier. The objective of the data collection exercise is to develop a measure of relative spawning habitat-use upstream of the drawdown zone so that it may be compared to similar measured in the drawdown zone. This will provide a means of judging the relative importance of drawdown zone habitat to the overall spawning success of the species. Visual surveys will use snorkelling gear and/or streamside observations. Surveys must be completed during conditions that allow accurate visual assessments, such as clear water. Redds will be counted and approximate locations mapped. Observer error in redd counts (see Dunham et al. 2001; Al-Chokhachy and Budy 2005) must be controlled by using the same observers for all within-stream comparisons. To the extent possible, the same observers should be used among years. It should be noted, however, that the information of primary concern is relative spawning intensity within and above the drawdown zone, and for this we will concentrate on obtaining repeatable rather than unbiased, precise results. The study will rely on experienced observers using consistent methods and there will be no attempt to quantify bias or precision.

Within the drawdown zone, redd surveys will be more detailed to allow an assessment of recently inundated redds and a prediction of which redds will likely be inundated as reservoir levels rise. This will be necessary because reservoir levels tend to increase for some time after the initiation of cutthroat trout spawning, but not always to the same maximum each year. Thus, the drawdown zone during any one year may be different than the inter-year operational range of the reservoir. Of interest is not just how many redds are within the inter-year operational range, but how many redds actually get inundated in each year.

To track this, a surveyor's rod and level will be used to establish 0.5 m elevation contour intervals at the mouth of each of the nine target tributaries. Elevation bands will be flagged/marked to the extent possible for use in subsequent years. Redds will be enumerated within each of the 0.5 m contours below the existing reservoir water level to the bottom of the operational range.

A subset of redds (at least one redd in each target stream) will be inspected to confirm that visually identified redds are actually redds, and to determine the stage of egg development as un-eyed, eyed, or alevin. The stage of egg development will be useful to indicate which species was most likely to have made the redd.

A continuously recording data logger should be installed to gather temperature observations (installed prior to spawning activity) that can be used to estimate the accumulated thermal units (ATUs) required to bring the eggs to the observed stage of development, and to therefore estimate the time of spawning. The calculated time of spawning can then be used to help determine the most likely species of trout or char to have been spawning during that period, based on local life-history information for each species. ATUs and species periodicity are listed in Anon. (2004). Temperature loggers should be installed in each of the target streams, as well as in at least two locations on each reservoir.

The following descriptive data should also be collected during the redd surveys in each stream:

1) Representative photographs of all target streams and assessment sites.
2) Daily average reservoir water elevation at time of survey. This will be used to as a reference to calculate the elevation of redds in the drawdown zone from water depth measurements.
3) Daily average reservoir water elevation over the course of the incubation period. This data will be used to assess the frequency and duration of redd inundation events, and hence provide an indicator of spawning success similar to the WUP ESH performance measure.

4) Daily stage level of each target tributary stream to be collected by pressure transducer data loggers. This data will be used to assess the frequency and duration of low flow events that could potentially impact spawning success in the tributaries. This will in turn provide a measure of effective spawning habitat in streams that is comparable to the ESH PM by tracking flow condition during incubation compared to that during the spawning period. If resources allow, repeated measures of wetted width at roughly 10 randomly chosen locations over a range of stage elevations would refine the effective spawning habitat measure even further.

2.3.1.3 Incubation Conditions

Seepage

This experiment is designed to test Impact Hypothesis $H_0 4$. To compare conditions within inundated and non-inundated redds, *in situ* readings taken with seepage meters. The experiment will be multi-factorial and replicated, assessing the following variables: water elevation (0.5, 1.0, and 2.0 depth), tributary (two streams), and season (spring, summer).

To permit assessment of conditions within inundated redds, a literature review will be conducted of relevant physiological studies for incubation of salmonid eggs prior to the field work. The literature review will summarize findings in the primary literature regarding incubation success relative to measures of dissolved oxygen, temperature, and intra-gravel flow rates. To the extent possible, the review should focus on the major species of concern for this Monitor, cutthroat and rainbow trout, and to a lesser extent, Dolly Varden. A comparison will then be made between the conditions as measured from the seepage meters and the conditions required for incubation as indicated in the scientific literature.

Seepage meters have been used successfully in the past to measure the rate of groundwater inflow to lakes and ocean. These meters are not standard equipment and may have to be constructed specifically for this project. Detailed descriptions of the meters can be found in Lee (1977), Martin et al. (2002) and Rosenberry (2005). Briefly, the meters consist of a closed-end cylinder with a single port, to which is attached a plastic bag (Figure 3.1**Error! Reference source not found.**). The bag is attached and allowed to fill over a set time period. The volume of water is measured and a rate of water inflow is calculated. Studies show that pre-filling bags with 1000 mL of water reduces bias in measurements (Shaw and Prepas 1989; Martin et al. 2002).

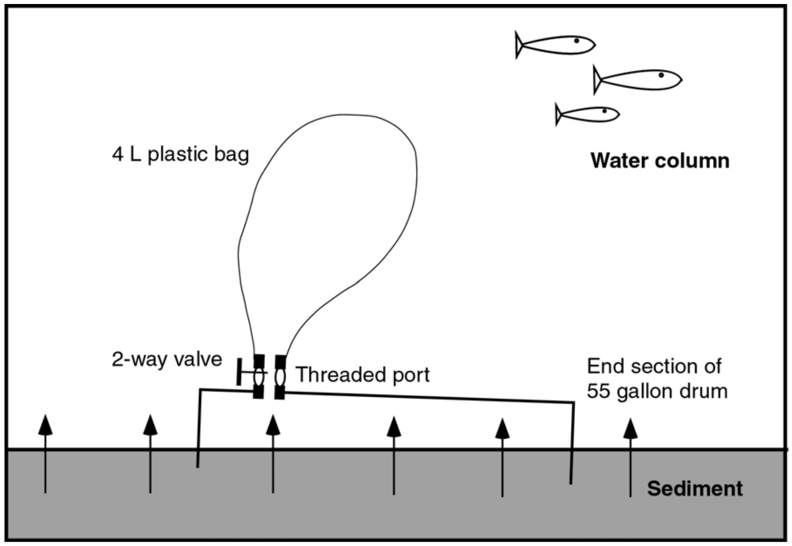

Figure 3.1 Schematic of a seepage meter (from Martin et al. 2002).

Seepage meters will be deployed in short transects from an elevation above full-pool (i.e., experimental control) to 2 m depth, and measurements taken based on a randomized design (Table 3.1), to avoid introducing biases from timing of measurements. The order of streams will be randomized, and the order of water depths within streams will be randomized. It is assumed there will be at least four seepage meters used simultaneously, one for each depth. Seepage rate will be measured at least three times per site, depending on seepage rate, which will be considered time replicates. Selection of season is meant to cover potential variation in groundwater inflow rates due to stream discharge rate, so dates should be selected to cover a date during the wet season and another during the dry season.

Table 3.1 At least three seepage meter measurements will be taken at each combination of depth and stream. This set-up will be repeated in spring and summer.

	Spring		Summer	
Depth Below Full Pool	**Stream 1**	**Stream 2**	**Stream 1**	**Stream 2**
0m (Control)	**xxx**	**xxx**	**xxx**	**xxx**
1.0m	**xxx**	**xxx**	**xxx**	**xxx**
2.0m	**xxx**	**xxx**	**xxx**	**xxx**
3.0m	**xxx**	**xxx**	**xxx**	**xxx**

In addition to measuring seepage rate in relation to water depth, stream and season, it will be necessary to carry out a number of specific controls, referred to here as duplicates, blanks and equilibration controls. Duplicates will be measured to assess variation in seepage rate due to small-scale differences in location. These will be measurements taken a short distance on either side of a transect, usually within 3 m distance. Duplicates should be measured in at least two sites. Blanks will be measured using sand-filled children’s rigid wading pools. These pools will be placed at depth at experimental sites, a seepage meter attached, and measurements taken in a manner identical to experimental units. Blanks should be paired with experimental units to allow a valid comparison. Finally, equilibration controls should be taken to assess the effect of deployment duration on seepage measurement rate. In this form of control, a seepage meter is deployed and sequential measurements taken at a number of points after the deployment. Typically there is a backpressure effect from installing a seepage meter and an equilibration control allows one to assess the time to equilibration. Duplicates, blanks and equilibration controls should be measured in at least two sites for each season. It is important to note that all sites should be located within the tributary channel.

Seepage rate will be calculated independently for each replicate by measuring water volume in seepage collector bags using appropriate lab ware (e.g., graduated cylinders, volumetric flasks). In addition to volume, at least two replicate measurements of DO and temperature must be taken from the seepage meters as the bags are emptied to measure volume. This is to be done for each combination of depth and stream. Such measurements should be separated in time; for example, before and after the experiment or between replicate seepage measurements.

The following descriptive data should also be collected at the time of the seepage measurements in each stream:

1) Substrate composition, including degree of embeddedness, at each seepage meter. These are likely some of the many variables that may explain the difference between site variability in seepage. May be of use in refining the PM statistic for future use, especially in terms of incubation success.

2) Representative photographs of all sites.

3) Daily stage level of each target tributary stream to be collected by pressure transducer data loggers. These data may be used to explain potential between site variance in seepage values (e.g., used as an indicator of potential ground water charge) as well as identify those redds in the drawdown zone that may become stranded at low flow and reservoir elevation values.

4) Surface water temperature and DO of reservoir near the study sites to provide a contrast for the seepage water measurements that are collected.

Incubation Tests

This study is designed to test Impact Hypothesis $H_0$4. To directly compare conditions within inundated and non-inundated redds in reservoir littoral areas, one year of incubation tests will be conducted by planting eyed trout eggs in incubation devices (e.g., cassettes or tubes) within and above the drawdown zone of the reservoir water level on selected study tributaries. The experiment will be replicated, assessing the following variables: water elevation (replicate sites (minimum five) at varying depths within the tributary channel flowing through drawdown zone) and tributary (two streams flowing into Upper Campbell Reservoir). This design would allow tracking of the duration and frequency of inundation at each site and stream as is calculated for the ESH PM. The boxes should be placed in similar substrate types to minimize the introduction of substrate as a confounding factor, though it is understood that this may not be possible. Placement of replicate sites should be done with this risk in mind.

Incubation devices will be deployed and measurements taken based on a randomized design (Table 3.2), to avoid introducing biases from timing of measurements and deployment order of incubation device. Deployment order will be determined by first randomly selecting the order of streams, then by the randomly selecting the order of depths. There will be a minimum of five replicates for each combination of depth and stream. Although there may be variation in groundwater inflow rates due to stream discharge and season, the experiment will be conducted during a single time of year coinciding with the natural development time for eyed-eggs of rainbow or cutthroat trout (depending on egg availability). It will be up to the contractor to secure a source of eggs to carry out the experiment.

It is expected that this will be a short-term experiment, likely running less than six weeks. Ultimately, duration will need to consider development rate of the embryos, prevailing environmental conditions, reservoir filling schedule, and other factors. Scheduling of the field sampling will be finalized at the kick-off meeting upon discussion with reservoir operations planning staff over the upcoming filling schedule. It may be necessary to conduct this experiment in serial trials, rather than in parallel, to accommodate the availability of eggs and/or incubation devices. In this case, conducting trials on streams in random order seems to be the most appropriate. The end goal of the data collection process is to have a data set suitable to compare measured incubation success with ESH PM values and hence test the validity of the PM (i.e., test of $H_0$4)

Table 3.2 At least four incubation devices will be deployed at each combination of depth and stream.

Depth (from full pool)	Stream 1	Stream 2
0 m (Control)	x x x	x x x
1 m	x x x	x x x
3 m	x x x	x x x

Incubation trials are often conducted using “Scotty-Jordan” cassettes but these may be difficult to deploy at treatment site depth unless scuba diver(s) are used. Another alternative is the use of incubation tubes for this experiment, which offer small size, relative ease of deployment, lack of sediment disturbance, and less conspicuous appearance. Briefly, these are perforated metal tubes that can be filled with a known number of eggs, capped, and augured into the sediment (Figure 3.2). DFO are currently experimenting with these devices (Mel Sheng, pers. comm.), and although they appear to have lower survival than Scotty-Jordan cassettes, they may still be appropriate for this experiment as *relative* difference in survival is of greater interest than absolute survival. These devices are not standard equipment and would likely require special manufacture for this experiment.

Figure 3.2 Specially constructed "tube" incubator, with anchor pin, ceramic drill bit head, and auger attachment. Photo courtesy of Mel Sheng, DFO, Nanaimo.

At the end of the experiment eggs will be removed from each device, their condition assessed (dead or alive (sub-categories: hatched, dead alevin, live alevin). Incubation success will be calculated independently for each replicate by scoring the number of eggs that are alive or dead within each incubation device as well as the stage of development. If results of the study indicate that incubation success is not simply binary (i.e., dead or alive) it may be necessary to develop a scale by which development is measured (e.g., normal, slightly delayed, substantially delayed, dead).

The following descriptive data should also be measured at the incubation sites:

1) Substrate at each incubation basket site.
2) Representative photographs of all sites.
3) Water temperature of tributary stream at start and end of experiment.
4) Daily stage level of each target tributary stream to be collected by pressure transducer data loggers.
5) Surface water temperature and DO of reservoir near each study stream at start and end of experiment.
6) Inter-gravel dissolved oxygen and temperature, collected at depths similar to the burial depth used for incubators.
7) Daily average reservoir water elevation throughout the study.

2.3.2 Safety

A safety plan must be developed and submitted to the BC Hydro Representative for all aspects of the study involving field work, in accordance with WCB and BC Hydro procedures and guidelines. Boat operators must be certified (Coast Guard). The boat must be of sufficient size and power to safely operate in a variety of rapidly changing weather conditions seen on these reservoirs. The crew must be equipped with appropriate safety equipment and communication means while carrying out any field work. All snorkelers must be certified in swift water rescue. All divers must be professional, certified divers.

2.3.3 Data Analysis

All data will be entered into a common database in a 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 use power analysis to assess the detectable limits of each component of the Monitor, i.e., the magnitude of change in the data that must occur in order to illicit a statistically significant response in the parameter of interest. 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.

2.3.3.1 Effective Spawning Habitat Performance Measure

The ESH performance measure will be calculated and supplied by BC Hydro, based on daily reservoir water levels and data from tributary confluences.

2.3.3.2 Acoustic Surveys, Aging and Diets

Fish abundance and biomass in Campbell River reservoirs is known to be fairly low, as they are oligotrophic water bodies. Density (fish per m^3 or per m^2) will be determined from the hydroacoustic transects according to standard echo-trace counting methods, (Thorne 1983, MacLennan and Simmonds 1992), using appropriate computer software as necessary. Accuracy of acoustic measurements must be assured by shop and field calibration tests (e.g., by the equipment manufacturer, and prior to the survey using a standard size sphere). Target strength (TS) will be determined by the split-beam method (MacLennan and Simmonds 1992). Lengths of each fish will be estimated from using Love's (1977) equation for fish insonified within +/-45 degrees of dorsal aspect:

$$\text{Length (mm)} = 10 * 10^{((TS + 1.6 \log (kHz) + 61.6) / 18.4)}$$

TS is affected by factors other than just fish size (MacLennan and Simmonds 1992) and Love's (1977) equation is a generalization from many fish species and sizes, so sizes determined in this way are less precise than direct measurement of a fish. Length is considerably more difficult to ascertain from laterally-measured TS, so fish length will not be estimated from side-looking transducer data. Down-looking data should be used for depths greater than about five meters, and lateral data depths less than that.

The volume sampled in each spatial cell will be calculated from the acoustic beam angle and distance travelled on a transect (e.g., Kieser and Mulligan 1984). Population estimates can then be made for each transect within specific depth intervals, and expressed as number of fish per m^3, or as number of fish per m^2. Fish density becomes a simple calculation of the total number of fish counted divided by the volume sampled. For population estimates, each transect provides one replicate of each depth interval. Mean fish density will be expanded in proportion to stratum volume, and resulting abundance estimates will be summed to obtain the total population estimate. The reservoir volume data will be provided by BC Hydro, the same data set used in the Campbell River WUP process. Variance and 95% confidence intervals of this estimate will be calculated as for a simple random sample with depth intervals the only stratification (Cochran 1977).

The main results of acoustic surveys will include population size and biomass estimates for total population, each species and for cohorts of salmonids. Results will be summarized in tables, figures, maps, and echograms.

Results of the annual acoustic surveys will be used to test Impact Hypothesis $H_0 1$ and $H_0 2$, and to provide useful background information for testing Impact Hypothesis $H_0 3$. Results from the initial year of the survey will be analysed to assess its efficacy and support recommendations for any changes in survey design and distribution of survey effort in subsequent years. Results will be used to build an indicator of fish abundance in reservoirs, preferably by species and age class. It is expected that the indicator will be built on data for rainbow and cutthroat trout, though the exact nature of the indicator will require analysis of real data. For example, to obtain reasonable statistical accuracy it may be necessary to pool age classes or species. It may be possible to use growth rate data (obtained from fish surveys and aging analysis) as an indicator of conditions in the reservoirs, as either a primary or corroborating indicator. The statistical properties of the chosen indicator must be presented along with a discussion of its sensitivity, reliability and repeatability. Results from the survey will be presented on maps and in summary form in tables and graphs. Analysis of age structure, growth rates and diet will be presented for all salmonid species.

The test of Impact Hypothesis $H_0 1$ will be completed at the end of the Monitor, although an initial test will be completed for the summary report after five years. When the WUP is implemented there is an expectation that adult salmonid abundance in the reservoirs will increase as a result of improved spawning and incubation conditions in reservoir tributaries. This would show up initially as a change in recruitment of younger size classes, and later in abundance of adult salmonids. The test of $H_0 1$ will therefore assess the abundance and biomass of adult salmonids as a trend through time or as a comparison of adult salmonids before and after some period. There are a variety of methods available for trend analysis of animal populations (e.g., Link and Sauer 1997); a simple t-test (e.g., Welch modified two sample t-test) may be appropriate for comparing pooled abundance estimates before and after a selected time threshold. Both of these tests may be weak due to small sample size and small treatment effect, which should be assessed with statistical power analysis.

The test of Impact Hypothesis $H_0 2$ will also be completed at the end of the Monitor, with an initial test completed for the summary report after five years. As noted above, when the WUP is implemented there is an expectation that salmonid abundance in the reservoirs will increase as a result of improved spawning and incubation conditions in reservoir tributaries. This would show up initially as a change in recruitment of younger size classes, and later in abundance of adult salmonids. However, it is acknowledged that there will be inter-year variation in the amount of functional spawning habitat available, due to differences in weather and also somewhat in the operations. In essence what we are looking for here is a correlation between ESH and the year class strength of salmonids in the reservoir. The test of $H_0 1$ will therefore assess correlation between the abundance of adult salmonids vs. the ESH performance measure. Because the acoustic survey has some success in differentiating between large and small fish (and therefore approximate age) it may be possible to estimate recruitment of very young fish and adult abundance. On the other hand if it is possible to assess only relatively large fish, then the test of $H_0 2$ will only be possible after several years of acoustic surveys, with the strongest test occurring at the end of the 10-year WUP implementation period. This test will use Pearson correlation tests or simple regression to assess the strength of relationship between functional spawning habitat and reservoir salmonid abundance. This test may be weak due to small sample size and small treatment effect, and should be assessed with statistical power analysis.

2.3.3.3 Fish Survey

Data from fish captured by gill nets and Gee traps will be used for several purposes. Relative abundance in the captures will be used to apportion the abundance estimate from the acoustic survey into species and mean weights by cohort. For small fish that are detected with acoustics, but are too small to be captured in gill nets or traps, counts will be obtained from the acoustics and biomass will be estimated using a dB/kg relationship from this study or the literature, if there is evidence that small fish are indeed salmonids (and not for example sticklebacks). Catch rates (CPUE) in shoreline and offshore gill net panels will be used to estimate relative abundance of fish in littoral areas within portions of the lake that were sampled. Temperature profiles of the water column will be used to help interpret vertical distributions of fish that are observed with acoustic and fish sampling. Age data from scales and otoliths will be used to help place fish into cohorts based on size. Diets will be used to help understand habitat segregation among species and cohorts, and help refine the abundance estimates based on the acoustic surveys. Diets will also be used as basic information on fish life history.

2.3.3.4 Spawner Snorkel Surveys

Results will be used to continue monitoring salmonids by snorkeling index sections in key tributaries of Buttle, Lower and Upper Campbell Lake reservoirs in order to document changes in salmonid spawner abundance and distribution. The result will document fish habitat conditions and any changes to the riparian area/watershed. Data from spawner abundance assessment will also supplement the hydroacoustic data in assessing impacts of reservoir operations on reservoir fish.

2.3.3.5 Redd Survey

Results will be used to test Impact Hypothesis $H_0 3$ and to provide useful background information for testing Impact Hypotheses $H_0 1$ and $H_0 2$. In truth, the data collected in this study component cannot unequivocally test $H_0 3$, so the “test” will be more of an assessment than an experiment that will allow strong inference. The results will nevertheless be of considerable importance.

Results from the initial habitat survey will be presented on maps and in summary form in tables. It may also be useful to compare the availability of habitat within and above the drawdown zones through the use of graphs.

Results from redd surveys will be presented on maps, and in summary tables and graphs. Results will be presented to allow a comparison of the abundance of redds within and above the drawdown zone using:

1) Absolute counts of redds,
2) Absolute count of inundated redds,

3) Proportion of total counts per stream, and
4) Number of redds relative to available habitat.

Comparisons may be strengthened through the use of basic statistical tests, such as t-tests, to compare the use of habitats within and above the drawdown zone. The data should be explored to assess relationships such as intensity of spawning versus distance from reservoir. The report should provide a detailed description of prevailing environmental conditions at the time of the study.

2.3.3.6 Incubation Conditions – Seepage

Results will be used to test Impact Hypothesis H_04. The conditions as measured using seepage meters will be summarized graphically and with tables. Analysis of variance will be used to test for significant differences among depths, streams, and seasons. Pairwise differences may be examined using post hoc tests. Comparisons to controls should assess the potential influence of experimental artefacts. All statistical tests should be accompanied by estimates of statistical power.

A detailed comparison will be made between the conditions on CR reservoir littoral slopes and values published in the literature for trout incubation, with reference made to variation in conditions based on depth, stream, and season.

2.3.3.7 Incubation Tests

Results will be used to test Impact Hypothesis H_04. Incubation success in relation to depth and stream will be summarized graphically and with tables. Analysis of variance will be used to test for significant differences in incubation success among depths and streams. Pairwise differences may be examined using post hoc tests. All statistical tests should be accompanied by estimates of statistical power. A detailed comparison will be required between results of the incubation tests and the seepage meter results.

2.3.4 Reporting

In general, project reporting will consist of annual data reports, summary reports every five years, and a final report at the conclusion of the Monitor. Reporting requirements will be different for each component of the monitor as they have different durations.

Separate annual data reports will be prepared for the fish abundance and redd survey components of the Monitor. They 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 detailed description of the methods used, present the data collected that year, and report on the results of all analyses. Because the incubation condition component of the monitor is only one year in duration, it will immediately proceed to the final report stage as discussed below.

The fish abundance component is carried out annually for the duration of the monitor. The CC have requested that a summary report be prepared in Year 5 to collate all the data collected to date, summarizes all the analyses, and discusses in detail the results as they pertain to the impact hypotheses, and more importantly, as they pertain to the management questions in Section 1.2. This will provide an early indication of the success or failure of the program to detect fish population changes and potential causal factors. During the 5-year review BC Hydro will also provide an early assessment of the WUP, though the implementation interval would likely be too short to determine with certainty whether the WUP was successful in meeting its reservoir spawning objectives.

At the conclusion of each component 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, and
4) Discusses the consequences of these results as they pertain to the current BC Hydro operations.

Each report will be due in the spring of the year following the data collection period. This should provide sufficient time to integrate findings in those years that multiple study components are simultaneously carried out. All reports will be submitted to BC Hydro who will distribute them to the Monitoring Advisory Committee for review and comment prior to being finalized for general release.

2.4 Interpretation of Results

2.4.1 Impact Hypothesis $H_0$1.

Rejection of $H_0$1 (one or more of its sub-hypotheses) indicates that the abundance of adult trout has changed in BC Hydro reservoirs in the Campbell River system following implementation of the WUP. Since the hypothesis is not specific to a particular mechanism, the reason for the change may be tied to BC Hydro operations or to some other factor.

Failure to reject $H_0$1 would suggest that operational changes resulting from the WUP's implementation had no measurable impact on adult trout abundance. There may be a number of reasons for such a result:

1) There was only a minimal response to the treatments used,
2) The techniques used are inappropriate,
3) The resolution of the Monitor was too low to detect a change (too small a sample size),
4) The change in reservoir operations was too small to illicit a measurable ecological response (too small a treatment), or
5) There is some other limiting factor that either that masks the ecological response to operational changes, 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 would put the results of the Monitor into the proper context.

2.4.2 Impact Hypothesis $H_0 2$

Rejection of $H_0 2$ (one or more of its sub-hypotheses) indicates that the abundance of adult trout is correlated with functional spawning habitat in the drawdown zone of BC Hydro reservoirs in the Campbell River system.

Failure to reject $H_0 2$ indicates that adult trout abundance is not significantly correlated with ESH at the time of the cohort's emergence, and that changes in ESH following WUP implementation had no measurable impact on adult salmonid abundance. There may be a number of reasons for the result:

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

Power analysis will be used to ascertain the statistical resolution of the Monitor, to help differentiate among potential reasons for results.

2.4.3 Impact Hypothesis $H_0 3$

As noted earlier, data collected in this Monitor cannot unequivocally test $H_0 3$, so the "test" will be more of an assessment than an experiment that will allow strong inference. Data will be collected and presented to allow FTC members to assess the extent of spawning within and above the drawdown zone of Upper and Lower Campbell reservoirs. Whether spawning within the drawdown zone is biologically significant will be determined largely be based on professional judgment of FTC members. This judgment will be informed by results of the redd survey, as well as other components from this Monitor.

2.4.4 Impact Hypothesis $H_0 4$

Rejection of $H_0 4$ indicates that groundwater movement in inundated areas of tributaries to Campbell River reservoirs is sufficient for successful incubation of trout eggs. In fact, testing of $H_0 4$ may not occur through simple rejection or "acceptance." For example, it may be that some portions of inundated tributaries have sufficient groundwater movement for egg incubation whereas other areas do not, or that some times of year offer greater groundwater flow than other times. Rejection or failure to reject the hypothesis will ultimately have to be qualified to the conditions assessed during the experiment. However, it is expected that sufficient variation in environmental conditions will have been assessed that strong general patterns will emerge. Depending on the results of this study component, the ESH PM may require adjustment for future WUP investigations.

Rejection or failure to reject a hypothesis will ultimately have to be qualified to the conditions assessed during the experiment. However, it is expected that sufficient variation in environmental conditions will have been assessed that strong general patterns will emerge. Depending on the results of this study component, the ESH PM may require adjustment for future WUP investigations.

2.4.5 General

These experiments are field trials in which environmental conditions will vary naturally: BC Hydro operations are only one of the potential causative agents. Testing of hypotheses in this Monitor will, to the extent possible, consider other causes for experimental results. Before accepting or rejecting hypotheses that link BC Hydro operations to population-level effects, it will be necessary to explore other reasons for experimental results, such as specific environmental variables or other development activities in the watershed, and statistical power of experiments. The conclusion that WUP-related changes in operations do not have an impact of reservoir fish ecology will be accepted only if the other causal explanations are reasonably ruled out (i.e., process of elimination).

2.5 Schedule

The fish abundance survey work will be carried out annually for the duration of the 10 (9 years for hydroacoustic) year monitoring period. The first year of the study will be considered a pilot year to test study approaches and methodologies. Based on the success of the pilot year, study approaches and methodologies could be fine-tuned for better effectiveness. This work will be carried out at the same time each year, i.e., late summer. The contractor will endeavour to carry out these studies during the same week each year to ensure between-year compatibility of the data. A data report will be prepared each year, due in spring of the year following data collection. In Year 5, the data report will be more comprehensive, summarizing all of the data and analyses collected to date, including that of other study components in this monitor, and provide a preliminary discussion of the findings, particularly as they pertain to the implementation of the WUP. Data collected in Year 10 will be the last under the present program. As with the previous reports, the final report will be due in spring of the following year.

The redd survey component of the monitor is to last two years. Though the monitor is tentatively scheduled to start in Year 2 of the monitoring period, it can be started in any year. As with the fish abundance monitor, data reports are due in spring of the year following data collection. Because this component of the monitor is only two years long, the second report due in spring of the following year will be a final report.

The incubation studies, of which there are two parts, are to be completed in one year, with a final report due in spring the following year. Though this component of the monitor is tentatively scheduled here to start in Year 4 of the monitoring period, it can be started in any year. There may be cost efficiencies in carrying out this study in conjunction with the redd survey.

Integration of all study components will occur in Year 10 of the monitoring program and will form part of the final report on the fish abundance work. A summary of the schedule is provided in Tables 3.4a to 3.4d

2.6 Budget

The total cost of the 10-year reservoir spawning habitat monitor is estimated to be $1,508,483 based on a 2014 start.

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