Canadian Avalanche Hazard Mapping Project

*Chris Stethem, †David McClung, ¶Bruce Jamieson and *Peter Schaerer
*Chris Stethem & Assoc. Ltd., †University of British Columbia, ¶University of Calgary

Abstract: The objectives of the Canadian Avalanche Hazard Mapping project were to prepare uniform national guidelines for risk analysis and avalanche mapping, to inform land managers about recognition and mitigation of avalanche hazards and to develop a training course in avalanche mapping for land use planning. Uniform practices for evaluation of avalanche risk and facility planning should result in reduced loss of life and property damage. Risk determination under the Canadian Guidelines includes avalanche return period, the probable consequences of an avalanche and probable exposure to the avalanche. Consequences are defined by predicted avalanche impact pressure or destructive potential based on the five part Canadian system for classifying avalanche size.

Keywords: Avalanche, Risk, Mapping

Introduction

Over the past 50 years avalanche mapping practice and policy in Canada has evolved largely in response to accidents, which had a particular impact on one region or industry sector in Canada. The regional nature of these concerns and solutions resulted in adoption of a variety of statutes and policies on avalanche risk. Often it was left to the avalanche consultant to define acceptable risks or mapping practices.

The objectives of the Canadian Avalanche Association (CAA) Avalanche Hazard Mapping (AHM) Project were:

- To establish uniform Canadian guidelines for avalanche risk evaluation and mapping for facilities affected by snow avalanches.
- To inform land managers about avalanche hazards and their mitigation.
- To design a training curriculum to provide uniform delivery of such guidelines and methods to planners, engineers, geoscientists and avalanche professionals.

The National Search and Rescue Secretariat (NSS) New Initiatives Fund, under sponsorship from Parks Canada, funded this project. Uniform practices for evaluation of avalanche risk and facility planning should result in reduced loss of life, property damage, and rescue call-outs.

Corresponding author address: Chris Stethem, Chris Stethem & Associates Ltd., 409 8th avenue, Canmore, AB, Canada T1W 2E6; tel: 403 678-2477; fax: 403 678-3486; email cstethem@snowsafety.ca

The AHM project team included Dr. David McClung, Dr. Bruce Jamieson, Mr. Peter Schaerer and Mr. Chris Stethem (Chairperson). Additional members of the team included Mr. Arthur I. Mears, as technical reviewer, and Ms. Janice Johnson as adult education specialist. The project was completed between September 2000 and September 2002.

Publications

Two new publications resulted from the AHM project:

- *Guidelines for Snow Avalanche Risk Determination and Mapping in Canada* (Canadian Avalanche Association, 2002a). These are technical guidelines, which are directed at consultants and planners working with snow avalanches.
- *Land Managers Guide to Snow Avalanche Hazards in Canada* (Canadian Avalanche Association, 2002b). This guidebook provides a general description of the snow avalanche hazard, how it is assessed and mapped by planning professionals, and how to find avalanche-planning expertise.

Stakeholders across Canada were identified and contacted at the outset to inform them of the project objectives. Once the initial drafts of the publications were prepared, the stakeholders were invited to review and comment on the contents. These comments were very important in the process of revision and final publication.

Risk Determination

In a general sense, risk is the chance of injury or loss as defined as a measure of the probability and severity of an adverse effect to health, property, the environment or other things of value (Canadian Standards Association, 1997). Risk determination under the Canadian Guidelines includes avalanche return period, the probable consequences of an avalanche and probable exposure to the avalanche. Consequences are defined by predicted avalanche impact pressure or destructive potential, based on the five part Canadian system for classifying avalanche size (McClung and Schaerer, 1981).

The Canadian guidelines include the following applications:

- Work sites
- Transportation routes (rail and road)
- Energy and communication structures (transmission lines, surface pipelines and telephone lines)
- Recreation operations (ski areas, commercial backcountry operations)
- Forest harvest areas
- Occupied structures

Thresholds to initiate action are defined by avalanche return periods and critical avalanche sizes for work sites, transportation routes, energy structures and recreation operations. The typical action or planning and map types are described for each application. Locator maps, which identify potential avalanche terrain, are typically used in planning for these applications. When the project moves into construction and operation, avalanche atlases are often prepared to clearly illustrate the potential avalanche terrain for a series of locations.

For example, in a highways application the thresholds are: a return period of 30 years and a Size >2 for planning and passive control measures; or 10 years and Size >2 for an active avalanche control programme. An avalanche atlas is typically used for an operating highway.

Forestry is a major industry in Canada. Forest harvest practices can lead to creation of new avalanche paths in cutblocks (Type I problem) or the expansion of existing avalanche paths running into cutblocks (Type II problem). Either type can result in a potential for damage to the standing forest or to pre-existing down slope facilities and other resources, such as transportation routes.

The Guidelines recommend an initial assessment by the forestry proponent to identify if there is a concern for snow avalanches. This is based on slope incline (critical threshold 30°) and snow supply sufficient for destructive avalanches. If a potential for snow avalanches is identified, then a detailed avalanche risk analysis is completed.

The potential avalanche risk resulting from forest harvest is assessed using risk matrices, which combine avalanche frequency (or return period) and destructive potential based on avalanche size to determine a qualitative risk rating (i.e. high, moderate or low). Moderate risk will normally require modification of the harvest design.

Two application matrices are given, one for risk to the forest and one for risk to forest and down-slope facilities or essential resources. For example, where a highway lies below a potential forest harvest area, the moderate risk threshold is a Size 3 avalanche with an average frequency of 1:30 years, or a Size 2 avalanche with an average frequency of 1:3 years. In the case of exposure of the forest resource only, a greater risk is accepted. In this case the moderate risk threshold is a Size 3 avalanche with an average frequency of 1:10 years, or a Size 2 avalanche with an average frequency of 1:1 year. Forest harvest practices that are likely to result in Size 4 (or larger) avalanches are unacceptable regardless of frequency. These matrices are based on research by the Avalanche Research Group at the University of British Columbia.

The risk for occupied structures is defined in terms of predicted avalanche impact pressure and return period (Figure 1). The zone definitions are:

- White zone - An area with an estimated avalanche return period of >300 years, or impact pressures <1 kPa and a return period >30 years.
- Red zone - An area where the return period is ≤30 years and/or impact pressures are ≥30 kPa, or where the product of impact pressure (kPa) and the reciprocal of the return period (years) exceeds 0.1 for return periods between 30 and 300 years.
- Blue zone - An area between the Red and White Zones where, for return periods between 30 and 300 years, the product of frequency and impact pressure is less than 0.1 and the impact pressure is greater than or equal to 1 kPa.

The critical values of 30 years, 300 years and 30 kPa, and the zoning colour scheme are similar to those developed in Switzerland (Switzerland, 1984).

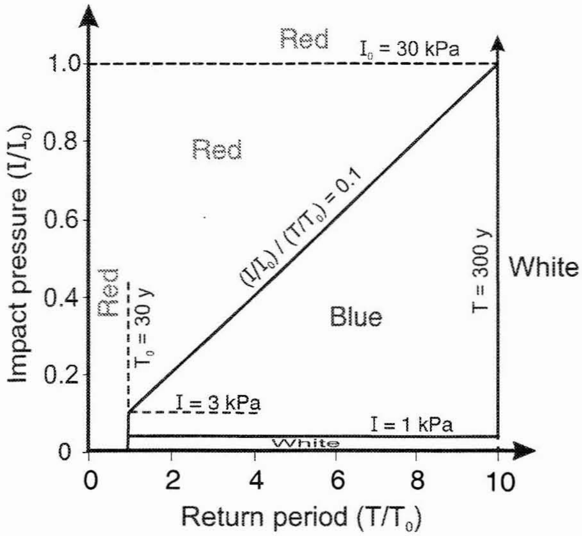

Figure 1: Definition of Red, Blue and White zones for land use planning.

New construction of permanently occupied structures, such as residential subdivisions, are only recommended in the white zone, whereas some temporarily occupied structures, such as industrial plants, may possibly be permitted in the blue zone with specified conditions for avalanche protection.

Avalanche Hazard Mapping Course

The Avalanche Hazard Mapping Course is an intensive ten-day course combining pre-course reading, academic lectures, mapping laboratories and fieldwork. Course prerequisites include a CAA Level 1 Avalanche Course, a CAA Introductory Mapping Course (or equivalent training), four years experience in avalanche work or related fields and university courses in probability and statistics, mathematics and physics.

Long-term records of avalanche occurrence are often lacking in Canada, where large areas of mountain terrain are relatively uninhabited. The evidence of damage to vegetation, determined from aerial photography and in the field is therefore a very important part of the mapping process. An explanation of extreme value statistics precedes the introduction of snow supply analysis and statistical models for avalanche runout determination. Theory on avalanche dynamics is used to introduce dynamic models of avalanche motion. The results of avalanche runout models are then combined with the evidence gathered from the field to prepare zoning plans for occupied structures.

One of the important areas of interest for the participants is avalanche risk assessment in forestry. Forest harvest operations are often in steep mountain terrain. Checklists were developed for the AHM course to assist participants in systematic assessment of Type I (Table 1) and Type II (Table 2) avalanche risk in forest harvest.

A systematic approach to site assessment, combined with judgment gained through experience in avalanche terrain, is essential to reduce uncertainty in frequency magnitude estimation. The intent is that the user first establishes the applicable risk assessment criteria (for example Size 3 avalanches with an average frequency of 1 in 10 years) and then work through each element of the checklist to determine its contribution to the risk. If this is a Type I problem, and several key factors such as slope incline, snow supply, surface roughness, potential starting zone size and terrain features are identified as 'likely' contributors to the risk of the Size 3 avalanche with a 10 year average frequency , then it is reasonable to recommend some modification of the harvest design.

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Table 1: Type I Forestry Avalanche Risk Assessment Checklist.

Evaluation Factor	Data	Contribution to Avalanche Risk		
		Likely	Possible	Unlikely
Incline in harvest area (°)				
Incline below harvest area (°)				
Roughness				
HS_{30} snow supply				
Threshold snow supply				
Snow climate				
Wind				
Vegetation				
Cross-slope shape				
Down slope shape				
Terrain features				
Potential start zone area(s)				
Relevant av. observations				
Aspect				
Conclusions				

Table 2 – Type II Forestry Avalanche Risk Assessment Checklist

Evaluation Factor	Data for Existing Avalanche Path
Start zone incline	
Start zone features	
Start zone area	
Aspect	
Wind	
Roughness	
HS_{30} snow supply	
Threshold snow	
Snow climate	
Track incline (°) above harvest	
Track configuration	
Path width (m)	
Aval. history, frequency & magnitude	

Evaluation Factor	Data for Harvest Area	Contribution to Increased Avalanche Risk		
		Likely	Possible	Unlikely
Incline in harvest area (°)				
Incline below harvest area (°)				
Cross-slope shape				
Down slope shape				
Terrain features within / below harvest area				
Vegetation / surface material				
Est. frequency & magnitude post-harvest				
Conclusions				