AVALANCHE ACTIVITY AND INTERACTION WITH HARVESTED TERRAIN: TERRAIN ANALYSIS AND DECISION SUPPORT SYSTEMS FOR RISK MANAGEMENT.

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ABSTRACT: The destruction of valuable timber due to snow avalanches that interact with regenerating and mature forest stands has become an issue of great concern in western Canada, in the mountain ranges of British Columbia. The avalanche research group at the University of British Columbia has been collecting information on destructive snow avalanches which initiate within cut blocks and on those which descend into cut blocks. Information gathered is being used to study relationships between terrain and vegetation parameters and relationships with frequency and magnitude. Results of this study will be the foundation for decision support systems to minimize risk generated by destructive avalanches in future logging operations. In this paper, the direction of the research group's current research is discussed and preliminary results are highlighted.

KEYWORDS: snow avalanche, forestry, decision support, resource management, G.I.S.

1. INTRODUCTION

Since 1996 the University of British Columbia's Avalanche Research Group (ARG) has identified and collected data on over 300 destructive avalanche paths which interact with cut blocks harvested by clear cutting. The information has been collected with the intention of studying relationships between harvested terrain and various aspects of snow avalanche activity: these include as magnitude/frequency relationships of avalanches in forest harvested terrain; magnitude, frequency and dynamics of avalanches in forested terrain and decision support for logging in steep terrain. The purpose of this paper is to briefly discuss the issue of snow avalanche interaction with forested harvested areas and the direction of the ARG's current research.

2. SNOW AVALANCHE/ CUT BLOCK INTERACTION

Each winter there are more than 300,000 large avalanches ≥ size 2 (based on the Canadian Classification System) in the mountains of western Canada. Virtually all of these avalanches occur in forested zones and 80% occur in British Columbia. Tree removal can cause snow avalanche activity on seasonally snow-covered slopes previously unaffected by this hazard, creating destructive new avalanche trigger zones. In addition, existing avalanche paths can be laterally and longitudinally extended if adjacent tree cover is lost.

The research has shown that in British Columbia an estimated 10,000 clear cuts have been affected by snow avalanche activity. Because of increased pressure on forest resources, operations are moving onto sensitive areas with steeper slopes. As a result, risk of interaction with avalanche terrain is greatly increasing and several environmental and safety concerns have resulted (Table 1).

3. THE STUDY AREAS

The data have been collected in study areas including the southern districts of the Vancouver Forest Region in the Coast Mountains, and three districts of the Nelson Forest Region in the Columbia Mountains (Fig. 1).

4. DATA COLLECTION

Terrain, snow supply and vegetation parameters used in the study have been collected from a number of sources including: professional avalanche reports from consulting firms and forestry technicians, field measurements,

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interpretation of aerial photography, topographical maps and forest cover maps. Also, a Geographic Information System is being used to determine terrain parameters from digital elevation, and digital forest-cover maps, and to model variables such as regional snow supply. From these sources an exhaustive set of variables has been produced for each individual avalanche path.

Table 1: Environmental and safety concerns resulting from avalanche interaction with harvested terrain

1. Destruction of valuable mature timber
2. Removal of soil cover down to bedrock.
3. Effects on structures. (residences, roads, power line structures)
4. Dislodgment of material can form pre-cursors to debris torrent activity.
5. Effects on streams and fish habitat.
6. Effects on the safety of forest industry personnel.
7. Prevention of re-generation of forest covers by avalanche activity.

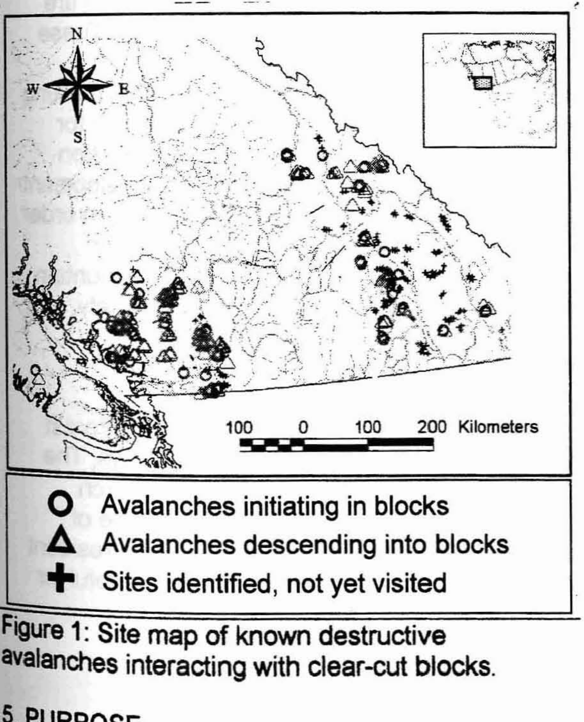

Figure 1: Site map of known destructive avalanches interacting with clear-cut blocks.

5. PURPOSE

The study is the basis of two separate MSc. theses. The first thesis topic focuses on avalanches initiating within clear cut harvested areas, where there was no conclusive evidence of avalanche activity previous to harvest. The avalanches in this study either flow only within the cut block, or continue beyond the base of the cut block into mature forest stands below. The aim of this thesis is to develop a risk based decision support system taking into account frequency/ magnitude relations as a function of terrain, climate and vegetation variables and consequences.

The second thesis topic focuses on natural avalanche paths which descend into forest harvested areas. The concern is widening and lengthening of original runout zones, leading to destruction of regenerating timber, and damage to structures and riparian zones. Terrain, vegetation, climate variables are being collected and analyzed using custom designed extensions to existing GIS software. The data will be used to formulate models of risk for decision-making processes.

6. PRELIMINARY RESULTS

Risk is defined as:

Risk = Event frequency x Vulnerability x Exposure

Much of this study is concerned with the vulnerability of stationary components of the environment such as trees, soil, and riparian systems; and constructed structures such as roads, residences, and power lines, therefore for much of the risk assessment the exposure parameter can be ignored. However, the exposure parameter is included because it must be considered when assessing risk to industry personnel. Since vulnerability is a function of avalanche magnitude and the inherent properties of the object affected by the hazard, risk can be looked upon as a function of frequency and magnitude.

6.1 Terrain and vegetation parameters

Preliminary analysis of the data (McClung, in press) show that the start zones of destructive avalanche paths, which initiate within cut blocks, are characterized by typical average start zone slopes from 30 to 50 degrees. Start zones also have moderate cross slope concavity and moderate to high down slope concavity, possibly reflecting the observed tendency for start zones to be located within shallow bowls below the over-steepened berms of logging roads.

The majority of start zones have a relatively low to moderate wind index of two to three, based on the scale of one to five developed in Schaerer (1977), indicating that concerns of wind loading should be directed toward rolls and irregularities where localized drifting may be focused. No events were found with a surface roughness greater than three meters and 75% had a surface roughness between one to two meters. This may indicate that three meters is an adequate height for stumps left in place to support the snow pack, although the necessary height will vary depending on the local snow supply. These results are characteristic of destructive avalanche paths initiating on clear cut harvested slopes. Such results will be valuable as support for decision systems created to decrease the risk of avalanche activity initiating in harvested areas.

6.2 Frequency and magnitude parameters

Preliminary results have also shown significant correlations among variables of terrain and forest cover to snow avalanche frequency (Table 2) and magnitude (Table 3). These correlations were found by statistical analysis of data collected from historical records of avalanches that affecting British Columbia highways.

Table 2: Predictor variables of high correlation to frequency in different areas or that are significant in multivariate relationships with frequency.

Variable	Sign of correlation
Wind index	+
Starting zone roughness	-
30 year max. water equivalent	+
Starting zone elevation	+
Starting zone incline	+
Track incline	+
Runout zone incline	+
Runout zone elevation	+

The results of the highway data analysis identify important variables and correlations which are also possibly significant to frequency/ magnitude studies in harvested terrain. In effect this lays a solid basis for the development of theoretical analysis of risk-based decision support for logging in steep terrain.

Table 3: Predictor variables of high correlation to magnitude in different areas or that are significant in multivariate relationships with frequency.

Variable	Sign of correlation
Wind index	+
Vertical drop	+
Starting zone elevation	+
Starting zone confinement	+
Track incline	-
Track confinement	+
Runout zone incline	+
Runout zone elevation	+

7. CONCLUSION

The in-depth study of destructive snow avalanches and interaction with harvested terrain has revealed that paths are characterized by common variables which are easily measured and estimated by snow avalanche and forestry professionals. Secondly, information gathered on avalanche paths affecting highway operations in southern B.C. has identified variables which are correlated with frequency and magnitude. These predictor variables along with knowledge of variables characterizing avalanche paths affecting forest harvested areas lays the groundwork for theoretical development of risk based decision support for logging applications. The development of decision support systems is necessary in order to reduce the destruction of valuable timber resources and the negative impacts on mountain forest environments and forest worker safety.

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REFERENCES:

McClung, D., 2000. Characteristics of terrain, snow supply and forest cover for avalanche initiation caused by logging. (in press).

Schaerer, P.A., 1977. Analysis of snow avalanche terrain. Canadian Geotechnical Journal. 14(3), 281-287.