Cheakamus Project Water Use Plan

Monitoring Program Terms of Reference

- Trout Abundance Monitor in Cheakamus River (Daisy Lake Dam to Cheakamus Canyon)

Revision 1: February 2007
1st Submission: November 2006

22 February 2007
Terms of Reference for the Cheakamus Water Use Plan  
Effectiveness Monitoring Program

Overview

This document presents Terms of Reference (TOR) for the effectiveness monitoring programs for the Cheakamus Water Use Plan (WUP). These programs will monitor outcomes of the recommended operational changes, and provide information on which to base future operating decisions.

The first submission of the TOR was in November 2006 for the Cheakamus River Juvenile salmonid outmigrant enumeration monitoring program. This document is Revision 1 and provides detailed Terms of Reference for the following programs:

1a) Cheakamus River Juvenile salmonid outmigrant enumeration monitoring: A five-year monitoring program to enumerate juvenile salmonid outmigration from the Cheakamus River mainstem and key side channels. Previously submitted to the Comptroller of Water Rights on 20 November 2006; leave to commence was received 28 November 2006.

1b) Cheakamus River chum salmon escapement monitoring and mainstem spawning groundwater survey: A five-year monitoring program to enumerate chum spawning escapement and examine groundwater in mainstem spawning areas.

2) Trout abundance monitor in Cheakamus River (Daisy Lake Dam to Cheakamus canyon): A five-year monitoring program for rainbow trout in the non-anadromous section of the Cheakamus River.

3) Cheakamus River steelhead adult abundance, fry emergence-timing, and juvenile habitat use and abundance monitoring: A five-year monitoring program to examine the effects of mainstem flows on steelhead production.

4) Monitoring stranding downstream of Cheakamus generating station: A three-year monitoring program to examine stranding downstream of the Cheakamus generating station tailrace on the Squamish River.

5) Monitoring stranding downstream of Daisy Lake Dam: A one-year monitoring program to monitor fish stranding downstream of Daisy Dam.

6) Monitoring groundwater in side channels of the Cheakamus River: A five-year program to monitor the effect of Cheakamus mainstem flows on groundwater-fed side channels.

7) Cheakamus River benthic community monitoring: A three-year monitoring program and modelling exercise to examine the effects of mainstem flows on the benthic community.

8) Monitoring channel morphology in Cheakamus River: A five-year monitoring program to examine the effects of flows on channel morphology in the Cheakamus River mainstem.

9) Cheakamus River recreational angling access monitoring: A one-year monitoring program to examine the benefits to recreational angling access (available angling locations) of the 1 January to 31 March 5.0 m³·s⁻¹ minimum flow release from Daisy Lake Dam.
Cheakamus River Monitoring Program #2: Trout Abundance Monitor in Cheakamus River (Daisy Lake Dam to Cheakamus Canyon)

1.1 Program Rationale

1.1.1 Background

The upper part of Cheakamus River between the anadromous fish barrier and Daisy Lake Dam is known to support a resident rainbow trout population. Char and sculpin are also present. An important uncertainty in the Cheakamus WUP process was the relationship between discharge from Daisy Dam and the quantity of resident trout habitat, and the resulting trout abundance. The impact of the change of the WUP flow regime on the rainbow trout population was uncertain because: i) the actual differences in discharge downstream of Daisy Dam between the WUP and pre-WUP flow regime are uncertain, and ii) the impact of the pre-WUP operation is uncertain. Limited sampling has been done in the past, nor were any field studies been done during the WUP process, that evaluated the status of this population and how it may be impacted by Daisy Lake Dam operations. The only study done during the WUP that pertains to this population of trout was an air photo interpretation exercise that qualitatively rated the value of hydraulically unique habitats identified from photos taken at different dam discharges. This analysis produced a “Rated Usable Area” statistic that summarized the quantity of habitat in terms of equivalent prime habitat units (ha) and how this quantity changes with river flow. This statistic was used as the foundation for a performance measure designed to track changes in habitat (and by association fish abundance) when modelling alternative operations. Because no fish density or abundance data were collected to support this habitat rating scheme, the value of the habitat rating scheme, and hence of the performance measure, was deemed questionable by some CC members. This created considerable uncertainty in the outcome of any change to the operating regime from the existing pre-WUP operations.

The abundance of resident trout downstream of Daisy Dam was considered by the CC to be a critical component in the WUP trade-off process. There were two reasons for this importance. First, was resident trout’s inherent value to CC members who consider it to be an indicator of ecological health. The second and probably more important reason was because there was a general perception among CC members that trout abundance was highly susceptible to changes in Daisy Lake Dam flow releases, particularly relative to pre-WUP dam operations. Because of its relative importance and a WUP fish management objective, as well as the high level of uncertainty surrounding the consequence of flow regime changes, the CC members recommended that a monitor be carried out to track the status of rainbow trout populations. The purpose of the monitor would be to relate changes in trout abundance to changes in Daisy Lake Dam operations if such a relation exists.

1.1.2 Management Questions

Table 2-1 outlines the minimum flow requirements for the WUP flow regime and pre-WUP flow regime. The flow releases from Daisy Dam are based on the minimum flow requirement from Daisy Dam, additional flow requirements downstream at the
Brackendale gauge, and during periods of high inflows such as during the spring snowmelt, the inflows to Daisy Reservoir. Changes in flow required to maintain the minimum flow at Brackendale are unpredictable and can create variability in the flow regime experienced by the resident trout population. Of particular concern is the fact that these changes will follow a pattern that is opposite of the system's prevailing hydrology (higher releases at times when flows are naturally low). However, hydrological modelling exercises have found that the magnitude of these changes are relatively small, and may be “masked” by the influence of local inflows from Rubble Creek immediately downstream of the dam. As a result, the impact of these short-term fluctuations is not expected to be biologically important, particularly when one considers that such fluctuations in flow are well within the range found in the natural environment. For this reason, the monitor will only be concerned with the impact of changes to the base flow release on the resident trout population, and that short-term fluctuations in flow will be largely ignored. The only exception will be flood flow releases, which could have an impact. Such events will be noted and incorporated in the interpretation of study result, but studies specifically design to identify flood-related impacts will not be carried out because the ability to regulate flows is limited during floods.

Table 2-1: Overview of Minimum Flow Release Requirements Prior to the Water Use Plan and Under the Water Use Plan Flow Regime

<table>
<thead>
<tr>
<th></th>
<th>Pre-WUP (m³•s⁻¹)</th>
<th>WUP (m³•s⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum flow from Daisy Dam</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jan 1 to Mar 31</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Apr 1 to Oct 31</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Nov to Dec 31</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Additional flow releases</td>
<td>Based on inflows to Daisy Reservoir</td>
<td>Based on flow requirements at Brackendale Gauge</td>
</tr>
</tbody>
</table>

Thus, the consequence of the WUP change in Dam releases is uncertain, largely because the impact of the current regime is unknown. If one were to assume that habitat and flow are positively correlated, then one would expect a potential reduction in habitat during the 3 m³•s⁻¹ base release, and a potential increase in summer rearing habitat with the 7 m³•s⁻¹ base flow. This change in base flow leads to the following fish management question:

1) Do Daisy Lake Dam releases affect the resident rainbow trout population located immediately downstream of Daisy Lake Dam? The parameters of interest include fish density or relative abundance, age class distribution, size-at-age, and relative condition.

1.1.3 Summary of Impact Hypotheses

The management question outlined above will be addressed through a test of four impact hypotheses. The impact hypotheses relate to three key phases in the life history of rainbow trout; spawning success, summer rearing (growth and survival), and over-wintering survival. Direct measures of these parameters are outside the scope of this monitor and therefore, the monitor relies on the use of indicator
variables to test these hypotheses. Relative spawning success will be measured in terms of inter-annual variability in fry abundance, while relative rearing success will be explored through tests of size-at-age and relative condition and relative abundance data, and over-wintering survival will be noted by tracking the ratio of age-class specific densities. These variables will be tested using the following impact hypotheses:

\[ \text{H}_01: \] Relative spawning success, as indicated by fry density at the time of sampling, is not correlated with average (or some other summary statistic) discharge during the spawning, incubation, emergence, and early rearing phases of development.

It should be noted that test of this hypothesis will require some measure of adult spawner abundance to account for inter-annual differences in egg deposition.

\[ \text{H}_02: \] Relative rearing success, as indicated by relative condition, size-at-age, and abundance, is not correlated with average (or some other summary statistic) discharge during the summer growth season.

The summer low flow period is generally considered to the standard time during which population censuses are taken for inter-annual or treatment related comparisons. As result, test of \( \text{H}_02 \) with respect to abundance will also lead to an indirect test of general population success. In should be noted that density measurements may have to be corrected for local habitat quality constraints (a covariate) if between-site or between-system, or between-treatment comparisons are to be made.

Test of \( \text{H}_02 \) will rely on inter-annual variability of Daisy Lake Dam releases in response to downstream requirements at the Brackendale stream flow gauge to provide the necessary range of flow treatments. At this time, it is unknown to what extent flows in the upper reaches of the Cheakamus River will vary, though it is not expected to be very large. As a result, it may be possible that the range of annual flow treatments may be too small to create the contrast needed to test for a measurable effect. Furthermore, confounding factors unrelated base flow levels might also mask the treatment effect. For these reasons, tests of the hypotheses above are not expected to uncover relationships unless there are clear and very strong responses to small changes in base flow conditions.

In addition to the impact hypotheses above, there will also be a general test of the assumption that resident trout populations are not impacted by the change to WUP based operations. The general compliance based hypothesis will make use of the fish abundance and morphology data collected for hypotheses \( \text{H}_01 \) to \( \text{H}_03 \) by examining the data set for temporal trends. The impact hypotheses are as follows:

\[ \text{H}_03: \] Relative spawning success, as indicated by fry density at the time of sampling, remains stable or increases through time following implementation of the WUP.

\[ \text{H}_04: \] Relative rearing success, as indicated by relative condition, size-at-age, and abundance, remains stable or increases through time following implementation of the WUP.
The test of these hypotheses assume that the current flow regime out of Daisy Lake Dam is superior to the WUP for promoting trout population growth and that the current status of the population is at or near its maximum potential given the non-operational constraints in the system. Like hypotheses H₀₁ and H₀₂, these will be low power tests because of many confounding factors.

1.1.4 Key Water Use Decision Affected

The key water use decision that could be informed by results of the monitoring would be the seasonal flow release from Daisy Lake Dam. The WUP flow regime from Daisy Lake Dam will change considerably from the pre-WUP regime, where releases were governed by the flow requirements at the Brackendale stream flow gauge. Flow releases from Daisy Dam under the WUP are likely to be lower during November to December, and possibly higher during April to October. This change was recommended during the WUP primarily to benefit salmonids in the lower reaches of the river, and was assumed not to impact resident trout populations. The only evidence available to support this assumption was the relatively insensitive RUA performance measure (PM) used in the trade-off analysis (Marmorek and Parnell 2002). There was considerable uncertainty in the validity of the PM because it relied primarily on air photo interpretation techniques that have yet to be tested for robustness, accuracy, and predictive capability. This uncertainty was one of the factors that lead to a division among CC members regarding the appropriateness of various flow regime options and their consequences to the resident trout population. Results of the monitor will reduce this uncertainty and will provide information to inform future decisions.

1.2 Program Proposal

1.2.1 Objective and Scope

The objective of this monitor is to collect the data necessary to test the Impact Hypotheses outlined above and hence, address the Management Questions. The following aspects define the scope of the study:

a) The study area will be restricted to the upper section of Cheakamus River bounded by Daisy Lake Dam at its upstream end and the start of the canyon reach.

b) The resident rainbow trout population will be the focus of monitoring, and all species captured will be documented.

c) The monitor will be carried out annually for five years.

d) Sampling will be carried out over a two-week period at a standardized time of the year.

e) A data report will be prepared annually summarizing the year’s findings.

1.2.2 Approach

The general approach to the monitor will be to carry out annual fish population censuses to track changes through time and whether inter-annual differences are related to prevailing hydrological conditions. The census variables of interest include
juvenile abundance, adult abundance, size at age, and relative condition. These variables collectively allow testing of hypotheses concerning rearing success, and spawning success.

The monitor does not incorporate a before-after WUP implementation comparison in its design, nor are there target values set for specific population characteristics. This monitor is designed strictly as a tracking process to ensure that the resident fish population does not deteriorate through time as was assumed by some members during the WUP. The other design aspect of the monitor is to ensure that sufficient data are collected to determine whether the cause of a decline, if one is detected, can be attributed to the new operations.

It should be noted that the population census data is to be collected by sampling techniques that are prone to error when applied to large river situations such as the Cheakamus River. As a result, the ability for the monitor to detect statistically significant differences through time is relatively low unless the magnitude of change among the population variables is very large. It is unlikely that subtle changes in population character will be detected. Inherent in the design of the monitor is the assumption that such small changes in population character do not have an impact of its persistence or resilience.

To help minimize error, all sampling will be carried out at a standardized time of the year and over a short period of time (maximum two weeks) to minimize the effect of within-year differences in population character. Fish sampling will be carried out primarily by multiple removal using BC Resource Inventory Standards Committee standard electrofishing techniques. The only exception will be the adult fish census, which will rely on angling or another suitable technique for sampling since the areas these fish are likely to reside (i.e., deeper faster waters) are too dangerous to fish by electroshocker. Also, the adult fish census, designed as an indicator of the spawning fish population, may be sampled at a different time of the year than the juvenile fish census.

To overcome high variance in the data due to sampling error, the monitor will have to be carried out annually for the full duration of the WUP implementation period so as to maximize the number of sampling periods. This will maximize the resolving power of the statistical tests to detect differences in the population data over time.

1.2.3 Methods

Task 1: Project Coordination

Project coordination involves the general administrative and technical oversight of the program. This will include but not be limited to:

1) Budget management.
2) Staff selection.
3) Logistic coordination.
4) Technical oversight in field and analysis components.
5) Liaison with regulatory agencies.

**Coordination with WUP Monitoring and Other Monitoring Programs**

To help answer high-level questions regarding the relation between Cheakamus River discharge and fish production, data from this resident trout program will ultimately be used in combination with data from the steelhead monitoring program (#3), the benthic community monitoring program (#7), the channel morphology and hydrology program (#8), and possibly other WUP monitoring programs. For example, the benthic community monitoring program will require that juvenile specimens be collected under this program and Program #3, and sent to the benthic program for analyses of stomach contents. Therefore, it is critical that data collection is coordinated among programs.

To ensure that data collection is coordinated among the inter-related monitoring programs for the Cheakamus WUP, an important task for this program is to develop and maintain communication with project leads for the other monitoring programs. This could involve a workshop at the start of the field season to ensure that the trapping locations and methodologies will meet the data requirements of the other programs, and vice-versa. Logistical changes within the scope of the program may be required.

**Task 2: Field Methods**

**Pilot snorkel survey**

In the first year, one or two snorkel surveys covering the area from Daisy Dam downstream to the start of the canyon will provide information on the general distribution of each rainbow trout lifestage that may assist in site selection. In addition, this snorkel may provide an index of adult abundance that can be compared with the information from the angling sampling of adults (see below). The most appropriate seasonal and diel timing for this survey(s) will be determined. Late winter may provide suitable sampling conditions for adult enumeration.

**Information Review and Site Selection**

Site selection for electrofishing will occur during the first year of the monitor. A first step in site selection will be to review existing fish sampling data upstream of the Cheakamus Canyon (e.g., Clark 1989; contact Ron Ptolemy, BC Ministry of Environment), to determine if sampling can correspond to existing sites. Site selection should reflect the general character of the river, and include both high and low quality habitats. To assist with comparisons with data collected under this program, the information review will include a summary of quantitative data from previous fish sampling.

Once selected, the location of each site will be marked by flagging and/or wood stakes, including the position of all nets used during the sampling procedure. GPS co-ordinates will also be collected for each site and net location so that they may be documented on maps and air photographs for future reference.
A minimum of ten sites will be selected for sampling. This assumes that a single three-person crew is capable of sampling at least two sites per day. The actual number of sites selected however will depend on several factors, including the degree of difficulty to access the site, the time it takes to set up nets and a fish processing centre, the level of effort to measure habitat quality, and the number fish caught at each site. Although total effort is by project scope, it can be spread over a two-week period to accommodate challenges with field logistics. All sites are to be sampled during the same two-week period each year so that the data can be directly compared between years.

**Fish Capture**

Fish capture will be carried out using two different methods. A multi-pass electroshocking program will be used to estimate juvenile abundance, which will be reported as a density value (i.e., fish•m\(^{-2}\)). Adult abundance will be reported in terms of Catch per Unit Effort (CPUE) which will be based on a targeted angling program. Details of the two programs are as follows:

**Electroshocking Program**

Sampling will be done by a three-person crew equipped with a fish electroshocker and appropriate stop nets. A minimum of two passes will be done for each site, which is to be enclosed by nets if possible and passes should be separated by a minimum of 30 minutes. Fish captured during each pass will either be immediately processed before starting the next pass, or will be stored in separate containers until all passes are completed. The total number of passes done at each site should be sufficient to ensure that population estimates have a CV of less than 0.2. This will require that the analysis of electroshocking data be done in the field.

During the first year, details of the fish capture methodology used at each site will be clearly documented so that it can be accurately repeated in subsequent years. Some of the parameters to be recorded include; the duration of each pass, voltage level and pulse rate of the unit, the use of stop nets and their location, the time between passes, the anode and cathode arrangement, position of netting crew, total area of the electroshocked site, and a general sketch of the anode sweep pattern.

Electroshocking results will be verified by snorkel at each site, where feasible, to confirm the fish distribution within and around the shocked site.

The benthic community monitoring program (#7) will require that juvenile salmonids be sampled, sacrificed and sent to Program #7 to examine stomach contents. For efficiency, theses samples will be collected under this program and/or the steelhead production program (Program #3). Stomach samples from 15 juvenile salmonids for each stream-rearing salmonid species of interest will need to be collected from near the benthic invertebrate sampling sites (i.e., 15 samples per species in each of the years of benthic sampling, in Years 2 and 3, for a total of 30 individuals per species). Subject to sampling permit approval and conservation concerns, species collected for the benthic program would include rainbow trout/steelhead, coho salmon, Chinook salmon and bull trout. Coordination of the collection of stomach samples will be determined through communication under Task #1.
Adult Enumeration

Enumeration of adult rainbow trout will be carried out by team of competent fly-fishers working in tandem in an upstream direction. Sampling will begin at the downstream end of the study section, and proceed upstream to the confluence of Rubble Creek. Total level of effort is not to exceed 24 hours (i.e., a crew of two anglers working six hours per day for two days). Like the electroshocking program, the adult survey is to be carried out at the same time of year each year, and preferably with the same anglers. The time of year that the survey is to be carried out will depend on when trout reach maturity. Pilot surveys, including the snorkel surveys described above, may be necessary during the first year to determine when that is.

Fish Morphology

Captured juvenile fish will be anaesthetized, enumerated, and its taxon identified to the nearest species. They will also be measured to the nearest 1 mm for fork length and wet weighed to the nearest 1 g. In addition scale samples will be collected and stored on slides for future reference. Once processed, the anaesthetized fish will be allowed to recover and then released.

Adult fish caught by fly-fishing are only to be measured for fork length so as to minimize handling. In addition, scale samples from a total of ten adult fish will be taken over the course of the sampling period to assess the age structure of the spawning population. These fish will be selected through a systematic sampling paradigm based on the rate of adult fish capture.

Habitat Assessment

Habitat assessments will be carried out at all electrofishing sites. These assessments will consist of standard descriptions that use RIC standard measurement procedures and definitions for substrate composition, cover availability, and flow metering for depth and velocity transects.

Task 3: Data Analysis

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

Fish Density Estimates

Fish density estimates will be calculated from the multi-pass electroshocking data using the maximum likelihood estimation procedures. If the pattern of removal departs significantly from expected values, then a Bayesian approach to the analysis should be used as it tends to be more accurate in such cases (e.g., Mantyniemi et al. 2005 and references therein). If the Bayesian approach is needed, a uniform prior capture probability of 0.5 should be used. Regardless of the techniques used, fish density estimates should be calculated separately for all age classes and reported to include estimates of standard error (or equivalent).
As indicated in the Habitat Assessment sub-section above, it may be necessary to qualify the density measurements by considering habitat quality as a covariate in analyses. Discriminant function analysis will be used to develop a habitat-rating scheme for this purpose that is based on the substrate, cover, average depth and velocity data collected at each site. Alternative analytical approaches to developing such rating scheme maybe used as necessary.

Additional inferences will be derived from comparing densities with theoretical maximum densities calculated from a provincial model of electrofishing data that uses measures of water chemistry (for application to the Cheakamus River, see notes in Ptolemy and Wilson 2006).

**Adult Abundance**

Adult abundance will simply be reported as CPUE value calculated by dividing the total catch by the total level of fishing effort (rod hours).

**Size at Age**

Fish age will be determined by length frequency analysis using common applications (program MIX [www.math.mcmaster.ca/peter/mix/mix.html](http://www.math.mcmaster.ca/peter/mix/mix.html) or similar) and validated with the scale ageing. Size at age will be calculated by averaging the fork lengths of all fish of the same age class. Regression analysis will be used to estimate the average annual growth rate of each age class.

**Relative Condition**

Relative condition of each fish will be calculated using standard formulae and then averaged for each age class. Fish condition will be used to examine H04. Differences in condition between age classes, as assessed by ANOVA, will indicate age specific limitations to growth and perhaps survival.

**Relative Spawning Success**

Relative spawning success will be reported as an indicator variable calculated as the average density of fry corrected by the relative abundance of adult fish. Though the result will resemble an actual measure of spawning success, it should not be interpreted as such. The variable will have little value in the short term, but as the data set increases with the number of years, between year comparisons can be made.

**Between Year Comparisons**

Between year comparisons of variables above will be the means by which hypotheses H01 to H04 are tested. Such comparisons will take on two forms. In the first form, inter annual differences will be explored by regression analysis on hydrology related parameters, including average discharge at key times of the year, the occurrence of flood events, and exceedence probabilities of key discharge values. The intent of such analyses is to establish correlations, if not a causal relationship, between annual hydrological events and the population parameter of
interest. It is through these correlation analyses that hypotheses $H_0.1$ and $H_0.2$ are tested.

The other type of between year comparison will be an exploration of annual trends. In this case, regression analysis is used to examine the likelihood that the population parameter of interest increases, decreases or remains the same over time. It will be through this trend analysis that hypothesis $H_0.3$ and $H_0.4$ will be tested.

**Task 4: Reporting**

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

Every five years, a summary report will be prepared that summarizes all the results to date and discusses in detail the results as they pertain to the impact hypotheses, and more importantly, as they pertain to the management question in Section 1.2.

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

a) Re-iterates the objective and scope of the monitor.

b) Presents the methods of data collection.

c) Describes the compiled data set and presents the results of all analyses.

d) Presents a summary of quantitative fish data from previous historic sampling (as described in the Information Review section above)

e) Discusses the consequences of these results as they pertain to the current WUP operation, and the necessity and/or possibility for future change.

**1.2.4 Interpretation of Monitoring Results**

The implications of the monitoring program to the WUP and its potential for change in the future is linked to the outcome of the hypothesis tests outlined above. Rejection of hypotheses $H_0.1$ would suggest a causal link between the year’s prevailing hydrology and spawning success. Similarly, rejection of $H_0.2$ would suggest a causal link between the prevailing hydrology and rearing success. In each case, for the causal link to be associated with WUP operations, it must be demonstrated that the observed pattern in hydrology was caused by dam operations, and in particular the flow regime dictated by the WUP. Because there are several major local inflow sources immediately downstream of the dam, it is possible that the potential causal link is natural in nature.

Where hypotheses $H_0.1$ and $H_0.2$ deal with immediate (i.e., same year) responses to differences in hydrology, tests of $H_0.3$ and $H_0.4$ are designed to explore the potential for a delayed gradual response to the WUP. Rejection of the latter two hypotheses (which have be stated as a one tailed test) would suggest a negative impact to the resident fish population and that it took more than one year or one generation for it to materialize. If the population response is dramatic, then it may be necessary to
modify WUP operations to prevent further decline. The data collected to date would form the basis from which such an alternative WUP operating strategy would be developed.

By combining results of all hypotheses, it may be possible to determine whether the observed pattern is the result of WUP operations, or some other environmental factor. Rejection of all null hypotheses would suggest a very strong relationship between WUP based operations and resident fish populations, particularly if it can be shown that the hydrological events impacting the population are of WUP origin. Alternatively, if all null hypotheses are not rejected, then it may be concluded that WUP-based operations had no measurable effect on the population and that observed variance in population character is natural in origin. In between these two “extreme” outcomes, are 14 other patterns of hypothesis rejection, each leading to a unique conclusion regarding in the influence of WUP operation on the resident fish population.

1.2.5 Schedule

Monitoring is scheduled to occur annually for five years. At the conclusion of the monitor, a final report will be prepared that discusses the overall findings of the monitor.

1.2.6 Budget

Total Program Cost: $171,706

1.2.7 References


