THE DANGER ZONE

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ABSTRACT: Too many avalanche workers have made the decision to position themselves or coworkers, helicopters, snowcats, or vehicles, in the run out of an avalanche path when the risk is too high and avalanches have run full path. This paper introduces the initial part of our investigation to understand the context of the problem and to identify themes that may improve the safety of avalanche workers and those they are responsible for. The information for this investigation is based on a survey directed at avalanche workers in Canada and the U.S. This paper specifically looks at the following topics: a) How to uniformly describe this avalanche character. b) Is there a pattern of surprise among experienced avalanche workers regarding avalanches of this character? c) Is there useful but isolated institutional knowledge that can be shared? d) What are the next steps?

KEYWORDS: risk, relative size, destructive size, forecasting, professional incidents, near-miss, full-extent

1. INTRODUCTION AND OUR MOTIVATION

This is not science; it is opinion based on practice, a collection of institutional experience, and a compilation of knowledge gained from applied judgement by avalanche workers. It is the authors' inference from their standpoint and level of awareness that a pattern seems to exist; an anecdotal pattern that there has been failure in the recognition of full-extent avalanche potential by professionals. In professional incidents in Canada alone (Avalanche Canada, 2026), there have been 9 fatalities since 2004 in avalanche runouts. Too many avalanche workers have made the decision to position themselves or coworkers, helicopters, snowcats, or vehicles, in the run out of an avalanche path when the risk is too high and avalanches have run full path.

Our motivation is to attempt to answer the question "what are we missing?" along with a desire to improve the safety of avalanche workers and those they are responsible for.

To investigate this, we created and distributed a survey to avalanche workers. We avoided confirmation bias by weighting and adopting the various perspectives and interpretations illustrated by the comments and long answers of the respondents. We applied our judgement and experience in the elucidation of themes from the responses.

2. THE PROBLEM

There is a quality of avalanche that is particular (or peculiar) to catching avalanche workers off guard. We're concerned with our community's collective ability to forecast the size of avalanche in relation to where we position ourselves and equipment in the path, and the type of assessment necessary to know when can we safely pick-up in the runout.

It was thought that naming this situation could improve things by helping to keep it "on-the-radar". We temporarily chose a working term "full-extent" as a descriptor to capture the mental image of an avalanche that involved more than half of the starting zone with mass on the upper end of a destructive size 2, or perhaps a size 3, and was consequential throughout its flow and into the runout, but not something as distinguishable and very large as a destructive size 4 or 5. This paper introduces the initial part of our investigation where we discuss the following topics.

- How to uniformly describe this avalanche character.
- Is there a pattern of surprise among experienced avalanche workers regarding avalanches of this character?
- Is there useful but isolated institutional knowledge that can be shared?
- What next?

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3. OUR SURVEY

A survey directed at avalanche workers in Canada and the U.S. was crafted to collect information to support our investigation. It had a total of 80 questions that included 36 which were relatively identical to ones asked 28 years ago by Bruce Jamieson and Torsten Gelseltzer (1998). We felt that the focus of their survey on “unexpected avalanches” was similar enough to our investigation that having a current set of answers would provide an interesting analysis against the earlier results. The link to the survey was distributed courtesy of the outreach of the CAA, ACMG, A3, AIARE, CAIC, and the USFS NAC.

The survey was made up of three parts concentrating on the following topics.

- Consideration of a definition of “full-extent avalanches”
- Capturing personal experience and seeking information on how respondents have historically identified conditions that suggested the potential for full extent avalanches
- Collecting information for a retrospective comparison through a repeat of the same questions in a survey done in 1998 by Bruce Jamieson and Torsten Gelseltzer.

The total of 45 responses from June to the first week of August 2026 were used for this initial stage of analysis. The experience base represented was remarkable, 93% have more than 7 seasons of experience, 56% more than 20 seasons.

In their primary role the past 4 seasons, the respondents represented an even mix of guiding and forecasting with a few technicians and search & rescue individuals and spread over all sectors. A similar even distribution was evident between those with responsibility in the runout (industrial, ski area, and transportation sectors: 50%) and guiding (cat-ski, heli-ski, and ski-touring: 43%). The balance of 7% were coded as public agency or rescue sectors.

4. SELECT RELATED LITERATURE

There is prior work that has relevance or provides background to this topic. It is described here to support the discussion.

The mental image that the authors hoped to capture with the phrase “full-extent” combines aspects of both the relative and destructive avalanche size scale.

The relative size scale (R scale) was detailed in pre-publication material for the revised Agriculture Handbook 194 presented at the 1975 USFS National Avalanche School. The scale was *“based on the [relative] volume of snow involved with size 1 reserved for snowslides that travel less than 50 m slope distance regardless of other dimensions. A size 2 avalanche moves a small volume of snow for the avalanche path on which it occurred. Sizes 3, 4, and 5 refer to avalanches that move medium, large, and very large volumes of snow for the paths on which they occurred.”* A useful diagram was provided that illustrates how the same physical sized avalanche would be different relative scale sizes (Figure 1). It is noteworthy when looking closely at the diagram, that it reflects not only how much of the starting zone releases, but also what extent of the path is involved.

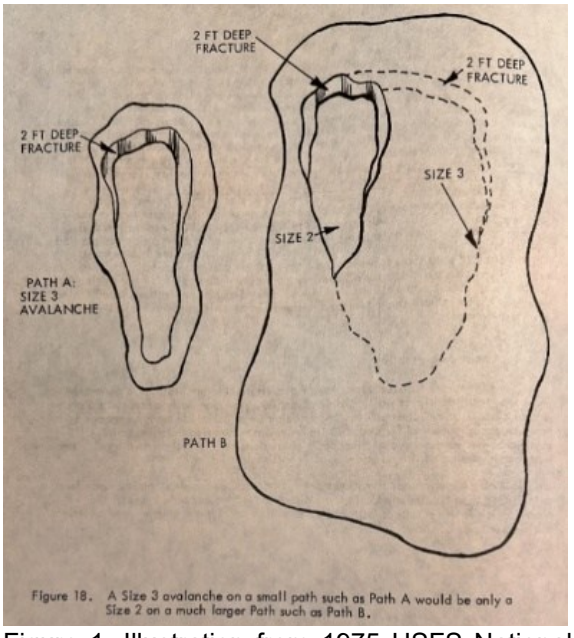


Figure 1. Illustration from 1975 USFS National Avalanche School Binder.

Only the descriptors without any context or the diagram ultimately made it into Appendix D of the Agriculture Handbook 489 (Perla & Martinelli, 1976). A modern visual and textual definition can be found in the avalanche.org glossary .

Gauer (2018) utilized the R scale to define avalanches of interest for hazard mapping as typically R4 or R5.

The Canadian Avalanche Association Industry Training Program (2024) has adopted a modified destructive size table (D scale) that incorporates work

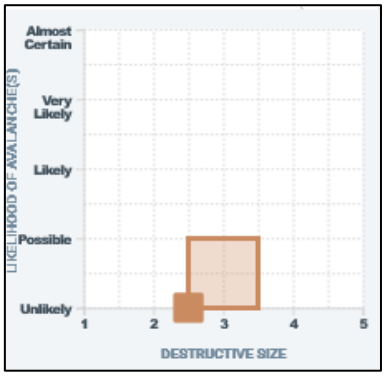


Figure 1. Representation of large, low likelihood avalanche problem type on InfoEx hazard chart.

by Jamieson and others (2014) attributing typical deposit volumes along with typical slab height by McClung (2009) to the various sizes (Table 1).

A graphical hazard chart was introduced during the development of the Conceptual Model of Avalanche Hazard (Statham et all, 2018). It is used in InfoEx and other places to show likelihood and consequence. One of the original functions of the hazard chart was to provide a visual that keeps large, low likelihood avalanche problems perceptible. This is done to maintain operational awareness of the problem (Figure 2).

Atkins (2004) introduced the idea of avalanche characterization. He gave structure to the articulation of the character of instability to allow avalanche workers to quickly and consistently summarize meaningful detail. Important here is that he broke down each of his categories by relative size. He argued that "complete expression of snowpack instability includes an assessment of ease of triggering, an assessment of spatial variability, an assessment of trend, and an assessment of the character of avalanches likely to occur as a result of that instability." The concept of avalanche character has been generally adopted in the use of avalanche problem types.

Table 1. Destructive size chart from CAA-ITP materials.

Size	***Destructive potential***	***Typical mass (t)*** *McClung and Schaerer 1981, 2006, p. 322*	***Typical deposit volume (m^3)*** *Proposed by Jamieson et al. (2014)*	***Typical Impact Pressure (kPa)*** *McClung and Schaerer 1981, 2006, p. 322*	***Typical path length (m)*** *McClung and Schaerer 1981, 2006, p. 322*	***Typical slab height (m)*** *After McClung (2009) and converted to slab height (measured vertically)*
1	Relatively harmless to people	<10	40-100	1	10	0.2-0.25
2	Could bury, injure or kill a person	10^2	300-700	10	100	0.4-0.5
3	Could bury a car, destroy a small building, or break a few trees	10^3	2,500-5,000	100	1000	0.75-1.0
4	Could destroy a railway car, large truck, several buildings, or a forest with an area up to 4 ha.	10^4	20,000-35,000	500	2000	1.7-2.2
5	Could destroy a village or a forest of 40 ha.	10^5	150,000-250,000	1,000	3000	3.3-4.4

5. THE STORY IN THE RESPONSES

This section discusses what the authors deduced from the initial survey data in answer to the three topics outlined earlier; a uniform description, any patterns of surprise, and potential isolated institutional knowledge.

5.1 How to uniformly describe this avalanche character.

There was such abundant discussion with the earliest responses that we reworded the proposed definition for better clarity and better target the range of avalanches. The revision proposed that "full extent avalanche means one that has a destructive size from D2 to D3.5, and is at least a medium-sized avalanche relative to the path (i.e. an R3 or greater), with most of the start zone releasing, running the length of the track, and at least the top of the run-out zone. Additionally, though a full-extent avalanche

runs to most of its maximum slope-length potential, this definition does not necessarily refer to very large, climactic or historic."

We purposely included descriptors to ensure a common interpretation of the relative size scale was considered in answers.

- R1-very small relative to what the path can produce
- R2-less than half of the starting zone
- R3-more than half of the starting zone and traveled some of the track
- R4-most of the snow in the starting zone and ran far into its runout
- R5-all available snow and expanded the runout.

It seemed that respondents with a broader understanding and regular use of the relative scale felt there was no need to create a new definition. For some, "full-extent" brought to mind an avalanche larger than what we were targeting. A saged and elequent avalanche professional summed the issue quite well, "… the definition of 'full extent avalanches' encompasses just about every avalanche scenario that concerns me." A valid observation was made that in areas lacking vegetation, including trim line characteristics (e.g. expanded the runout) does not help with the categorization. Another highly insightful comment was that the phrase did not communicate the level of danger and consequence, something we considered core to differentiating this character of avalanches.

5.2 These are not the droids you are looking for.[*]

The authors chose to drop "full-extent" and adopt R3D2+ in the balance of this paper as the pseudonym for an avalanche that involves more than half of the starting zone with mass on the upper end of a destructive size 2 or size 3 and is consequential throughout its flow and into the runout, but not something as distinguishable and very large as a destructive size 4 or 5.

5.3 Is there a pattern of surprise among experienced avalanche workers regarding avalanches of this character?

A subtle theme seemed to be present throughout the responses. It reflected the variation of perspective, experience, and the position of the element of risk relative to the role or sector of the respondent. And could be summarized as whether one was considering whether the path might avalanche if traveling down it or whether any avalanche triggered in the path will reach the runout. It generally organized in the form of those with responsibility in the runout (industrial, ski area, and transportation) versus those in guiding (cat-ski, heli-ski, and ski-touring).

Only one of the respondents had not witnessed what met the description of an R3D2+. 91% (40) of them had been responsible for initiating such an avalanche. A 50/50 split was present between guides and forecasters having initiating an R3D2+. There was more experience with such by those with responsibility in the runout versus those in guiding.

Over half (24) had been involved or moved out of the way with 11(25%) of the cases reporting the avalanche resulted in harm or structural damage. 91% (39) had been surprised by an R3D2+, 29 of whom being surprised that it ran full-extent. Of those who were surprised it ran full-extent, the variation between those with responsibility in the runout versus guiding was 59% versus 34%. Two thirds of those who were simply surprised that it avalanched were guides (mostly in the ski-touring sector).

Respondents' reflection on what factors had been overlooked leading up to the surprise formed themes around underestimating connectivity, depth of the weak layer, and propagation potential. The role that terrain shape played was highly ranked. A lack of familiarity with the bare terrain was also reported.

If we break the answers out by responsibility in the runout and guiding; the guiding group included these individual responses for what had been overlooked:

- The amount of faceting in the track.
- Buried wind slab.
- Features hard to identify from above.
- A weather event that either wasn't observed, or subtle in nature.

[*] popular culture reference from 1977 movie *Star Wars.*

- Deep slab that was considered dormant.
- A rapid change in conditions when attention was elsewhere (lunch).
- Obscured ridge tops where winds were strong (forecast was for light) and no telemetry available.

Those in the runout responsible group included these individual responses:

- Non typical climatic conditions, cold avalanches traveling much faster than typical in warm coastal conditions.
- No recorded history of it achieving that relative size.
- The tipping point of the system arrived at a lower threshold than expected.
- Propagation into adjacent terrain lower in path and with the additional mass from the PWL resulted in it running further than was expected with the loose dry and the storm slab alone.

A theme within this group's answers referred to a change in conditions mid path:

- Wet snow avalanche reaching dry snow in the track at the elevation of the inversion.
- A typical dry D3 slab reaching wet snow in the track and growing to a gouging D5.
- Presence of mid-elevation PWL wet slab combined with warm-wet snow in runout led to excellent entrainment and easy running avalanches.

All overlooked factors seem sensible in retrospect with nothing jumping out. It may have been more enlightening to have asked "what factors or evidence were you basing your expectations on?"

5.4 Is there useful but isolated institutional knowledge that can be shared?

As one respondent observed, an interview would be better than the survey. Surveys are constrained by the structure and content of the questions along with the perspective and interpretation of the reader. Regardless, there was valuable information to mine and share.

Avalanche problem types are the accepted present-day expression and practice of Atkins' avalanche character described earlier. The incorporation and use of avalanche problem types when forecasting R3D2+ avalanches was evident as a theme in the responses. All types were associated with full-extent avalanches. Persistent slab (including deep and PWLs) occupied a strong majority. Notable was the inclusion of wet slab and the older terminology, hard slab. The concept of a hard slab was highlighted as important in answers to several other questions where resistance or density of the slab was considered to be a factor in forecasting width or length. Storm slab problem type was explicitly named for producing full-extent avalanches on short slopes.

One respondent observed that avalanche problem type related to the length of an avalanche, that a persistent/deep persistent slab could be a more independent predictor of length regardless of terrain.

Several questions centered around forecasting the width and length of R3D2+ avalanches. One would expect our current understanding of avalanches would influence the factors suggested. The most frequent answers for forecasting width were:

- Propagation propensity;
- Presence, type, and uniformity of a PWL;
- Terrain geomorphology, physical constraints of starting zone width and lack of limiting features (rock ridges/cliffs, couloirs, thick timber).

There were several instances of "balancing answers" given by separate responders such as: "very little if any weight is put into snowpack tests" versus weighting "the extent of ECT tests".

Themes around PWL and terrain emerged when digging into more detail regarding the answers about width factors. Contributions of the respondents included:

- A stubborn PWL develops a deeper slab before potentially avalanching.
- Greater vertical meters of start zone and track steepness without noticeable areas of compressive stress [unsupported in colloquial terms] leads to the higher potential for these types of avalanches.
- Everything that enhances uniformity in the starting zone causing it to behave similarly: wind pattern on the whole slope, lack of disruptions to the slab, consistent aspect and incline combination, areas of even snow cover atop uniform terrain.
- Uniform terrain has smooth ground cover, minimal variation in shape, nothing below 30 degrees. Like a tilted tabletop or a steep roof.
- Dormant layers reactivate when loaded fast enough.

Many answers about length pointed to the same factors as for width. And, similar to width, factors from our current understanding of avalanches were most commonly suggested: conditions in the track, entrainment, total path length, bed surface, mass or load, and snow temperature. Acceleration was listed which is an interesting way to combine a number of factors into one.

A question targeted use of the spatial distribution component of the conceptual model. Widespread and specific seemed to help in forecasting for a larger geographic area but the distribution of evidence was not a factor when it came to the path scale. Dietzfelbinger summarized this nicely in one of his responses, “If you mean to ask that there is much evidence in relevant locations, the question is easy. But we seem to be talking about a situation with little available evidence.”

We asked participants to reflect on the apparent number of near-misses or incidents with professionals and full-extent avalanches, and provide thoughts on “what do you think might be missing from professional avalanche training?” Their answers are provided here both to strengthen the collective professional avalanche community and to prompt discussion among its members. Specific topics for training included:

- Angulee: Terrain shape estimation via lidar data or dry slope photos.
- Bacardit: More systematic methods to reduce risk at work.
- Blench: Estimating size using all the tools available. There is overemphasis on the descriptors in the destructive size table.
- Sharaf: Address spatial variation and spatial continuity as influences on avalanche size.
- H. Sheppard: Recognition of events that require a mindset shift, overcoming bias based on snow climate of primary work history.
- Thumlert: Better hazard forecasting and runout prediction, more training on large avalanches including many examples.
- Anonymous: It’s also important to let people understand that they can have a good process for making a decision, that still leads to a bad outcome.
- Anonymous: Addressing the psychological factors that allow us to proceed in a fashion we know is ill-advised would-be fertile ground for additional learning.

A collection of thoughts addressed the big picture:

- Geary: Categorizing things into boxes in a binary way gives the answer about what can be done (eg. Conceptual model and run lists). However, newer workers don't seem very good about taking a step back and looking at things holistically, or realizing the nuances of terrain (e.g. most newer guides seem to have a poor understanding of hard wind slabs formed during arctic outflows).
- L. Kelly: I don't think it's a problem of initial training. I think it is a comfort level that grows over time with initiating smaller avalanches. When PWLs and longer lasting problems persist, operational pressure combined with "avalanche fatigue" leads to lapses in mitigation techniques and underestimation of propagation potential.
- Stanier: Perhaps it is fundamentally that people don't fully address their uncertainty and choose to minimize exposure rather than completely avoiding terrain in complex conditions where full extent avalanches are possible?
- Webster: Every year every forecaster gets surprised. More emphasis on operating with a wide margin of error.

Experience stood out as a theme in the answers to this question. The following capture the central idea.

- M. Klassen: When there is a differential between how much training one has with how much field experience one has it can lead to a feeling that one can outthink the avalanche problem. We need to understand/recognize that there are times that only avoidance of most or all avalanche terrain can contain the problem.
- Anonymous: Experience without formal education can be a prison but formal education without experience is a sure way to grow overconfidence and set yourself up for a potentially deadly failure.
- Anonymous: Time in the field. The latest generation of guides and patrollers all rush through their courses, doing them very young (I somewhat include myself). We need more structured mentorship and time.
- Anonymous: This is a problem that teaches well in an experiential environment; I think we need improved & frequent sandbox style training environments - where candidates explore & make errors, and are supported by a positive learning environment. This should extend into the apprenticeship phases of career development. It is disheartening to see multiple guiding, &

avalanche control environments where new workers, or apprentices, receive little structured support & mentorship.
- Anonymous: More than knowledge, time to absorb that knowledge. Empirical practice to help understand how small changes could create quite different outcomes.

6. CONCLUSIONS AND NEXT STEPS

What follows here are some initial conclusions, some general thoughts, planned and proposed next steps investigating this question. There are also some items where we feel immediate change could improve the situation.

6.1 The danger zone

We are concerned with R3D2+ avalanches; an avalanche that involves more than half of the starting zone with mass on the upper end of a destructive size 2 and size 3, and is consequential throughout its flow and into the runout, but not something as distinguishable and very large as a destructive size 4 or 5. Ones that are considered to be in the lower left of the hazard chart in Figure 3, but at the end of the day are in the box above and slightly right and typically associated with a PWL or storm slab.

We are uncertain about naming this character of avalanches; however, we have identified some initial (low-hanging fruit) improvements that could reduce the number of surprises and close calls from them. These are discussed next in PWL monitoring, situational awareness, and forecasting sub-sections.

6.2 PWL monitoring

The prevalence of PWL and avalanche problem types in the themes suggest greater diligence and consistency in monitoring PWLs would improve the situation. We have observed numerous ways organizations accomplish this from PWL snow boards in the weather plot to graphical snow profile summary whiteboards. There is a PWL monitoring feature within InfoEx, however the observable wide discrepancy in how it is used points to a need for standardization, consistency, and training. An issue that this survey highlighted is the term dormant, which was used a few times in the responses we have shared. We argue that dormant (as described in Figure 4) biases one towards stability. We believe either the current definition of dormant needs revision to convey that it's triggerable or another category between Active and Dormant of Triggerable.

Monitoring PWL in absence of avalanche activity takes time and patience, but is fundamental to our ability to practice safely.

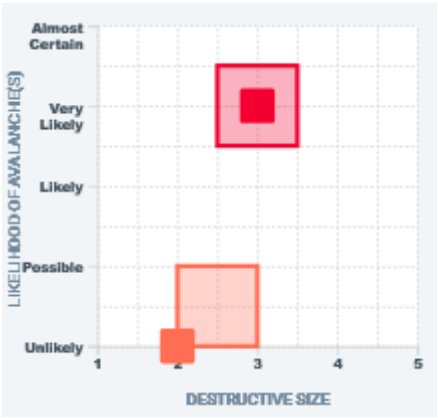


Figure 3. Graphic representation of underestimation of the problem and the R3D2+ it develops in to.

Active

This is your classic PWL. The PWL has been around for a while and there is regular avalanche activity (natural and/or human triggered) on it. Your concerns around the PWL relate to current persistent or deep persistent avalanche problems.

Dormant

You know that the PWL is still around, but there might not have been any avalanche activity on it for a while. However, you are concerned that the layer might become reactive again in the future. For example, with a dramatic change in weather or the first time it really warms up. Hence, you still want to keep track of this layer.

Figure 4. InfoEx help pop-up with definitions for PWL status categories as of August 2026.

6.3 Situational awareness

What makes a piece of terrain opportune for a surprising R3D2+? Can a set of reminder questions help on-site assessment or recognition? Can we generate a list of simple but not miss-interpretable characteristics to estimate whether the start zone supports uniform slab and weak layer development? Is there a clue to observe that captures the situation where the start zone typically doesn't propagate

full width due to some slight change and has the connectedness to go larger? Or is that just trying to outsmart the avalanche when we draw the margin? We anticipate being able to frame this out with further survey results.

A question we do know should be part of every AM meeting is “Are the risk controls adequate to provide an adequate margin (not just reduce)?

6.4 Forecasting

The published avalanche problem type descriptions (Statham et al, 2018) associates typical relative sizes with each of the problems. This component appears to be missing in much of our practice. It is our interpretation and personal opinion that hazard assessments need to include the specific forecasting of relative size along with the existing practice of forecasting likelihood and destructive size. Langeland & Steinkogler (2023) described something similar, forecasting the probability of each individual destructive size.

6.5 Next steps

In addition to the 9 fatalities since 2004, there have been several near-miss incidents; snowcats and helicopters have been struck in the runout with no fatalities. And this is not limited to Canada. In the US, there have been highway avalanche workers struck in their vehicles on the roadway, guided ski touring parties involved, and ski area workers and structures affected. Presentation of this paper at ISSW2026 will bring the question to a targeted audience. The survey will remain open for a month following to gather additional responses and incidents to bolster our dataset. These responses will be included in further work to collate isolated institutional knowledge to be shared in trainings and articles.

The retrospective and analysis of the modern results compared to those from the earlier questions posed by Jamieson and Geldsetzer will be completed once the survey is closed and results will be disseminated through the avalanche associations’ publications.

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