EXECUTIVE SUMMARY

- **Project number**: Y082282

- **Project Title**: Using GIS and Multivariate Statistical Analysis to Assess the Relations between Aquatic Habitat Indicators and Forest Harvesting at Both Stream Reach and Watershed Scales

- **Project purpose and management implications**

  Using appropriate indicators is an important approach to support sustainable forest and watershed management and has been widely recognized in the scientific and resource management communities. This approach is particularly relevant in BC because of the recent introduction of the results-based Forest and Range Practices Act (FRPA). In spite of significant efforts devoted to selection of forest sustainability indicators, many identified watershed indicators have not been well tested and applied in supporting the design of forest management strategies for protection of both terrestrial and aquatic resources in BC, which greatly constrains our ability to plan and respond to the potential effects of forest harvesting. Meanwhile, due to the hierarchical nature of forest stream systems, aquatic habitat indicators are likely to be scale-dependent, subjecting to factors operating at multiple spatial scales. Therefore, it is necessary to assess stream habitat indicators at both stream reach and watershed scales. In response to this need, the purpose of this project is to identify sensitive and measurable aquatic habitat indicators at both stream reach and watershed scales.
for supporting the design of sustainable forest and watershed management strategies.

The management implications of the project include:

1) Understanding the interactions between forest disturbance and aquatic habitat indicators at both stream reach and watershed scales will enhance our ability to plan and respond to potential impacts of forest disturbance throughout the interior of British Columbia in an informed and science-based manner, such as implications in ecosystem restoration by addressing the potential effects of forest harvesting and salvage logging, and designing sustainable forest management strategies in large-scale watersheds or landscapes of BC interior;

2) The Ministry of Forests and Range through the FRPA Resource Evaluation Program is currently in the process of developing, testing and applying various indicators and measures to evaluate the effectiveness of FRPA in the stewardship of forest resource values. This project will compliment these efforts and will further develop science-based tools that could be used to evaluate the function and condition of forested watersheds within the BC interior.

- **Project start date and length of project**

  This project started at the 2006/07 fiscal year, and is expected to accomplish in three years. As 2007/08 is the second year of the project, there is one applicable former project number: Y071282.
• Methodology overview

1) Research hypotheses and site selection

Our key research hypothesis is that there are significant relations between forest harvesting and aquatic habitat indicators (in-stream wood, pools, substrates, embedment, etc.) at both the stream reach and watershed scales in BC interior watersheds. The empirical relation between forest harvesting and aquatic habitat indicators developed from this project will also provide important guidelines for designing forest management practices and watershed restoration strategies.

Selection of study sites is critical for this project. So far, we have sampled 50 sites. Basically, we used the following criteria for selection of sites: A) headwater mountain streams, mainly second to fourth orders; B) low gradient (3 – 10%) for being sensitive to disturbance; C) mainly disturbed by forest logging activity with various intensities (i.e., pristine / undisturbed, moderate harvested and intensively logged) with no or minimal agricultural or urban activities. These criteria should be able to reduce variations as much as possible with regards to geomorphic setting and basin morphology.

2) Field survey

For each site sampled, a representative reach with a total length of 120 m was selected. The reach was divided evenly into six sections at 20 m intervals. At each section, bankfull width, bankfull depth, wetted width, wetted depth, stream gradient, and left and right bank slopes, and \( D - b \)-axis of the largest stone moved
by hydraulic forces, were measured. Bankfull width and bankfull depth were
defined by a change in vegetation (e.g., no moss cover to moss-covered ground),
an apparent discoloration in the bank material, or a change from a steep bank
angle to more horizontal. Substrate size and embedment were measured by
following a “zig-zag” approach at the start, middle and end of the reach
respectively. In this project embeddedness was estimated by noting the
discoloration of individual pieces of substrate removed from the stream riffle area,
and the b-axis of that piece was measured as the substrate size. A general
qualitative definition of pools and riffles was used in this study. Pools are defined
as areas in the reach containing slow-moving water where the stream bottom is
concave and both the width and length are at least ½ of the wetted channel and the
residual pool depth is at least 10cm. Residual depth is the depth that, if flow was
reduced to zero, water would fill pools just up to their lips that are located at riffle
crests downstream, and is calculated by subtracting the downstream riffle depth
from the pool depth. All other channel features were defined as riffles. In
addition, if the stream unit is a pool, the elements that formed pools were also
identified. Large woody debris (LWD) was defined as woody debris with at least
1m in length and 0.1m in diameter at small end, and at least portion of which is
situated within the bankfull width of stream channel. In addition to its geometric
dimension, LWD orientation, position, function, decay class, stability, and
species, etc, were also recorded. LWD volume was computed based on the
assumption of cylindrical shapes.
3) **Quantifying forest harvesting disturbance at watershed scale**

To assess the impact of timber harvesting on forest stream watersheds, we need to quantify the logging disturbance at the watershed scale level. For each stream surveyed, we delineated a watershed boundary from the 1:50,000 BC Watershed Atlas, with the assistance of the Digital Elevation Model (DEM) and the 1:50,000 BC Stream Network, and calculated the watershed area. The historical forest clear-cut areas harvested as early as 1944 were then computed with the ESRI ArcGIS software year by year based on the watershed border and the corresponding 1:20,000 VRI – Vegetation Resources Inventory (Forest Cover Information), which was acquired from the B. C. Ministry of Forests and some private forest logging companies. Further, the percentage of clear-cut area were also calculated using the information of total watershed area for each surveyed basin. Since historical clear-cut area is highly correlated to watershed area ($r=0.92$, $p<0.0001$), which is deemed as a basin physical characteristic and independent of logging disturbances. In contrast, this is not the case for the relation between percent historical clear-cut area and watershed area ($r=0.18$, $p=0.24$). Therefore, percent historical clear-cut area was used to classify the sampled streams into three groups: (1) percent historical clear-cut area was no less than 25% (LG25), (2) percent historical clear-cut area was less than 25% but no less than 10% (LG10_25), and (3) percent historical clear-cut was less than 10% (LG10).

4) **Characterizing forest harvesting disturbance at stream reach scale**
The stream reach scale forest disturbance was characterized based on the year when the adjacent riparian forests were harvested. Thus, the sampled stream channels were classified into three disturbance categories based upon condition of the adjacent riparian forest. The categories are: (1) riparian forest harvested no less than 30 years ago (HT30), (2) riparian forest harvested more than 5 years but less than 30 years ago (HT5_30), and (3) undisturbed old-growth riparian forest (OF).

5) Data analysis

Statistical tests for the effects of the disturbance categories on the aquatic habitat indicators, including $D$, bankfull width, bankfull depth, relative width, relative roughness, stream gradient, substrate size, embeddedness, pool frequency, residual pool depth, LWD frequency, mean LWD diameter, total LWD volume, per piece LWD volume, and LWD volume per unit channel area, were performed using multivariate analysis of variance (MANOVA). If the effects of the disturbance categories were significant on an indicator variable, the least square means of the variable in the disturbance categories were further compared with Tukey’s tests. Watershed area and elevations among stream classes were also compared to ensure that streams were as similar as possible in terms of these watershed physical characteristics. If difference found, analysis of covariance was used instead. A probability level of $p \leq 0.05$ was used to determine significance in statistical tests.
• **Project scope and regional applicability**

   The scope of the project covers central and south interiors of British Columbia with samples collected across these regions. Therefore, we have reasons to believe that the findings of this project should be well applicable in these areas.

• **Interim conclusions**

   Preliminary results have shown that at watershed scale mean LWD diameter and bankfull depth are significantly different (p<0.05) among different disturbance intensity levels; while at stream reach scale, relative width (ratio of D to bankfull width) (D is the b axis diameter of the largest substrate particle found in the reach) and relative roughness (ratio of D to bankfull depth) are the indicators that showed significant difference (p<0.01) among different riparian logging disturbance types. Specifically, at watershed scale, the order of mean LWD diameter is LG25 (0.25 m) >LG10 (0.23 m) >LG10_25 (0.21 m), with a sole significant difference between LG25 and LG10_25; bankfull depth is the largest in LG25 (1.14 m), significantly higher than that in LG10 (0.82 m) and LG10_25 (0.81 m), with no significant difference between the latter two. At stream reach scale, on average, the order of relative width is OF (12%) > HT30 (8%) > HT5_30 (6%), similar to that of relative roughness, which is OF (73%) > HT30 (56%) > HT5_30 (39%), both having a sole significant difference between OF and HT5_30. The discrepancy in found aquatic habitat indicators sensitive to forest harvesting disturbance when assessed at different spatial scales highlights
the importance of spatial scales when assessing the relations between forest
harvesting and aquatic habitat indicators.

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