FIVE MOUNTAIN PARKS HIGHWAY AVALANCHE STUDY

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INTRODUCTION

The 5 Mountain Parks Highway Avalanche Study was completed for the Canadian Parks Service in 1993. The routes studied included Rogers Pass and Kicking Horse Pass, (Trans Canada Highway), the Radium Highway, the Icefields Parkway, the Maligne Lake Road, the Sunshine Road, the Minnewanka Road, the Field Road, and the Emerald Lake Road.

Each of the avalanche programs on these routes had evolved somewhat independently within local parks jurisdictions. The Canadian Parks service objectives were to ensure their future operations were undertaken in a cost effective manner which was commensurate with the hazard on each route and the common practices of North American Highway operations.

The methodology of the Five Mountain Parks Highway Avalanche Study included:

- Calculation of the Avalanche Hazard Index & Residual Hazard Index.
- Evaluation of the economic impacts of avalanche closures.
- Identification of acceptable closure levels.
- A survey of practices in North American highways operations.
- Evaluation & costing of present programs.
- Identification, hazard evaluation & costing of future program options.

The objectives of the current paper are to provide examples of the use of avalanche hazard index, summarize the practices identified in North American operations and outline the conclusions of the Five Mountain Parks Study.

THE AVALANCHE HAZARD INDEX

The avalanche hazard (Schaerer 1974, 1989) is the probability of damage as a result of an interaction between snow avalanches and vehicles on a road. The avalanche hazard index is a numeric expression of the avalanche hazard on a road. The index is determined by calculating the probability of moving and waiting vehicles being hit by various types of avalanches and multiplying the probability by weight according to the severity of damage. The calculation of the avalanche hazard index is described in detail by Schaerer (1989).

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The avalanche hazard index is a function of:

- the frequency of avalanche occurrences;
- the width and depth of avalanches at the road;
- the number of avalanche paths at the road;
- the distance between the avalanche paths;
- the volume of traffic during the avalanche season;
- the speed of the traffic.

Residual Hazard Index

The residual hazard is the avalanche hazard that remains when avalanches and traffic have been controlled. A residual hazard exists because the time of occurrence and the size of avalanches cannot be predicted exactly, and the application of control methods that would prevent any avalanches would be uneconomical.

In the Five Mountain Parks study, the past observed frequency of avalanche occurrence was applied in calculation of the hazard indices. Detailed records of occurrence and experienced observers were available for most routes, with the term of record varying from 20 to 30 years. All avalanche occurrences were taken into account in calculation of the Avalanche Hazard Index (AHI - uncontrolled hazard), while only road open occurrences were taken into account in calculation of the Residual Hazard Index (RHI - controlled hazard). The difference between the AHI and RHI is the hazard reduction by current measures.

The Simplified Avalanche Hazard Index

The calculation of the avalanche hazard index requires data about the average width and frequency of occurrence of two types of avalanches at each individual avalanche path. Because this information often is difficult to obtain, a simplified hazard index was developed for the comparison of the hazard among roads and the control measures applied, as compiled in the survey of North American practices.

The simplified avalanche hazard, I_S, is:

$$I_S = A \times p \times N/100$$

where:

- A = average annual number of avalanches that cover the full width of the road (sum of all paths);
- p = average number of avalanche paths per road kilometre; the road length per avalanche path is limited to a maximum of 1 km.
- N = average daily winter traffic volume (vehicles per day).

Table 1
Categories of Avalanche Hazard

HAZARD	DETAILED INDEX	SIMPLIFIED INDEX
Very Low	<1	<5
Low	1 to 10	5 to 50
Moderate	10 to 40	50 to 200
High	40 to 150	200 to 750
Very High	>150	>750

ANALYSIS OF AVALANCHE HAZARD INDICES

Hazard indices have been calculated for each of the Five Mountain Parks Routes. The hazard index information for those routes with a moderate hazard or greater (index >10) are illustrated in Figure 1.

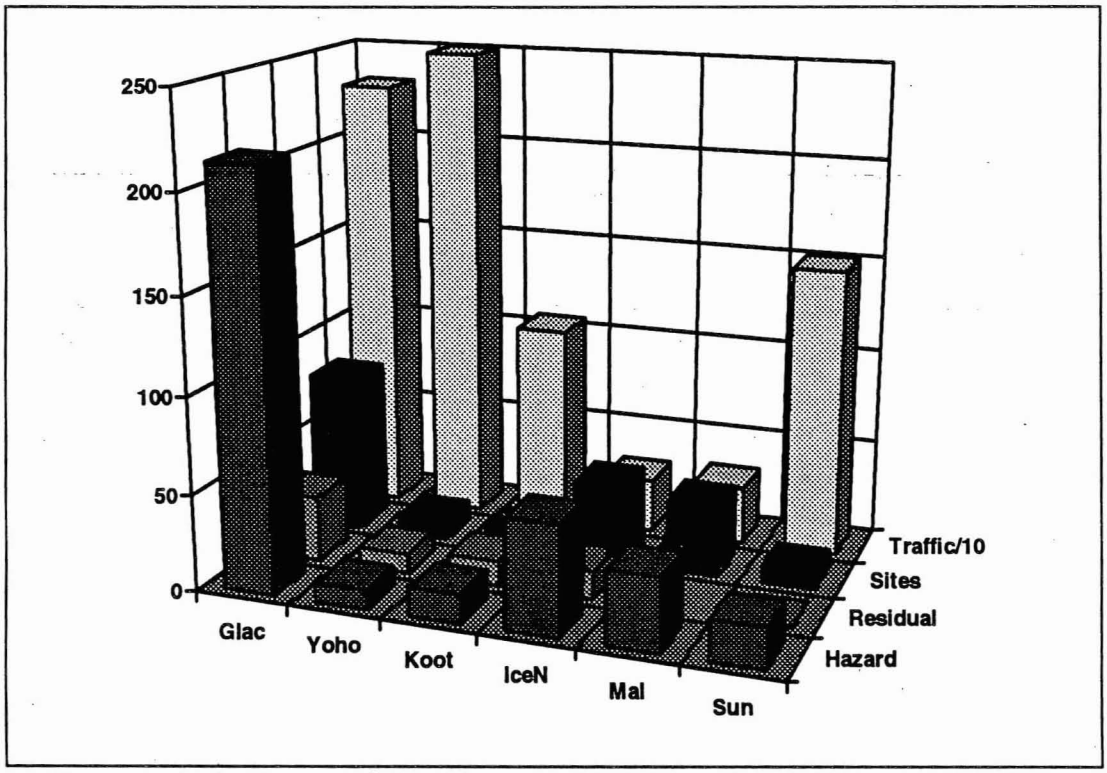

Figure 1: Avalanche Hazard & residual hazard indices, number of sites and traffic volume for the routes with a moderate or greater avalanche hazard index. Glac is Roger's Pass, Yoho is the Trans-Canada Highway in Yoho Park, Koot is the Kootenay Parkway, IceN is the Icefields Parkway, Mal is the Maligne Lake Road and Sun is the Sunshine Road.

The Rogers Pass in Glacier Park (Glac in Figure 1) stands out in terms of hazard. The very high hazard index (214) is a function of the relatively high traffic volume (2300 vehicles per day), the large number of avalanche paths (130 paths affecting the highway at 82 sites), the short distance between paths and the heavy snowfall climate which results in frequent avalanches. In the absence of the existing structures, the avalanche hazard index would be approximately 850, 650 of which would lie on the east side of the Pass where 1500 meters of snowshed are present. The residual hazard as of 1992 was moderate. By the combination of structures, artillery and preventative closure, the overall hazard had been reduced by 96%.

In the study it was identified that approximately 44% of the Rogers Pass residual hazard was at the Beaver Valley avalanche area, where artillery control is not applicable. A structural option of highway relocation and wide road ditching at key sites was identified and has since been implemented. It is estimated that this will reduce the residual hazard in the Beaver Valley by approximately 80%.

On both the Trans-Canada Yoho Park and the Kootenay Parkway traffic volumes are relatively high, the number of sites is low and the avalanche hazard index is moderate. However, the residual hazard is only slightly reduced. Historically, occasional helicopter bombing was the only control method and closure was only usually applied after avalanches blocked the roadway. With this type of control strategy a similar avalanche hazard index and residual hazard should be expected.

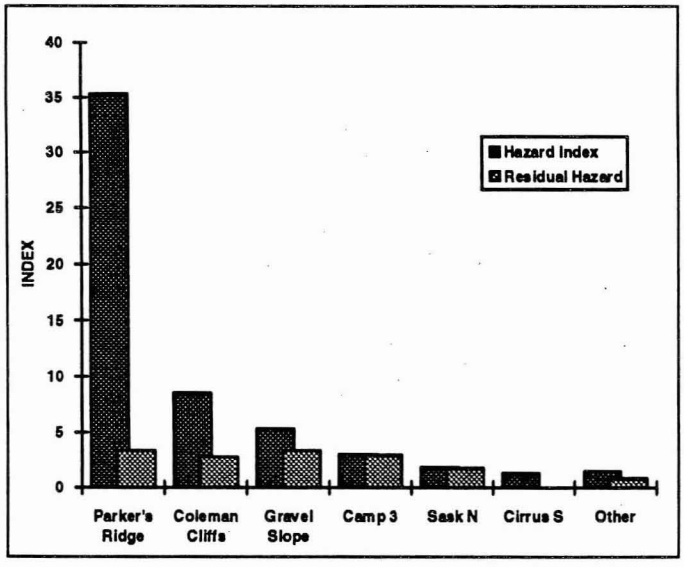

Figure 2: Hazard reduction at key sites along the Icefields Parkway.

On the Icefields Parkway a high avalanche hazard index and moderate residual hazard were identified. A hazard reduction of approximately 74% has been achieved by intermittent explosive control by recoilless rifle, avalauncher, helicopter bombing, and closure.

Multi-day closures during major storm periods are accepted by the public, as this is primarily a recreational route. These major storms are observed infrequently.

The long term record of hazard reduction varies widely at key sites along the Icefields Parkway (Figure 2). At first glance the avalanche hazard index implies Parker's Ridge

should be the key area. If, however, the question is how should future programs change in relation to the current program, then closer analysis of the residual hazard is required. The current control at Parker's Ridge is quite successful, whereas this is not the case at all sites (Figure 2). The hazard reduction at these key sites ranges from 90% to 1%. Planning of future options must therefore pay close attention to the desired reduction of residual hazard at specific sites.

The avalanche hazard index may also be used to analyze the impact of future traffic growth. When various rates of increase are applied to the model, projections of how the hazard will change result. This can be done for the entire route or specific sites.

The analysis for the Kootenay Parkway (Figure 3) shows a jump in hazard in the late 1990's under strong traffic growth (7.5%). A more detailed evaluation of the data reveals this increase is attributed to the path Assiniboine 2.

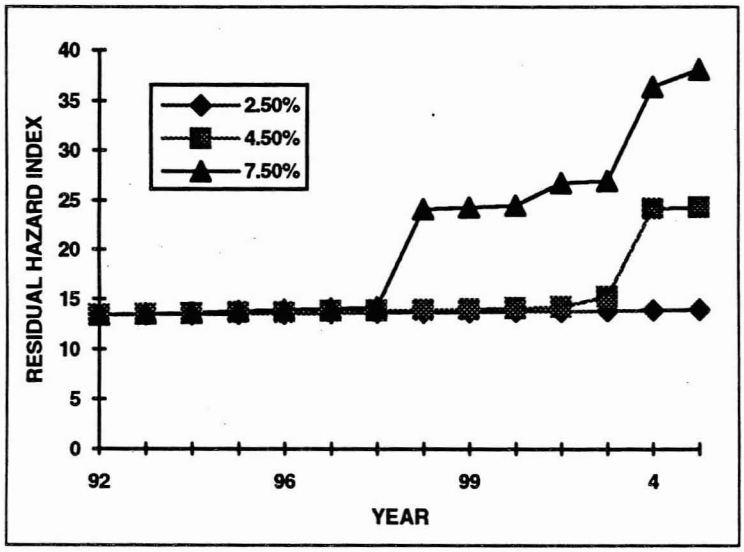

Figure 3: Residual hazard index for the Kootenay Parkway under 2.5, 4.5 and 7.5 % traffic growth through the year 2005.

Further analysis led to the conclusion that active control and better data acquisition in the Assiniboine avalanche area would allow a low residual hazard through the year 2005. A fixed recoilless rifle emplacement and remote weather station have since been installed.

NORTH AMERICAN PRACTICES IN HIGHWAY OPERATIONS

During the course of this study, a survey of North American operating practices was done by direct communications with highway agencies, selected site visits, application of past experience and a review of published information. Thirty seven highway avalanche program areas were included. Hazard indices were calculated using both the detailed and simplified avalanche hazard index method.

The practices identified in this North American survey are summarized in Table 2.

TABLE 2 - NORTH AMERICAN PRACTICES IN HIGHWAY OPERATIONS

	PERSONNEL	EXPLOSIVE CONTROL	STRUCTURES	DATA	CLOSURES
VERY HIGH	Full and part time personnel in forecasting and control operations	Active control operations with multiple fixed & mobile explosive systems	Snowsheds and earthworks (mounds, diversion berms, benches & dams)	Multiple remote alpine weather stations + Alpine snow plot observers	Short control closures with occasional preventative closure.
HIGH	Full or part time personnel in forecasting and control operations	Active control operations at all accessible sites	Earthworks & wide road ditching	Remote alpine weather stations	Short control closures with occasional preventative closures
MODERATE	Part time personnel for forecasting and control operations	Mobile or fixed explosive control at key sites	Wide road ditching & occasional earthworks at key sites	Remote alpine weather stations	Preventative closures
LOW	Maintenance staff, with periodic site visits by avalanche technicians	Occasional heli-bombing	Wide road ditching	Some remote weather stations or shared data	Preventative closures
VERY LOW	Maintenance staff				Preventative closures in exceptional circumstances.

The majority of highway operations surveyed (27) were in Canada and as such there is a bias to practices in Canadian operations in the survey, especially in the low and very low hazard categories. Of that portion in Canada, the majority were located in British Columbia.

COSTS

Costs for highway avalanche programs vary widely depending on the extent and hazard of the avalanche area, the closure policy, the operating methods, personnel & equipment, and the capital investment for structures. Location in regards to residential centres can also add greatly to highway maintenance costs, in the case where distances are great and camps are required. Cost comparison between programs must therefore be approached very carefully.

In Figure 4 cost per unit of avalanche hazard index (AHI) is compared to cost per unit of hazard reduction for five sites in the Mountain Parks. Sites 1, 2 and 3 have similar costs per

unit of AHI to costs per unit of hazard reduction, implying that the hazard has been reduced substantially by the dollars spent. On the other hand the dollars spent per unit of hazard at sites 1 and 5 are substantially more those spent at site 2. The difference is closure policy. At site 2 longer closures are applied to control the hazard and this can be accomplished at low cost. Sites 3 and 4 on the other hand have a wide gap between the dollars per unit AHI and the dollars per unit hazard reduction. This reflects the more passive control strategy on these routes where traditionally avalanches have been allowed to block the road before the road is closed. Fewer dollars are spent on active control operations, however a greater risk is accepted. This implies that a low cost program is not necessarily the most effective option.

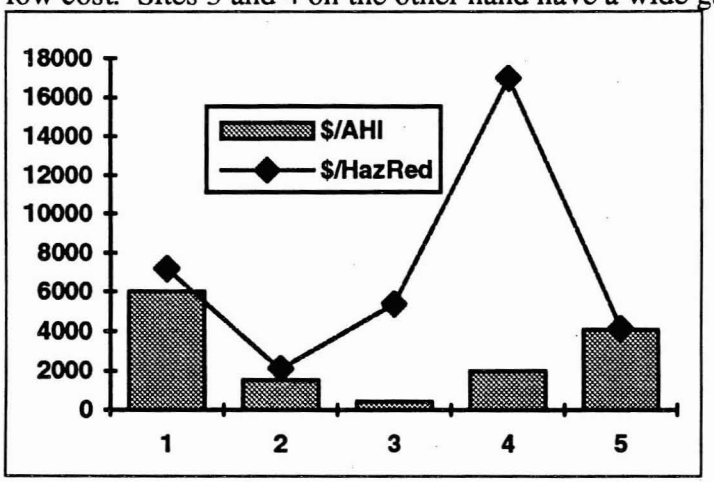

Figure 4: Cost per unit of avalanche hazard index compared to cost per unit of hazard reduction five control operations..

CONCLUSIONS

The avalanche hazard index, residual hazard and the concept of hazard reduction are valuable tools in analysis of current highway operations. This can be accomplished through use of records of avalanche observation for existing routes or through estimation by experienced observers for new highway routes. The value of the transportation network as a key economic asset has not been discussed in this paper, however, this element must be included in comprehensive cost benefit analysis. Closure policy must also be determined prior to identification of control strategy.

The general recommendations of the Five Mountain Parks Highway Avalanche Study included increased use of the 106 mm recoilless rifle, highway relocation and earthworks, maintenance and additions for snowsheds, a park wide data acquisition 7 management system, a training centre at Rogers Pass and an integrated traffic management plan with adjacent jurisdictions.

REFERENCES

Armstrong, B.R. A Quantitative Analysis of Avalanche Hazard on U.S. Highway 550, Southwestern Colorado, Western Snow Conference, 1981.

B.C. Ministry of Transportation & Highways: Avalanche Occurrence Data, and Avalanche Atlas Series.

Bowles, D., and Sandahl, B. Avalanche Hazard Index for Highway 210 - Little Cottonwood Canyon Mile 5.4 to Mile 13.1, 1987.

Icefields Parkway Avalanche Atlas, Jasper National Park, Environment Canada, Canadian Parks Service.

Mears, A.I. and Newcomb, R. Teton Pass and Glory Bowl Avalanche Hazard and Control Analysis. Wyoming Highway Department, 1989.

Morral, J. Ponding Area Analysis & Development of a Staged Traffic Management Plan, Glacier National Park. University of Calgary, November 1991.

Perla, R., and Martinelli, M, Jr., 1976. Avalanche Handbook. U.S. Department of Agriculture-Forest Service 1976.

Rindt E. 1989. Proposal on Km. 7.5 Relocation of TCH Glacier National Park. Public Works Canada, 1989.

Schaerer, P.A. The Avalanche Hazard Index. Annals of Glaciology 13 p. 241-247. International Glaciological Society, Cambridge, U.K., 1989.

Schleiss, V.G. Rogers Pass Snow Avalanche Atlas. Environment Canada, Canadian Parks Service. April 1989.

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