AN APPROACH TO SKI AREA AVALANCHE CONTROL

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Introduction

The Lake Louise ski area is situated east of the Continental Divide in the Canadian Rockies, within Banff National Park. The present lift-serviced area forms a rough triangle measuring about 5.6 km along each side, and ranges from approximately 1500-2600 m above sea level. The climate may be classed as High Alpine, with the characteristic relatively shallow snowpack and very cold winter temperatures. The snowpack is usually quite weak, with temperature gradient metamorphism common in the lower levels of the snowpack.

The ski area is a private business operating on public land leased from Parks Canada. The lift company is responsible for all skier services other than avalanche control. To prevent an obvious conflict of interest, Park Wardens are responsible for carrying out all avalanche forecasting, control and rescue functions. There are 46 distinct controlled avalanche slopes within the Lake Louise ski area. Many of these have more than one trigger zone.

Hazard Monitoring

In a ski area, where people are constantly skiing avalanche trigger zones, the forecaster must have an intimate "feel" for each of the slide paths. Constant monitoring of the snowpack on each slide path is necessary, so that a reasonable margin of safety can be maintained. <u>The only way to do this is to spend as much time as possible out on the slopes</u>.

Ski testing and other physical tests are the most reliable methods of monitoring the hazard. The rammsonde is a most valuable tool for detecting instability in hard slab/ depth hoar snowpack. Often a ski pole is used as a primitive ram, and, with experience, can provide some useful information about the strength of the base. Visual indications of avalanche activity on similar adjacent slopes are obvious hints to the ski area forecaster.

Each week, a snow profile is taken. The data collected may not give an absolute definition of the potential avalanche hazard, but it does indicate whether the base is getting stronger or weaker. By knowing the condition of the base from the snow profile, the results of weather influences can be predicted.

By combining the intuitive "feel" gained by ski testing and ski stabilization of each slide path with snow profile and weather data, the hazard can be monitored reasonably well.

In the Lake Louise area, experience has shown that surface direct-action avalanches during major storms are relatively easy to forecast and control. The most challenging problem is forecasting the effect of storms and weather on the depth hoar base. Large avalanches caused by weakening of the base due to temperature gradient metamorphism have been released in the absence of any new snowfalls.

The factors considered at Lake Louise are:

1. Condition and depth of base
2. New snow depth, penetration point
3. Snowfall intensity
4. New snow settlement
5. Temperature
6. Wind speed and direction
7. Accumulated snow on site
8. Weather forecast and barometer reading
9. Visual indications
10. Physical tests.

As it is difficult to quantify each of the factors accurately, no attempt is made to rate each factor numerically. Instead, a "yes" - (contributing to stability) "no" - (contributing to instability) system is used. This type of contributory factor analysis is an aid to the forecaster, but must be used with understanding the system's inherent weaknesses. All factors may not be given equal weight when assessing the hazard. The forecaster must have experience in the local area to know which factors are most important in a given situation. A common occurrence is to have a high hazard due to the condition and depth of the base, (e.g., depth hoar) while all other factors indicate minimal hazard. In this situation, this one factor will dominate all others.

If records have been accurately kept, time profiles from previous years will assist the forecaster in assessing what avalanche conditions will be. By comparing similar conditions, a rough idea of probable avalanche activity can be obtained. When all available information has been gathered and assessed, the forecaster produces the daily "Avalanche Hazard Forecast".

Public Information

In ski area avalanche control, it is most advantageous to have the skiing public interested in, and aware of, avalanche hazards. Temporary closures are most acceptable if the skiers realize they will be allowed to ski the closed area as soon as it is safe.

A "Daily Avalanche Hazard Forecast" form is compiled each morning and posted beside a map of the ski area. The map shows ski runs, avalanche paths, and avalanche closure areas. This information is posted at the ticket booths, day lodges, and at ski-touring registration boxes. In this way, the public can easily determine which areas are open and closed, when closed areas will open, and also read a short avalanche hazard synopsis. In addition, all avalanche areas are posted with flip signs, which are opened to display the sign face when the area is to be temporarily closed. These closure signs are official and are legally enforceable in a National Park. The above, along with word-of-mouth communication, have proven effective in getting our message to the public.

Hazard Control

Avalanche hazard control is accomplished by temporary and permanent closure, protective or ski stabilization, and stabilization by explosives delivered by hand, avalauncher or helicopter, depending on operational requirements. Each avalanche path controlled is described in the Avalanche Control Plan. This plan has a photo of each slide path showing the site and trigger zones, and a written text outlining hazard rating, location, size, slope, aspect, terrain characteristics, skier access routes, rescue access routes, stabilization methods to be used, and the precise procedures for closure, skier traffic control sweeps, visual checks, and clearance to proceed with control measure.

The most basic means of stabilizing the snowpack is to ski out each snowfall. This is usually only possible for minor storms and on small slide paths. Skiing cuts up the snowpack, reducing tension in the surface layers. Skiing mechanically disturbs the snow, promoting age-hardening. The age-hardened snow in the ski track then acts as an anchor for surrounding weaker snow. Intensive skiing of an area will pack and age-harden the snow enough to increase the density of the snowpack to a state where the formation of depth hoar is inhibited. This is a most advantageous situation and is an early season objective. After each slope is tested for safety, the public should be encouraged to ski them, skiing out as much terrain as possible.

Permanent closures of avalanche paths are counter-productive in that the avalanche areas are not skied out and become a greater hazard to those who enter in spite of closure signs. It is also implied that the slope is unsafe at all times. This is rarely true. Occasionally, permanent closures are necessary where the terrain precludes effective stabilization by any means.

In the Lake Louise area, a very real problem is spring avalanches caused by isothermal conditions. Well-packed ski runs have avalanched, producing an unacceptable hazard. Over the past two seasons, experiments have been done with the use of explosives in isothermal snow. As the snowpack nears isothermal condition, the snowpack is warmed from the ground and from the surface. The slopes experimented with were planted with one pound charges strung in a line across the slope, connected with detonating cord. This was done in the morning when the surface was frozen. In a safe location, as close as possible to the previously planted explosives, a snowpit was dug and the temperature of the strongest layer in the snowpack monitored. When the temperature of the strongest layer reached the range of -1°C to -½°C the charge was detonated and, in every case, the entire snowpack was set in motion. The snowpack was cleaned out down to ground level and the hazard removed for the remainder of the season. Further testing will be necessary to confirm the application of this method in a wider range of terrain conditions.

Discussion

FITZGERALD: What are your Avalauncher target distances?

ISRAELSON: Up to 1200 m.

FITZGERALD: What is your accuracy at that range? Do you fire during storms with indirect firing techniques (blind firing)?

ISRAELSON: We can consistently hit our smallest target which is a gulley 60 m wide. We do not use indirect firing techniques. We point and shoot only in clear weather. Generally, our storms are of short duration and we are able to wait out the storms. Also, we do not fire during poor visibility periods because we have ski-tourers in the area, and we have to be certain that slopes are clear before initiating control.

SALWAY: What percentage of your Avalauncher projectiles are duds (misfires)?

ISRAELSON: Less than one out of 100 rounds fail to detonate on impact. To be more precise, the ratio is 0.81%.

HOTCHKISS: How do you monitor and control wet slabs?

ISRAELSON: This is described in my written contribution. In the morning, when the snowpack is frozen, we bury a series of 0.5 kg charges of Nitron which are linked together with detonating cord. We then dig a snowpit on an adjacent slope and monitor the temperature of the strongest layer. When the temperature reaches between -1°C and -0.5°C, we detonate the explosives.

ANDERSON: You mention that your snowpack is shallow, what are your depths?

ISRAELSON: At our study plot the average is about 1 m to 1.5 m. The deepest on record is about 2 m.

HAMRE: Do you rigidly enforce your avalanche closures?

ISRAELSON: Violation of an avalanche closure is against Park regulations; violators lose their lift-tickets and are taken to court.