THE Avalanche REVIEW

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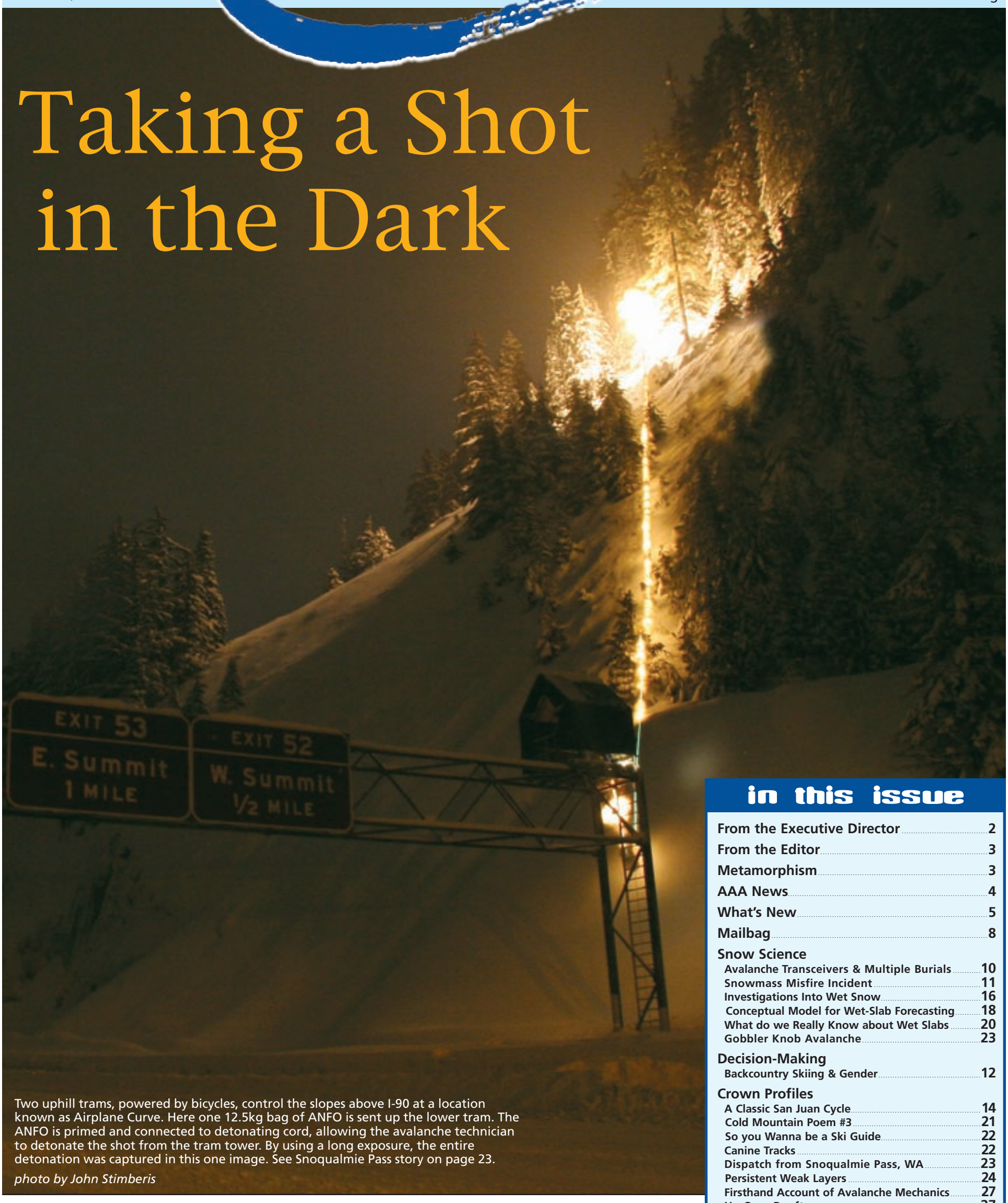
Taking a Shot in the Dark



Two uphill trams, powered by bicycles, control the slopes above I-90 at a location known as Airplane Curve. Here one 12.5kg bag of ANFO is sent up the lower tram. The ANFO is primed and connected to detonating cord, allowing the avalanche technician to detonate the shot from the tram tower. By using a long exposure, the entire detonation was captured in this one image. See Snoqualmie Pass story on page 23.

photo by John Stimberis

The Avalanche Review
P.O. Box 2831
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in this issue

mountain disappears in storm
skiing on memory
and instinct

—Haiku from Jerry Roberts

THE Avalanche REVIEW

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american avalanche association

The mission of the AAA is:

A. To provide information about snow and avalanches;
B. To represent the professional interests of the United States avalanche community;
C. To contribute toward high standards of professional competence and ethics for persons engaged in avalanche activities;
D. To exchange technical information and maintain communications among persons engaged in avalanche activities;
E. To promote and act as a resource base for public awareness programs about avalanche hazards and safety measures;
F. To promote research and development in avalanche safety.

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Contributions: Please submit material eight weeks prior to publication date. Include address and telephone number. Please submit typed manuscripts by e-mail or disk (CD or DVD), using any popular word processing program. Submit any figures as an EPS (prefered), PDF, TIFF or JPG file (300 dpi resolution at 100%). We will return materials if you include a stamped, self-addressed envelope.

Articles, including editorials, appearing in ***The Avalanche Review*** reflect the individual views of the authors and not the official points of view adopted by AAA or the organizations with which the authors are affiliated unless otherwise stated.

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from the executive director

Avalanche path "Daniel" on US Highway 160, Wolf Creek Pass in southern Colorado. *Photo by Mark Mueller*

Avalanche Work is "For Keeps"

Here it is the middle of February. What a winter – a wonderful winter, but very tiring. Snowfall and precip seem to be above average all over the West. When was the last time that happened? No have-nots? Somehow the wheels of AAA keep spinning, although at times I'm not sure how. As you may or may not know the work of AAA is done by folks most of whom have full-time avalanche jobs. Yes, some of us are paid, but not enough to chuck our real jobs. The phones are quiet and the e-mails few, which must mean everyone is busy – very busy. By the time you read this it will be near the end of our season. I'm hoping to have my Christmas cards sent by then. The first half has been crazy here in the east San Juans. What's in store for the second half of this winter?

The operation of AAA becomes more complex every year. We now have paid lawyers and accountants, and liability insurance: not just for our AVPRO course, but for our officers and directors. Despite this, we have been able to keep the dues at an affordable level. This can be attributed to an increasing membership as well as continuing strong sales of our *Snow, Weather and Avalanche Observational Guidelines*, affectionately known as SWAG.

The question of whether an increase in dues is warranted keeps coming up in our board meetings, but we hear very little from the membership about your opinion. One area where you will see an increase is in international mailing expenses for our overseas members and subscribers. The exact cost increase has not been established, but will be implemented with the summer renewal cycle.

Included in the summer letter will be a ballot for the election of a new or returning group of Governing Board members to take office January 1, 2009. Professional and Affiliate Members vote for Executive Board positions, and while Pros vote for the Section Representative where they work, Member Affiliates vote for their Member Affiliate Representative. Who are these people? Well, check out the TAR masthead or our Web site. Interested? Let me or any board member know of your interest or if you have any questions.

The second edition of SWAG is scheduled to go to the printers this summer. The first edition came out in 2004. We hope to include the updated Snow Classification on the Ground as well as several minor corrections. Ethan Greene, Director of the Colorado Avalanche Information Center, will be heading up the second edition working group. Let Ethan know of any information you would like added to the new edition or corrected from the first edition.

ISSW 2008 is coming up in September of 2008 at Whistler, British Columbia. I haven't been to Whistler since the 1988 ISSW and I skied there once in the spring of 1974. It should be another great occasion to educate ourselves, indulge our taste for Canadian beer, and once again connect with our fellow warriors of winter. Don't miss it.

It's been crazy here at Wolf Creek Pass. December snowfall was 460% of average and the snowfall hasn't let up much in January and February. It hasn't snowed in a few days which is why I can still muster the power to put a few coherent words on paper.

I'm reminded of the winter of 1981/82, during my formative years on the Squaw Valley Ski Patrol in the Sierra Nevada. It was a winter that just never let up. Climbing to my test slopes reminds me of the hedge maze in *The Shining*: eerie, silent snow-coated tree towers. We've dodged a couple of bullets on the highway, and I'm reminded of Monty Atwater's words in *The Avalanche Hunters* (my desert-island book) written in the mid '60s, "What with men in orbit, brush-fire wars in Southeast Asia, and annihilation in Peru (Nevado Huascaran), it would get no publicity at all. But it was for keeps." Remember, what we do is for keeps. Keep it safe out there and we'll see you at Whistler.

—Mark Mueller
Executive Director

Mark Mueller on Wolf Creek Pass. *Photo courtesy CDOT*

from the editor

Since Blase and I started writing these editorials a few years ago, I feel that I impose my particular ponderings onto my friends and readers. Earlier this winter I was interested in the deep-slab problem, therefore you were subjected to my questions and investigations. Now it is traveling season and wet-snow season; this issue of TAR reflects those concerns as well as a few interesting reports and photos from a notable winter throughout the hemisphere. Next year we'll be looking at fracture toughness among other topics: How do we measure fracture toughness in the field? Is it possible?

Now I am packing for what has become our annual spring ski trip to British Columbia; Karl Klassen's excellent article on persistent weak layers *(page 24)* helped me understand the complex avalanche dragons that may be lurking in BC this year. Karl's attitude of patience and respect is coupled with some great tools for dealing with these beasts; I hope his perspective and tools stay with me in the big terrain of BC.

We'll headed to Fairy Meadows, which is new terrain for me but imbued with tradition and reputation, which often creates higher expectations. "Oooh, I'd like to ski that…or get up high on the glaciers, or…" We're a small group, accustomed to touring together, articulating our observations, and respecting one another's opinions. We'll try to balance the science with the human factors and keep a rein on our desires based on the evidence. David McClung says it best in *The Avalanche Handbook*:

> An intuitive process in backcountry avalanche forecasting and decisions is the understanding that occurs naturally, based on past experience, combined with physical principles applied to the situation at hand.
>
> *The Avalanche Handbook*, p 216, McClung and Shaerer

I've been teaching avalanche courses and ski guiding all winter. A level I course in Big Cottonwood Canyon for the Friends of the Utah Avalanche Center was particularly memorable, as I was privileged to work with friends and mentors Bruce Tremper, Drew Hardesty, Evelyn Lees, and Tom Kimbrough. Teaching with these pros was intimidating and gratifying, in particular seeing Tom grinning at me from the back row as I shared my world view on the translation of Forecasting to Nowcasting. Tom chimed in on my closing statement to the class as I recap a series of do's and don'ts with a clear and simple, **"Pay attention!"**

The wet-snow material in this issue of TAR *(beginning on page 16)* has been percolating since the Professional Development Seminar in October. Three separate yet linked articles with several sidebars extend our understanding of the topic. Blase, Erich, Simon, and Bruce help us recognize the red lights that identify the wet-slab and wet-sluff phenomena. I like the correlations of events with the weather charts; in this internet-connected world more information isn't always better, but knowing how to weight the data and spot trends will help me make better decisions.

We expect some commentary regarding Margaret Wheeler's Gender Heuristics article *(page 12)*, and we're interested to hear your thoughts. What has been your experience with single-gender or mixed groups in the backcountry? Risk tolerance of men versus women?

We also expect a response from two sets of musings: one from Manuel Genswein *(page 8)* and one from Felix Meier *(page 10)* regarding recent articles on multiple burials. While I feel that TAR is the forum for discussions of this type, let's keep it civil and based on fact, experience, and research. Don't type anything you wouldn't say to an author face to face. We have updated TAR's submissions guidelines if you'd like to submit an article or letter. Pop me a note for the guidelines; they will be on the AAA Web site soon.

I hope you enjoy this issue of TAR; I am already planning ahead to next winter. I'll be in Whistler for ISSW 2008, so please introduce yourself, share a story or a beer, and tell me your suggestions and comments regarding *The Avalanche Review*. I look forward to it!

—Lynne Wolfe

Correction for TAR 26/3

From Bob Comey's Deep Slab photo sequence in TAR 26/3: The slab photo sequence was taken by Peter Linn, not Jim Springer.

metamorphism

At press time TAR learned of the death of **Mike O'Leary**, Cordova avalanche forecaster, Alaska native, and all-around good guy, in an avalanche on March 9, 2008, on Mt. Eyak in Cordova. The avalanche was triggered by Mike skinning back up to retrieve his dog, who was afraid of roll-overs. The crown fracture was 15' high; Mike was buried 18' deep. The AAA and *The Avalanche Review* send condolences to Mike's family and friends.

Look for a more in-depth tribute to Mike in TAR 27/1, and if you have photos or stories to share, please send them to TAR over the summer.

In other news, **Mike Bartholow and his wife Kristin Chamberlain**, plus their son Owen (whose facial expressions were captured in TAR 26/3) are leaving Vail Pass for lower and warmer climes in California. Kristen has a new job working as an Occupational Therapist in Sonora, and Mike has a few things in the works. He is available for hire as an avalanche instructor, backcountry ski guide and babysitter.

AAA thanks for following members for contributing an additional donation to further our efforts in 2006-07. In our fiscal year 2006-07, donations totaled $12,618 and amounted to 16% of our total income.

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Marco Johnson
Mark Moore
Oyvind Henningsen
Mark Saurer
Chuck Rea
Tom Kimbrough
Paul Baugher
Shep Snow
Stan Bones
Matt Hickok

Quinzhee McClelland Sawtell-Andersen

March 18, 2002 - February 18, 2008

Quinzhee was put down today. His life was short but full of excitement. His devotion to his family and his friends was immeasurable.

We will miss negotiating with him.

We will miss being hit from behind with logs by him.

We will miss his penetrating stare.

Most of all, we will miss his commitment to others, his companionship and his gentle heart.

Swim forever Quin!

— from Brad Sawtell, CAIC forecaster, Summit County.

AvPro instructor Don Sharaf goes over potential hazards for a tour. *Photo by Bruce Tremper*

AVPRO students do a quick crown profile on a skier triggered slide on 'Emma 2' in Little Cottonwood Canyon. The slide was triggered by a backcountry skier just an hour or two before the class came upon the site. SS-AS-D2/R2-I *Photo by Don Sharaf*

Letter to Ski Area Avalanche Control Program Supervisors from the AAA

The Ski Area Committee of the American Avalanche Association sent out a questionnaire in the spring of 1992 to areas throughout the West inquiring about information regarding avalanche control work at ski areas in the US. The intent of that questionnaire was to find out: "What are we doing," "How are we doing it," and "Is there a better way?" Thirty-six areas responded in '92, and the data collected at that time is still used today to determine how control is being done, how many explosives are being used, and who is doing it. At that time, the information was collected to share with peers and fellow avalanche control workers. In more recent years an additional need for this type of information has arisen; we need to explain our needs and safety records to state and federal regulators. For this reason the Ski Area Committee has again put together a questionnaire asking many of the same questions and adding some more recent pertinent ones. Your participation in this survey is important to the avalanche community and is extremely appreciated.

The following is a link to a survey that asks a variety of questions involving avalanche control work at your area. If there is no avalanche control work at your area your input is not needed. If you do AC, please have someone familiar with the program (Forecaster, Patrol Director, Mt. Manager) fill out all pertinent answers. It will take approximately 45 minutes depending on the size of your crew, and we request that you be as thorough as possible. We would like the name of the area and the person filling out the survey in case any follow-up questions are necessary, but both the area and person will be anonymous in the survey results. Thank you for taking the time to participate and look for results being posted in *The Avalanche Review* next winter. Please contact me with any questions.

www.surveymonkey.com/s.aspx?sm=K59NiM4Ks_2fn578a6dCpbQQ_3d_3d

Bill Williamson, AAA Ski Area Committee Chair
bwilliamson@schweitzer.com, (208) 255-3051

aaa news

AVPRO Continues, Seeks Instructors

Story by Don Sharaf

This year's AVPRO course ran in Little Cottonwood Canyon, Utah from February 23 to March 2. The original course dates were for early December, but anorexic early season conditions forced us to cancel that course. Unfortunately, the December roster was the first time that the AVPRO (formerly PAWS) was fully enrolled at 18. The course in February ran with 12 students who were originally enrolled in the earlier course. Sarah Carpenter scrambled to reschedule the course in February and pulled it off with nary a hitch.

This year's course was run by Don Sharaf and Ian McCammon with many guest instructors. Drew Hardesty and Bruce Tremper of the Utah Avalanche Forecast Center toured with the course and added perspective on the challenges of forecasting in the public realm. Bruce also shared some of his perspectives on dealing with the media in print, radio, and television. Liam Fitzgerald, Adam Howard, and Chris Covington spoke to the course about assessing and controlling the Little Cottonwood Road Corridor. Chris also spent a morning touring with half of the course tolerating deep and light powder conditions all the way. Dean Cardinale and Jimmy Collinson from the Snowbird snow-safety department talked about avalanche rescue and set up in-area avalanche scenarios for the course participants. Randy Trover, also from Snowbird, reviewed the Wasatch season history. Titus Case and Dan Howlett gave the participants an overview of Alta's avalanche-control program, in addition to a detailed discussion of avalauncher rounds and control work for the upper canyon. Thanks to all of them for sharing their many years of experience.

The biggest change in this year's course format was the addition of one day to the course. We scheduled a day off in the middle in hopes of keeping everyone fresh and hungry for more at the end of the course. Students spent the day touring in the backcountry, practicing beacon skills, practicing data pits, and sleeping in (except for one who went to work patrolling at Snowbird). The universal response among students and instructors was that the day off was a great change in the format and was worth the extra time commitment. We plan to keep the course at nine days (with eight days of instruction). The intensity of the days didn't change much from previous courses, averaging 10 hours per day. Travel time to roadheads/lifts was minimal (less than 10 minutes typically), and little time was lost to logistics…like lunch.

Sarah and Don are working on establishing venues and dates for the 2008/09 season, and those should be on the American Avalanche Association Web site by the time you read this article. We are writing a progression for getting more instructors involved in teaching AVPRO courses, and a primary goal for next year is to get more people involved in teaching these courses. The opportunity to teach and learn from other avalanche professionals in the industry is one of the best ways to continue your own avalanche education.

AVPRO tuition will increase next season in order to make it a sustainable course, demanding less volunteer time from the course designer and better compensation for the course instructors. Any extra funds will likely go into the scholarship fund for this course. At the fall board meeting, a tuition increase was approved and is tentatively set at $1100 for AAA members and $1200 for non-members. Given the training involved, we think it's still a good deal. Two scholarships will be given each year, and each course will have two "comp" spots for hosting ski areas.

submissions

- Seen any good avalanches lately?
- Got some gossip for the other snow nerds?
- Developing new tools or ideas?
- Send photos of a crown or interesting terrain.
- Send photos of avy workers throwing bombs, teaching classes, or digging holes in the snow.
- Pass on some industry news.
- Tell us about a particularly tricky spot of terrain.

07/08 DEADLINES

Vol 27, Issue 1.... 08/01/08
Vol 27, Issue 2.... 10/01/08
Vol 27, Issue 3.... 12/01/08
Vol 27, Issue 4.... 02/01/09

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Write it up; sent it in. *The Avalanche Review* content depends upon you!

what's new

Heading North for ISSW 08?

Before you leave, make sure the Canadians will WELCOME YOU at the border

Story by Halsted Morris

In early February, I was in British Columbia on a heliskiing trip. It was a great trip, and I had a great group. One of the guys in our group was supposed to be there with his girlfriend. But, as it turned out, while making their way through customs and immigration after flying into Kamloops, she was "turned back" by the customs and immigration officials.

The reason for her being turned back was that the Canadian Border Services computer database showed she had a DUI conviction eight years ago. Even though she had paid her fines and served her sentences, she was still denied access into Canada. She even tried a couple of days later to drive across the border. But once again she was turned back. Meanwhile her boyfriend went on to enjoy some waist-deep powder heliskiing with us. So far, I have not heard a status report on the state of their relationship…

While on the trip home I ran into Tom Murphy (AAA pro member/AIARE executive director) in the Vancouver airport. He too had heard of Americans who had been turned back at the border for past offenses. I had heard that the requirements for crossing the USA-Canadian border had tightened up recently but thought that was with the passport requirement rather than for past offenses. As Tom and I talked about this, I thought of all the AAA members who would be coming north to attend the ISSW in Whistler this coming fall. I figured it would be a service to the AAA membership to do a little research about this situation.

After a short Google search, I found the Canadian Border Services Agency Web site. I e-mailed them about who they would be turning back at the border. This is the reply that I received:

"Persons who are inadmissible to Canada include those who have been convicted of minor offences (e.g. shoplifting, theft, assault, dangerous driving, unauthorized possession of a firearm, possession of illegal substances), or of indictable criminal offences (e.g. assault with a deadly weapon, manslaughter). As well, those who have been convicted of driving while intoxicated (DWI) are considered members of an inadmissible class. Driving while under the influence of alcohol is regarded as an extremely serious offence in Canada.

Information on persons who are inadmissible to Canada is accessible from the "Visas and Immigration" section of Foreign Affairs and International Trade Canada's Canada-United States Relations Web site at the following URL:

PERSONS WHO ARE INADMISSIBLE TO CANADA
http://geo.international.gc.ca/can-am/main/visas/inadmissible-en.asp

Information for inadmissible persons about obtaining entry to Canada is accessible from the "Applications and Forms" section of the Citizenship and Immigration Canada Web site at the following URL:

REHABILITATION FOR PERSONS WHO ARE INADMISSIBLE TO CANADA BECAUSE OF PAST CRIMINAL ACTIVITY
http://www.cic.gc.ca/english/information/applications/rehabil.asp

Persons who are inadmissible to Canada because of past criminal activity and who wish to overcome the inadmissibility in order to obtain temporary or permanent admission to Canada can apply for individual rehabilitation if at least five years have passed since they completed their criminal sentences. This application can be used inside or outside Canada. To apply, please contact the nearest Canadian diplomatic representatives for additional information. Contact information for these officials is accessible from the "Embassies and Consulates" section of the Foreign Affairs and International Trade Canada Web site at the following URL:

CANADA'S REPRESENTATION ABROAD
http://www.dfait-maeci.gc.ca/world/embassies/cra-en.asp

Links to additional information about visiting Canada are accessible from the "To Visit" section of the above-mentioned Web site at the following URL:

DO YOU WANT TO VISIT CANADA?
http://www.cic.gc.ca/english/visit/index.asp

We hope this information will be helpful to you. Thank you for contacting the Canada Border Services Agency.

Internet: www.cbsa-asfc.gc.ca
E-mail: cbsa-asfc@canada.gc.ca
Canada Border Services Agency
Ottawa, ON K1A 0L8
Government of Canada
Gouvernement du Canada"

Before you lay out deposit money on ISSW, a hut trip, or heliskiing, you might want to make sure you will be allowed into the country. If you have questions, call the Canadian Embassies in Washington, DC, at (202) 682-1740 or in Seattle at (206) 443-1777.

Halsted Morris is Awards Chair for the AAA board. TAR did not inquire as to whether he found true love on his latest heliskiing adventure.

GEAR REVIEW:
Black Diamond Joule 175cm

Review by Lynne Wolfe

One joule is the work done, or energy expended, by a force of one newton moving one meter along the direction of the force.

When I sat down to write a ski review I had no idea that I would be discoursing on the merits of serial monogamy, but here goes…

In the beginning of the 2007-08 ski season, I made a vow to shrink my ski quiver – to cull out the skis that were no longer in favor. So I sold the 168 Dynafit FR 10.0s with TLT bindings and the Volkl Karmas with Fritschis. Of course I kept the Karhu Jak BC; they're the favored light, fat powder ski. And I made a big move into a Volkl Mantra 177 with Naxos for the ski areas.

But then Penn Newhard of Backbone Media, who promotes Black Diamond, threw a wrench into my plans. He offered me a pair of the new Black Diamond Joules to review, and of course (ski slut that I truly am), I accepted. I am certainly not Tinkerbell, and I don't ski like her either, so I went with the 175. With Dynafit Comforts and a guide's pack, I like a bigger ski.

My first day riding the Joules was at Targhee, one of those many "only 16" of new" days we had in January. After two runs, I had the first part of my review already written. "Do you ever meet someone new who you get along with right away," I exclaimed to my ski partners as we rode up the lift. By run #5 I had refined my statements, however. "The Joule is more like that demanding friend who won't let you get away with bad habits or being lazy."

Then I got some skins for the Joules and took them into the backcountry. The Karhus now gather dust in the garage. The Joules can handle the deep bottomless fluff as well as the Karhus, but if you are tossed a handful of crust or mank – as we often are in the spring while escaping the upper reaches of our powder stashes – these burly girls can still make long-radius, stable turns that are unruffled by less-than-perfect conditions.

The Joule has one less layer in its construction than the Kilowatt, making it a bit lighter and more responsive; I know a number of guys who ski the Joule. BD might think about not calling it a ladies ski, just a more nimble version, in order to appeal to a wider audience. But I sure have seen a lot of ladies on the 165s this year, and all of them had big smiles and wide, fast, stable turns.

A couple of negative points: they are certainly heavier than many solely backcountry skis these days. How do you retain all the performance while losing some poundage? They also are experiencing some delamination issues on the tail of one ski with no probable cause, but even after a first glue episode the topsheet wants to stand tall. Penn assures me that the delam issue, a problem in the first set of prototypes, was fixed in production.

So, you see, I'm not really a ski slut. I fell in love/lust all over again, and my previous amours are abandoned and lonely. I adore my Joules – until something even better comes along next year.

Paul Maniaci Memorial Event Benefits AAA and SAR

Story by Pete Maniaci

On March 11, 2008, Peaked Sports in Driggs, Idaho, held a memorial sale in memory of Paul Maniaci; all proceeds from the Paul Maniaci Memorial Sale will be donated to avalanche research and rescue operations. We raised $1268.21 for the American Avalanche Association, to be earmarked for education; $1268.21 for Search and Rescue Teton County, ID; and $2536.42 for Search and Rescue Teton County, WY.

Paul Maniaci died in an avalanche on March 10, 2007, in Darby Canyon on the west side of the the Tetons. Since Paul is my brother I am grateful for the generosity of Dick Weinbrandt, the owner of Peaked Sports and my boss, as well as the two Teton County SAR groups that responded from both sides of the Tetons, and the American Avalanche Association members who investigated this fatal avalanche.

Paul was a great travel companion, SAR member, teacher, husband, and brother. He served as the Western State College SAR Leader while he attended school in Gunnison, Colorado. His knowledge of avalanche conditions and terrain was similar to mine, and we were confident together. We had climbed together and shared numerous adventures over the years. Neither of us knew the danger that we would climb into that day. Although the Bridger-Teton avalanche forecast for the day was low and had been for several days, we set off a catastrophic avalanche. With the help of search and rescue volunteers, Paul and I were retrieved by helicopter: I was airlifted out the same day, and Paul was flown out the following day. Even though search and rescue members tried to lure Paul's dog, Mica, out of the canyon, he refused to leave and stayed overnight next to his owner. Paul would have turned 26 this March 11. He died one day before his 25th birthday just one year ago. The card we got him before he died had a curious phrase that he never saw, but I will never forget: "The brave don't live forever, but the cautious don't live at all – here's to the brave!"

I'd like to thank Peaked Sports; Dick and Kaela Weinbrandt; Nina Helm; AAA members Don Sharaf, Sarah and Don Carpenter, John Fitzgerald, and Lynne Wolfe who investigated and wrote up the accident; the members of Teton County SAR on both sides of the Tetons; and finally the Teton Valley community who continually offers support and compassion.

Thanks again for all the avalanche research and rescue volunteers who strive to eliminate accidents like this.

BCA Signs Agreement with Fire-Equipment Giant Draeger Safety

Backcountry Access, Inc., (BCA) signed an exclusive supply agreement with Draeger Safety, a leading international manufacturer and distributor of fire-safety equipment.

In 2004, BCA developed the Tracker FRT (Firefighter Rescue Transceiver) and ET (Egress Transmitter). These products are used for locating firefighters inside buildings and for marking and locating exits and other points of safety. They will continue to be designed and manufactured by BCA, but will be marketed under the names Draeger FRT 1000 and ETR 1000. Draeger will take over all marketing and distribution worldwide.

Nearly 40 fire departments have installed Tracker fleets across the U.S. This is expected to grow significantly under Draeger's extensive marketing and distribution network.

"We're incredibly honored and excited to have the number one player in the fire industry behind this technology," said BCA co-owner and marketing vice president Bruce Edgerly. "In their hands, Tracker technology will become a standard in this industry. We can't wait for the day that it saves a firefighter's life." He estimated the Tracker DTS has saved approximately 100 lives in avalanche incidents over the past 10 years, including two live recoveries this January.

Edgerly called the new relationship a perfect match, as BCA's existing sales and marketing network is targeted at the outdoor industry, not the fire-equipment industry. To further penetrate the multi-billion-dollar international fire-equipment industry, he said, would have required an enormous investment and created a potential distraction from BCA's core business. "We don't want to lose focus on what we do best," he said, "We're skiers, not firefighters: our biggest passion is snow safety and backcountry skiing. We want to focus on that and let Draeger take this technology to the next level in the fire industry."

"Every year, an average of 100 US firefighters die in the line of duty," said Draeger Responder Focus Group Manager, Rainer Westphal. "Many of these are caused by being lost, trapped, or disoriented. We believe that the Draeger FRT 1000 will complement our existing product line and can save as many – or more – lives in the fire service as it has saved in the mountains." He said the main selling feature of the Tracker is its ease of use under stress.

The FRT 1000 and ETR 1000 differ from BCA's Tracker DTS in that the units only transmit when the firefighter stops moving for 60 seconds. This is accomplished using a motion-sensing accelerometer. The firefighting version also has an auto-on function which switches the unit from off into standby mode when the firefighter leaves the fire engine. And instead of Tracker DTS's Special Mode button, the FRT 1000 has an "ET search" button which leads a distressed firefighter to exits or other points of safety that have been marked with ETR's, small transmitters with LED strobes. The FRT 1000 units are carried on the firefighter's SCBA waist belt in a fire-resistant Nomex holster.

Draeger Safety, based in Luebeck, Germany, is the world's leading manufacturer of Self Contained Breathing Apparatus (SCBA), gas monitoring equipment, thermal-imaging cameras, and other fire-safety equipment, with annual sales exceeding $2 billion.

For further information, contact BCA at (303) 417-1345 or info@backcountryaccess.com.

Back to School: From Above the 49th

Story by Mary Clayton

Our two organizations – the Canadian Avalanche Association (CAA) and the Canadian Avalanche Centre (CAC) – are distinguished from each other by a simple shift in focus. The CAA works for Canada's avalanche professionals; the CAC's programs and services are for the public. While the end users are different, the motivation and vision for each organization is remarkably similar. Both concentrate on improving avalanche safety, and both are constantly on the look out for better, more effective methods of achieving that goal.

In the last issue of TAR (26/3), I wrote about some recent CAA educational successes. This time we'll take a look at advances the CAC has made in the same field.

Driven by input from our advisory board, the CAC has, for the last few years, been looking for ways to reach youth groups with our avalanche safety messages. As many of you know, kids are an elusive target. Something that works for one age group will fall flat with another, and a message that speaks the right language this year will be hopelessly out of date the next.

Fortunately, some excellent work has been done by a number of individuals and groups in the past. A teacher in the Kootenays had developed some lesson plans for kids in grades 4 to 6. Over in Calgary, another retired teacher had created curriculum for junior high school students. And there were a number of mountain communities where outdoor programs had been developed that included components of avalanche safety. The challenge lay in finding a way to organize all these elements into a cohesive whole, with logical progressions for each age group and over-arching themes to guide the process.

Our first major step in the right direction came last year, with the development of a new ski resort in Revelstoke, the sleepy little town in the Selkirks where our office is located. In addition to giving us some great skiing, Revelstoke Mountain Resort (RMR) has set a new standard for commitment to avalanche safety. In February 2007, RMR donated $5000 to the CAC to create an avalanche-education program for every student in the Revelstoke school district. In December 2007, they renewed that commitment, allowing us to continue the project for the current winter season.

With this money we've hired Verena Blasy, a local teacher with experience in backcountry travel as well as curriculum development. Verena set to work collating the existing material, finding where the different programs overlapped and filling in where they diverged. She had to work hard to get that work done before the 2006/07 winter was over, but she managed to deliver the program to almost 200 kids before spring.

Verena began work a bit earlier this year and was delivering pre-season avalanche-awareness classes before December. Now another ski area has stepped up to the plate. East of Revelstoke, on the other side of Rogers Pass, is Golden, BC – Kicking Horse Mountain Resort (KHMR) is their local ski area. In early 2008, KHMR offered to fund a visit by Verena so she could deliver her avalanche-safety curriculum to all the students in their community.

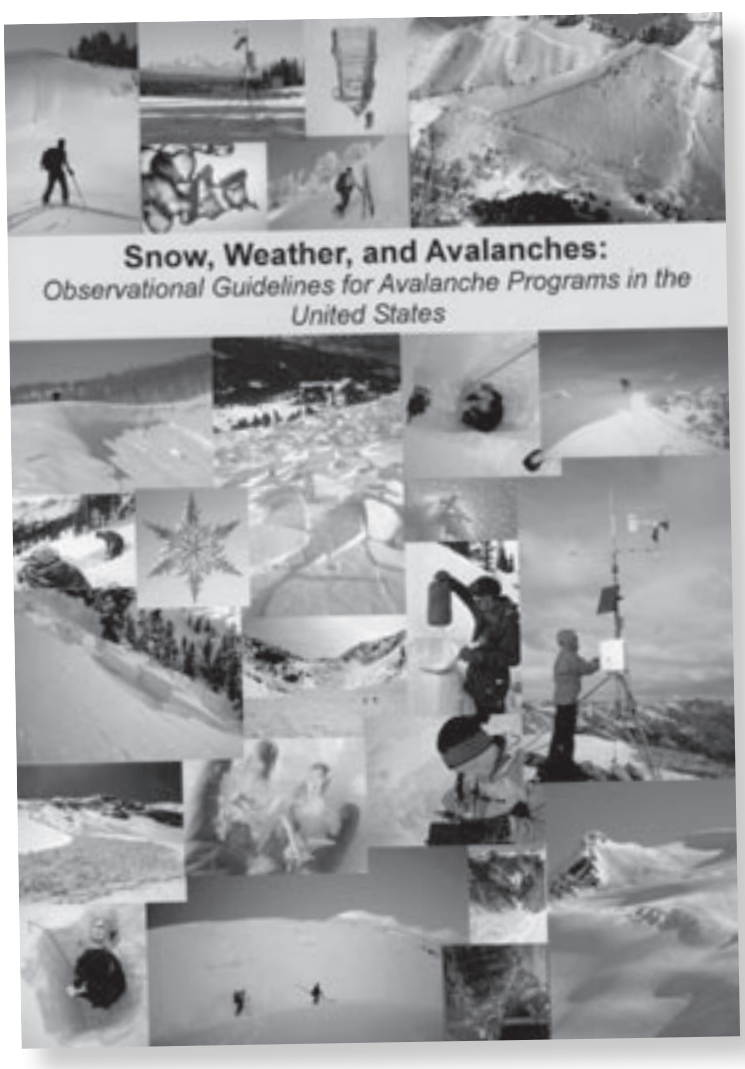
At the time of writing this article, Verena has reached out to some 600 kids this season, from grades 6 to 12 in Revelstoke, Golden, and Calgary. We're pleased to see the program catching on in our mountain communities, and we're already in discussion with other school districts about including avalanche awareness in their curriculum.

If you want to find out more about what's going on in the Canadian avalanche community, get a subscription to avalanche.ca, the quarterly journal of the CAA and CAC. At only $30 per year, it's a great value (if I do say so myself). To order, e-mail us at canav@avalanche.ca.

Mary Clayton is the Communications Director, Canadian Avalanche Association & Canadian Avalanche Centre.

Let's Go to Canada!

Don't forget to register for ISSW 2008: deadline for early bird rates is April 30! At this point the Americans are leading the Canadians with registrations – let's keep it that way!



SWAG Revision on Deck for Summer 2008

It has been four years since the American Avalanche Association and the USDA-Forest Service National Avalanche Center published *Snow, Weather, and Avalanches: Observational Guidelines for Avalanche Programs in the United States* (SWAG). This summer the two groups plan to review the current document, make necessary corrections/revisions, and publish version two.

The next version of SWAG will not look too different from the current version. The newly formed International Association of Cryospheric Sciences is planning to issue a new version of *The International Classification of Seasonal Snow Cover on the Ground* (Colbeck et al., 1990) this summer. This classification is Appendix F of SWAG and will be the most dramatic revision. The working group also plans to correct some errors in the current publication and include methods that have evolved since the last version.

If you have any suggestions for corrections, inclusions, or deletions for the next version of SWAG, please send them to Ethan Greene at the Colorado Avalanche Information Center. The working group to revise SWAG will be determined at the AAA's spring board meeting. If you would like to participate, please write Ethan at Ethan.Greene@state.co.us or Craig Sterbenz, AAA Standards Chair, at sterbie1@mindspring.com.

mailbag

Why Multiple Burials are Now Nearly Nonexistent and Why Signals Almost Always Overlap

Story by Manuel Genswein

Tracker BCA (Stopper, Lund, Edgerly) has recently published two very well-written marketing papers about multiple-burial problems: *How Common are Multiple Burials* (TAR 26/2, p20) and *Signal Strength Versus Signal Timing* (TAR 26/2, p23). From a marketing perspective, the papers are excellent. From a technological and rescue-technique perspective, the papers are purposely misleading, include many errors, and the content is counterproductive to the criteria of "survival-chance optimized" rescue procedures.

Just a few years ago, when Dieter Stopper was not yet employed by Tracker BCA, he wrote in *DAV Panorama*: "more than half of completely buried persons are part of a multiple burial scenario," but now suddenly his opinion seems to have changed. Now, being responsible for Tracker BCA in Europe, he is convinced that multiple burials are an extremely rare event – strange! Maybe less strange is looking at the fact that he is distributing the only major brand left which has, even in its most recent model – Tracker 2, no multiple-burial algorithms implemented which numerically indicate the amount of buried subjects and allow the user to "mark" buried subjects which have been found by the transceiver. Such algorithms, which allow a dramatic decrease in the complexity of the search (true "ease of use") in multiple-burial scenarios, cost a manufacturer considerably more than $1 million US in development costs.

On the other hand, there is Thomas S. Lund trying to convince the world that transmitters almost always overlap in "true multiple-burial situations" so that the "mark" function of technically sophisticated transceivers becomes obsolete. There is one very fundamental but completely wrong assumption in Lund's paper which is tragic for Tracker BCA: If the detection of positive edges would be as impossible during signal overlap as described in this paper, all digital search modes would be close to useless in multiple-burial situations, and only the true acoustical analog search could be applied. Only the fact that the digital search modes are able to track the positive edges (beginning of the signal) in the (vast) majority of all cases allows calculating and indicating a distance and direction indication. What digital-only transceivers are unable to do is to provide a fast and reliable overview of the scenario, but this is a different story.

By far the most reliable strategy in multiple-burial situations is the use of the constant timing of the transmitter as the determining separation criteria. Most of the unreliability in the marking process as described by Lund is only seen with a specific product using signal strength as a primary criteria to separate the signals of multiple buried subjects. As Lund mentions correctly, the "intelligent transmitter" (in non-marketing terms: the "stupid transmitter") of the same manufacturer destroys the fundamental criteria for reliable signal separation: constant pulse rate of the transmitter.

Some Important Points to Consider

It may take a lot of time to find, access, and turn off the transmitter of the buried subject.

Both papers assume that the transmitter of the buried subject can be easily and quickly located on the body and switched off by the rescuers. This is wrong; often it is necessary to completely free the buried subject in order to be able to switch off the transceiver. This is time consuming and might not be necessary in the early stages of the rescue. Therefore companion rescuers must be able to proceed to the buried subjects who have not been found yet while the transmitter of the already located buried subjects are still transmitting. This is equally valid for all cases in which reverse triage needs to be applied.

Total amount of cases taken into account and statistical tricks—

Stopper's statistical sample is by far too small: only six years from only one single state in Austria. The only relevant 100% mark for all these considerations are "buried subjects with no visible parts," as only they are of any relevance to the electronic search means such as a transceiver. The total number of people caught and any percentages derived from this amount are irrelevant and only there to make the important numbers look small. Furthermore, the perspective is always set to the "event/avalanche" and not to the "buried subject/victims." Whereas the "event" is most important in the prevention perspective, the search relevant rescue perspective is all about the "people" (body count). Having counted out 30 winters in Switzerland, I know that taking the "event " as the primary focus is one of the most powerful tricks to purposely hide the extent of the problem of multiple-burial accidents. Taking case #5, the accident of German Alpine Club – whose former safety chief was Dieter Stopper – as an example makes it clear: In Stopper's BCA statistics, this "case" is counted as "one event" – in the only multiple-burial search strategy relevant rescue perspective there were "12 cases" (12 people were completely buried with no visible parts).

Times of all individual components of the entire rescue add up to the survival chance critical burial time—

It is unacceptable to conclude that a search technique is low in priority just because other steps of the entire rescue chain may require considerably more time. The entire rescue process splits into several disciplines which, timewise, add up to entire rescue time. The full completion of each discipline is required to proceed to the next step (i.e., a successful completion of the search is required to proceed to the excavation). Therefore all disciplines are ***complementary to*** rather than replacing each other. Nobody is against a more systematic approach to shoveling or a more efficient organization, but those disciplines do not replace an efficient and well-structured search process.

Marking does not eliminate more than one buried subject

The comment of figure 3 on page 23 is completely and purposely wrong: Marking victim 1 with a transceiver which uses a transmit time pattern analysis would NEVER eliminate victim 2 or its signal at the same time in this case. Much more the indicated "stop" message shows that the transceiver has recognized both victims properly, but after "marking" victim 1 it is temporarily (for the duration of the overlap) not able to lead the rescuer to victim 2 and therefore indicates a "stop" message. Listening to the analog sound at the same time would immediately confirm the existence of the second victim.

Signal acquisition and processing time in single and multiple-burial situations—

The data acquisition required to recognize the different transmit patterns (buried subjects) does NOT slow down the distance or direction indication. In general, signal-processing times of modern transceivers are so fast that no transceiver is slower or faster in the rescuer's perspective; the time differences are so marginal that they are not detectable by human senses (in the range of a few milliseconds). As long as the positive edges of the signal from the victim that the rescuer is currently searching for can be detected, the result will be immediately shown to the user. The positive-edge detection applied for this is exactly the same as for single burials in all transceivers with distance and direction indication.

If a transceiver reacts "slowly" in a single-burial situation, this almost always is an indication that a product is forced to try to cover its deficiencies by applying extensive averaging functions.

Search system dependent search-strip width limitations—

"The 3-circle method is particularly suited for large deposition areas" – this statement is wrong. The opposite is true: the 3-circle method is the only search method for multiple burials that restricts primary search-strip width to 20m (D. Stopper, Berg, and Steigen). The method is therefore forcing the user to apply a very small survival chance minimizing signal search-strip width (formerly: primary search-strip width) – a real problem in large deposition areas. This is a restriction which only applies to the 3-circle method; no other search system for multiple burials in close proximity is suffering from such limitations.

Consequences for Teaching

"Marking" is the final step of each search process—

The "marking" functions of modern transceivers are capable of solving the majority of the easier scenarios as positive edge detection is in many cases still possible, even during a signal overlap. Marking should therefore be taught as the normal ending of EVERY search. When the rescuer has located the position of the loudest sound or the smallest distance indication in the fine search (formerly: pinpoint search), the shovel is placed at this position and the spiral probing applied until the buried subject is found by a probe hit. Now, as the search is finished, the buried subject always has to be marked. By teaching this procedure, the participants will be able to solve multiple-burial problems in the same way as single-burial problems. A multiple-burial problem becomes nothing less than a sequence of technically separated single-burial searches.

The fact that Tracker BCA's Lund is against teaching the marking functions as a primary means to the less trained user groups is typical for BCA's strategy: to reduce the efficiency of all avalanche rescue transceivers to the, by today's standards, low performance of their Tracker BCA.

The same is seen looking at search strategies for multiple burials. By their worldwide strong financial support to push the 3-circle method, they make sure that the by-far superior performance of devices with large search-strip width and analog sound are cut down by a search strategy which has been designed by Dieter Stopper to lower the efficiency of all devices to what digital-only units in combination with badly trained users can achieve (double filter = cut the efficiency twice).

With today's strictly survival change optimized search systems and search processes, only the following procedure makes sense:

Take advantage of the marking function as it represents the fastest possible way (most survival chance optimized) to get from a found buried subject to another that has not been marked as found yet. Only change to a search tactical approach (a search system, like the micro search strips) if the signal separation is not working properly anymore. In practice this means that for an accident with four buried subjects, you might be able to find the first three buried subjects with the marking strategy and only then need to switch to a more time-consuming search system to locate the fourth and last victim. Thanks to the fastest possible approach for the first three buried subjects, they take advantage of shorter burial times.

Conclusion

The truth is inconvenient for Stopper, Edgerly, and Lund of Tracker BCA: transceivers without multiple-burial algorithms and marking capabilities are completely out of date in a technological and rescue technical point of view. Although these functions are not capable of solving all problems, they are capable of solving the majority of easier multiple-burial situations which statistically make up the majority of all victims involved in a multiple burial situation (two to three buried subjects).

In order to be able to verify that the multiple-burial algorithms work properly, listening to analog tones – the only truly unprocessed raw data – is by far the fastest and most reliable procedure. Digital-only transceivers are a clear disadvantage in advanced multiple-burial situations as well as concerning range; and therefore are an inappropriate choice for advanced recreational and all professional users.

The harder, more complex scenarios remain to be solved with search tactical systems. These situations therefore demand search systems that are designed to work even in the most demanding situations. Therefore their homemade "3-circle method" clearly is not a good choice; rescuers should instead apply the more comprehensive and proficient "micro search strips."

Manuel Genswein is an independent avalanche instructor. He has taught courses for 15 years in over 20 countries. He writes TAR from the air, on his way to Islamabad in Pakistan to teach an avalanche rescue course to a completely new rescue team formed by an international humanitarian organization which belongs to the Aga Khan Foundation and the European Commission for Humanitarian Aid. He can be reached at manuel@genswein.com.

Above: Atypical avalanches we're seeing include multiple paths running together and natural avalanche activity on many infrequent slide paths around the Presidential Range.
Photo by Jeff Lane

Left: Even with 16% below average snowfall in mid-February, Hillman's Highway easily ran bigger than it had in decades. Favorable winds helped snow accumulate in the start zone; on the day of this slide wind speeds averaging 73mph created deep hard slabs.
Photo by Brian Johnston, USFS Snow Ranger

From: jslane@fs.fed.us
Subject: TAR article idea
Date: March 5, 2008
To: lwolfe@tetontel.com

Dear Lynne,

We've been so busy in the field that the February edition of TAR finally made its way up to our field cabin, where I was able to take a look at it this morning. It's probably too late for the next issue, but I thought I'd offer to write a short article about the season we're in the midst of here.

Our avalanche cycles on Mt. Washington (as well as the rest of the NH Presidential Range) have been unusually large and destructive. We've had two cycles that have been truly impressive and many others where avalanches have occurred in uncommon locations. Of the two large cycles, one produced an avalanche that destroyed 75-year-old trees and increased the runout path by about 4 acres (D4R5 for this path). A more recent cycle buried one of our first aid caches. Since the Mt. Washington Avalanche Center began issuing advisories and observing avalanches over 55 years ago, this cache is known to have been hit only twice. Brad Ray observed this in 1969 and heard of this happening once in the 1940s.

The same cycle brought highly destructive avalanches to the Gulf of Slides, which is outside of our forecast area but pretty close by. We've been speculating as to the reasons for this extraordinary avalanche activity, but haven't come up with anything definitive yet. Our thoughts as to why we're seeing this type of activity are related to elevation-dependent snow coupled with a lack of winds during the storm and subsequent increase in winds. I'm attaching a couple recent photos to give you an idea of what the area looks like, plus a bit of additional information on the weather patterns leading up to these events.

Sincerely,
Jeff Lane
Snow Ranger
Mount Washington Avalanche Center
White Mountain National Forest
(603) 466-2713 ext. 236

Here's some additional info about the cycles we've had:

- Through February, we were 15% below average for snowfall on the summit of Mt. Washington, but in the valleys we are having near-record years.
- The pattern this year seems to be frequent small snowfalls on light winds, so it's left sitting above treeline. Our big cycles have come when the winds slowly ramp up toward the 100mph mark and have tremendous amounts of snow to transport. In a typical year, it's less common to have snowfall without wind, so there wouldn't be as much snow sitting above treeline waiting to be moved by the stronger winds.
- Another pattern is many of our larger storms have come with S, SW, or SE winds, which have loaded some aspects better than others. NW winds tend to prevail here, so this is somewhat out of the ordinary.

For the third time since the 1940s, avalanche debris buried the first aid cache marking the entrance to the floor of Tuckerman Ravine. Jeff Lane explains, "This is one avalanche burial I am more than happy to dig out."
Photo by Brian Johnston, USFS Snow Ranger

snow science

Avalanche Transceivers and Multiple Burials

Story by Felix Meier

Avalanche beacons and multiple burials are a controversial issue. By evaluating properly selected signal features and by using suitable classification algorithms, it is possible to resolve multiple burial situations correctly in most of the cases, thus providing good guidance especially to users that never or rarely practice multiple burial searches. Some modifications to the standard EN 300 718, however, would make the process even more reliable.

The issue of avalanche beacons and multiple burials has been discussed in two recent contributions [1], [2] in *The Avalanche Review*. The first one [1] seems to be rather optimistic, but since we do not have pertinent data at hand, it will not be discussed here. The second one, [2], is rather pessimistic, and there are quite some arguments why the issue is much less of a problem than suggested in that paper.

PROBLEM STATEMENT

A certain percentage of avalanche accidents involve multiple burials [1], [3]. As explained in [1], part of these cases can be resolved using single burial search tactics. But some cases require a more sophisticated approach because there is a high probability that the searching transceiver will receive signals from multiple transceivers simultaneously.

Two search strategies are available for resolving such situations: The Micro Search Strip Method [3] and the Three-Circle Method [4]. Both strategies require some practice for efficient use. But it is a sad fact that about 90 percent of the transceiver users practice less than one hour per season, so in most cases they will not be able to apply any of these strategies properly.

Any support for resolving a multiple-burial situation that can be made part of the transceiver functionality will therefore be very helpful to most of the users. Even if such support is not perfect, it is still better than no support at all.

MULTIPLE-BURIAL ALGORITHMS

A good algorithm for resolving multiple burials is based on the following method:

At the end of the receiver chain, a suitable method is used for extracting one (or more) features of the received signal that shall be used for classifying it. The classification system then enters every new signal feature record into a pool of unassigned records. Every time a new record is added to this pool, the pool is checked for a subset of records that exhibit identical features and can therefore be assigned to a single transmitter. Once such a subset has been found, all records pertaining to it are removed from the pool and are assigned to a chain of records pertaining to a particular transmitter. When a new record comes in from the feature extractor, it is first checked for matching an existing chain of records. If it does match a pre-existing record set, it is assigned to that chain, and it may also be used for adjusting the feature values. If it does not fit into an existing chain, it goes to the unassigned records pool, and the pool is analyzed again for a possible new chain of signals from a new transmitter.

If a record fits an existing chain, it can be used for displaying information about the transmitter to the user if the user has selected that chain for display. If the user has "marked" that transmitter, the internal data records will be updated, but there will not be any indication to the user. This is to prevent signals from that marked transmitter from disturbing the search for another transmitter.

SIGNAL FEATURES

There are several features that may be used for characterizing the signal from a transmitter:

Pulse amplitude (or signal strength, for that purpose), is a measure for the distance to the transmitter. Since the strength of the received signal is also dependent on the relative orientation of the transmitting and the receiving beacons, it is subject to a lot of variance. Just imagine a searcher walking on avalanche debris and keeping his transceiver in the same orientation – nearly impossible. So it is really not a good idea to use pulse amplitude for classification.

Another feature that has been proposed for classification is the exact frequency of the transmitter [2]. Algorithms for extracting frequency information from a time domain signal are well known and widely available, e.g. the Fast Fourier Transform (FFT). One of the fundamental laws of those algorithms states that the obtainable resolution in frequency is equal to the reciprocal of the time duration of the signal sample being analyzed. The shortest transmitter pulse duration allowed by the standard EN 300 718 [5] is 70 ms. In order to not create any artifacts in the frequency domain, the signal to be analyzed should cover the entire interval under investigation. If no overlap is used (and that is pretty much a necessity because anything else would require enormous computing power), the maximum duration of the signal sample is thus 35 ms, resulting in a frequency resolution of at best 28.5 Hz. But most transceivers transmit within about ± 20 Hz of the nominal carrier frequency of 457'000 Hz, so that feature would not be very helpful for classification since most of the time, the signals from multiple transmitters would show up in the same frequency bin. The FFT algorithm is very computation intensive, and so there is very little bang for the buck when using this feature.

A third feature that can be used is the position of the signal pulse edges on the time axis. This feature is independent of the relative orientation of the transmitting and of the receiving antennas, and it can be measured with high resolution by a signal processor. Also, its short term stability is excellent unless the signals are emanating from an "intelligent transmitter." For more on that, see farther down. As has been explained in [2], when pulses from multiple transmitters overlap in time, some problems come up. But contrary to [2] which states that overlap makes multiple transmitter detection impossible and may lead to false "masking," we do believe (and we have checked it by practical implementation) that by proper evaluation of the received signal it is still possible to correctly handle multiple transmitters as well as "marking" most of the time.

When signals from multiple transmitters overlap, there will be steps in the amplitude:

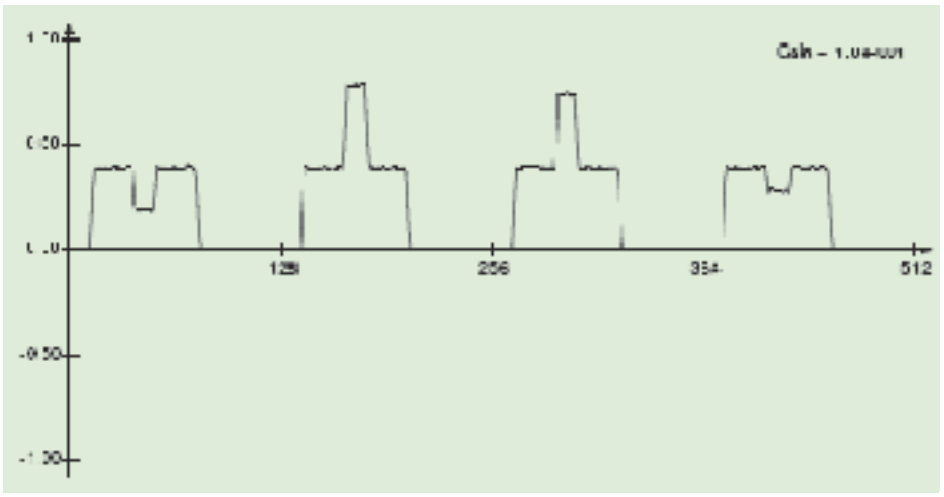


Fig. 1 Overlap

This is a simulated overlap of pulses from two transmitters at equal distance. The pulse duration is 300 ms, the pulse interval is 1000 ms for both transmitters, the second one of them is offset by 100 ms in time relative to the first one, and they transmit at exactly the same frequency. So the pulses do overlap for a duration of 200 ms. It may be surprising that the signals do not simply add all the time. But this is the reality, and it is due to the fact that the relative phase of the two transmitters is different for every overlap. Almost all beacons turn their 457 kHz oscillator off inbetween the pulses in order to save on battery power, and so they come up with a different phase every time the oscillator is switched on. If the signals from two beacons at equal distance have equal phase, the amplitude of the signal will double, if they are opposite in phase, the result is extinction. And all combinations of relative phase are possible, so the receiver gets a rich assortment of signal envelope shapes. But in any case there are edges that can be detected even if the signals overlap, and if interpreted properly, they can help a lot in mitigating the effects of overlap.

Also note that the signals may add in a way that does not affect the overall amplitude. In that case, there will definitely be a change in phase of the resulting signal vector, and this could also be used for purposes of classification.

Another complication to be considered is the fact that overlapping beacons may not transmit at exactly the same frequency. This may lead to periodic amplitude changes during the overlap:

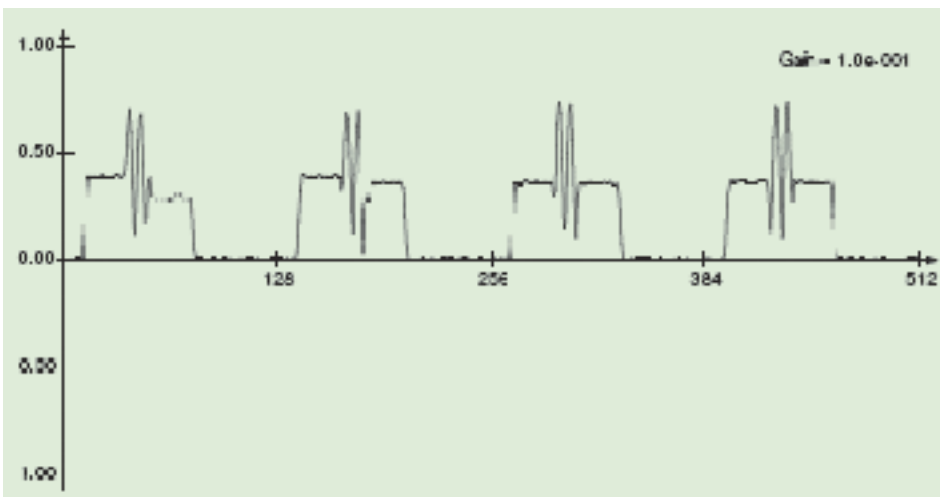


Fig. 2 Effect of Frequency Difference

In this example, the parameters are the same as in the first one, but with a frequency difference of 20 Hz. Even this situation can be resolved by a good classification algorithm. For larger frequency differences, there is the option of running multiple local oscillators in the receiver, thus obtaining a clean baseband signal for every transmitter that is detected. This, however, is a little more complicated, but feasible and obviously improves performance.

We have found out by experiment that it is possible to detect up to 80% of the edges during overlap. If this information is used in a good classification algorithm, the reliability of a multiple-burial resolution algorithm can be improved considerably, and will be much better than predicted in [2].

Obviously, the signal position on the time axis is subject to jumps if a signal originates from a so-called "intelligent transmitter." When an intelligent transmitter shifts the position of its transmit pulses in time in order to avoid overlap, the signal edges from such transmitter will no longer fit any existing chain at the receiver, and thus they will be considered emanating from a new transmitter. So focusing on a specific transmitter in a multiple-burial situation becomes next to impossible. To this author, it looks like "intelligent transmitters" are not an intelligent thing at all, since they affect the signal that is best suited for handling multiple-burial situations.

MARKING

With the above scheme, the marking of a transmitter can never lead to double markings as stated in [2], since a single transmitter will be marked only, based on some chain-specific icon on the display.

COMPATIBILITY

[2] also concludes that beacons that provide signal timing analysis and marking features are not downwardly compatible with the existing base of avalanche transceivers. As we have shown in this paper, this is not necessarily the case. If proper algorithms are used for signal analysis, the problems arising from some properties of the older beacons can be taken care of quite well. We have run many field tests and not noticed a particular loss in performance when searching for older beacons.

Transceivers with large deviations from the 457 kHz standard transmitter frequency do not affect compatibility in terms of multiple-burial resolution algorithms. However, as has been shown in [6], they do pose a problem since they require that receiver bandwidths be relatively large in order to accommodate their frequency offset. This in turn has a negative influence on the achievable range when searching for such beacons.

BEACON STANDARD MODIFICATION

We agree with [2] regarding the following items to be considered for the next overhaul of the EN 300 718 [5]:

Beacon pulse periods should be randomized to some extent. This would greatly reduce the probability of long duration overlap situations. It does not affect backward compatibility.

Beacon pulse width should be limited to e.g. 200 ms, since longer pulses increase the probability of overlap. Backward compatibility would not be affected.

The tolerance for the transmitter frequency should be tightened, e.g. to ± 50Hz. This requirement can be met with today's components without an undue increase in cost, and it would permit the construction of better receivers (see [6]). However, since narrowband receivers would then receive signals from transmitters with a larger frequency offset, backward compatibility with old beacons exhibiting a large frequency offset would be affected. A possible approach to this problem may be the introduction of a transition period of several years, similar to the one declared when concentrating on the 457 kHz beacons and abolishing the 2.275 kHz variety.

CONCLUSIONS

Some of the modifications to the standard EN 300 718 as suggested by [2] would really help to handle multiple-burial situations by good receiver algorithms.

"Intelligent Transmitters" play havoc with multiple-burial resolution algorithms, since they affect the must useful signal feature that can be used for classification.

Contrary to [2], we believe that even in case of signal overlap multiple-burial situations can be resolved properly in most of the cases by applying suitable feature extraction and classification algorithms.

ACKNOWLEDGEMENTS

The author would like to thank Reto Jaeger for his review of the paper and for making suggestions.

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Felix Meier is a consultant in electronics and software engineering. He has participated in all avalanche beacon standard groups since 1982. He was involved in the development of the Mammut Barryvox beacons. You can reach him at felix.meier@smile.ch.

Above: Material retrieved from the misfire site.

Left: The balloon that contains the sensitizing compound for the bulk of the cast shot was found about 30 feet from the blast crater. Notice the striations left from the rubber band.

Right: The thawed out cap/fuse assembly clearly shows the end of the blasting caps where they are crimped to the fuses as well as at least an inch and a half of the cardboard tube detonator wells – showing that the detonators were properly installed.

Snowmass Misfire Incident

Two incidents prompt in-depth review

Story and photos by John Brennan

On December 18, 2007, the Snowmass Ski area experienced a misfire with an Austin Powder White Cap cast booster. Better understanding how this explosive is manufactured will lead to knowing how this misfire occurred.

Basically, the bulk portion of this precast booster is not sensitive to detonating from a blasting cap. The mixture is a blend of TNT with various other compounds which likely are PETN, RDX, or HMX. To generalize, a mixture of TNT and RDX forms a common military explosive called Composition B. Some explosive manufacturers use reclaimed military explosives in their products. Because the White Cap's mixture alone cannot be detonated by a blasting cap, a sensitizing component is used.

Austin Powder uses a small balloon filled with PETN for the job. PETN, which can be ignited with blasting caps, is typically the core load in detonating cord. PETN is also used in an approximate 50/50 ratio with TNT to form the cap-sensitive cast explosive called Pentolite. The balloon is held in place between the cardboard detonator wells by a rubber band. While it is uncommon for the sensitizer balloon to somehow relocate itself, it is not unheard of. This is what occurred in the booster that resulted in the misfire at Snowmass.

Fernie Alpine Resort in Canada had a misfire with White Cap boosters on April 11, 2006. In his excellent article in the Summer 2007 *Canadian Avalanche Association Journal*, Fernie Ski Patrol Director Mark Vesely describes the event. Two individually primed White Cap boosters were taped together and used in an aerial cableway application. "First, the bomb tram failed to transport the shot out to its standard placement, Then, upon detonation, the two boosters separated, displacing one of the primed explosives into the blaster safety area, where it then detonated." While no serious injuries occurred, the potential for tragedy was immediately recognized, and an in-depth review of the accident was quickly and thoroughly conducted.

For a complete copy of Mark's article, or to further discuss explosive topics and concerns, please contact me at: jbrennan@aspensnowmass.com.

John Brennan is an avalanche tech at the Snowmass Ski Area and the Rocky Mountain rep for the AAA. He has also been a member of the International Society of Explosive Engineers for over a decade and sits on the NSAA Explosive Committee and the Artillery Users of North America Committee. His company, Avalanche Mitigation Services, aims to find long-term solutions to the explosives issues that face our industry.

Author Margaret Wheeler rips it up in Chamonix, winter of 1999.
Photo by Brett Schreckengost Photography
www.brettschreckengost.com

I like to go into the mountains with women. I feel like I'm safer when I do. When I'm out with my male friends, I know that I have to keep a sharp eye out for competition, pride, and all the other traits that tend to go along with groups of men…

—Bruce Tremper
Staying Alive in Avalanche Terrain

…under certain circumstances, men in the presence of female peers will behave more competitively, aggressively, or engage in riskier behaviors… Across all groups, accident parties that included women had a significantly higher exposure score.

—Ian McCammon
Heuristic Traps, TAR 22/3

Story by Margaret Wheeler

BACKCOUNTRY SKIING & GENDER—

The Collision of Hormones and Relationships with Decision-Making in Avalanche Terrain

or

The Possibility of a 'Gender Heuristic Trap'

Who are the biggest risk takers: men or women?

Who are the bigger risk takers, men or women? How does your gender affect your risk exposure level in the backcountry and, therefore, your decision-making process? These are tricky and controversial questions, and as such they become a matter of opinion – rather than science – almost immediately. Each of us has had experiences that shape our opinions, and we mingle this with the available body of knowledge from research studies and the media that focuses on these very questions. But for the backcountry user, how do we reconcile the contradictions offered by the two quotes above? And how do we integrate this factor of gender into what we know about human factors and decision-making?

In considering these questions, it is important to understand the evolving paradigm of backcountry skiing groups. Not only are winter backcountry user numbers in general increasing, the ratio of men to women is also changing. How many women were skiing in the backcountry 20 years ago? How many women are skiing or riding in the backcountry today? In 1988 you would have been hard pressed to buy a women's backcountry ski; in 2008 there are myriad skis and other backcountry tools available designed specifically for women.

If this paradigm is shifting, then it is of utmost importance to understand how the changing fabric of backcountry ski groups figures into the group decision-making dynamics. If we don't consider the ways in which gender shifts or exacerbates human factors in decision-making, we run the risk of creating a *gender heuristic*. If you believe that skiing in a mixed gender group will keep you safer (see Tremper's quote, at left), how can you protect yourself from the findings described by McCammon? A gender heuristic might look like either of these statements: "If we have at least one woman in our group, we better listen to her so we make better decisions and don't get avalanched." Or how about this one: "If we have a girl in our group then everyone starts acting like chickens without heads, posing and taking big air. Let's just go out as a group of the guys, ok?"

We all have perceptions, or mindsets, about gender; we all start sentences with the words, "Women like to...", or, "Men are always..." While these mindsets may help us process and accept the otherwise baffling behavior of our friends and lovers, they may set us up for mistakes in understanding group decision-making. One of the best ways to dissect a perception/stereotype is to pin it up on the wall, and evaluate it with an analytic eye as it squirms under a bright light. As we do so, we continuously ask ourselves: what are the underlying assumptions that contribute to our given way of thinking? To that end, here is a starter list of perceptions I have overheard about groups of men and groups of women in the backcountry.

What are some perceptions about male behavior in the backcountry?

- Men are driven by testosterone.
- Men are physically competitive (Who is the strongest? Every day out is a race.).
- Men are bigger risk-takers than women.
- Men are goal oriented (It isn't a good day unless you get to the top.).
- Men are ruled by their egos.

Now let's look at perceptions we have about women in the backcountry:

- Women won't take on as much risk as men.
- Women are more likely to make decisions that lead to group happiness over individual happiness ("I just want everyone to have a good day today.").
- Women are less likely to speak up in a mixed-gender group.
- Women are better communicators than men.
- Women are conscious of men's egos, and will seek not to bruise them.
- Women who are used to being The Only Girl at the Party are competitive with other women.

If each of these could be interpreted as fact, we could use them as solid guidelines in understanding our human decision-making process. But these are stereotypes, and allowing ourselves to be overly guided by such stereotypes, no matter how much they may resonate with our own experiences, can be a trap – especially in the backcountry. What if some of these are incorrect, even just some of the time?

The best I can do is to share some of my own experiences and observations, and examine how they may reinforce or deny each of the mindsets I've listed above…and what that means for decision-making in the backcountry. As I do so, McCammon's original heuristic traps (FACETS) immediately bubble to the surface.

Consider three anecdotes: one for all-male groups, one for all-female groups, and one for mixed-gender groups.

Who has higher risk-acceptance level: men or women?
Photo by Scott Schell

ALL MALE GROUPS:

Trying to Be One of the Guys – Ski Bum in Chamonix

(Any group I'm a part of will, of course, be a mixed-gender group; this is the closest observation I have!) Ski-bum culture is a social hierarchy determined by skiing ability: whoever skis the hardest is the coolest – period. My experience in Chamonix was characterized by the following:

- Working very hard not be "the girl in the back," uphill and downhill.
- Joining the race, every day, that started out of every tram, gondola, or skin track.
- Asking no questions, expressing no doubts. The decision to go or not go was always made before the day started and we got on the tram.

Looking at this experience from the perspective of gender stereotypes offers me limited insight in understanding the dynamics that developed. Was I exhibiting stereotypical male behavior, or female? How did my own background and desires affect my behavior? In contrast, looking at them from the perspective of McCammon's heuristic traps (familiarity, acceptance, consistency, expert halo, social facilitation, and scarcity), some patterns emerge. My friends and I were constantly driven by scarcity: we were seeking acceptance from our ski-bum peers, and we would commit each day before leaving our tiny apartment to execute the day's plan. As such, our risk-exposure levels were certainly higher than we realized at the time.

ALL FEMALE GROUPS:

Women's Expedition to Hanuman Tibba, Himachel Pradesh, India

This was a ski expedition in high-altitude, high-risk terrain. We were a group of four women: ambitious, motivated, eager to climb and ski a first descent off a big peak. This was an amazing trip, characterized by:

- Varied experience levels in the group: some of us had high altitude, big mountain experience…some of us didn't (I was the latter.).
- Ambitious and competitive women: all of us trying to make a name or build one – and in a mostly male-dominated industry
- High commitment level: we had traveled far to do this, spent time and money – not to mention blood, sweat, and tears – getting to our high camp.

Comparing this experience to my lists of stereotypes, I get mixed results. Yes, we were all used to be being the Only Girl at the Party, but did that drive us to be more competitive than we naturally are? I'm not sure. Were we taking on more risk because we felt we had something to prove, or because we were ambitious and had a common goal? Again, not sure. Under the stress of high risk and high reward in the mountains, our decision-making process seemed to me be gender free. From the perspective of heuristic traps, however, I can see that even though we thought our decision-

Continued on page 28 ➡

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From:    imccammon@******.net
Subject: Re: women and heuristics/ TAR article
Date:    March 6, 2008
To:      lwolfe@tetontel.com

Hi Lynne,
My apologies for the delay in getting back to you. Between teaching and
research it's been a busy winter!

Thanks for sending me the draft of Margaret Wheeler's excellent article on
gender & decision-making. A great topic, very timely, and part of a very valuable
discussion (OK I'm biased) that has broad implications for all of us.

I really like how the article deconstructs gender stereotypes and makes the
connection to decision-making. It's refreshing to see someone seriously
tackle a topic that gets talked about a lot. The qualitative approach is nice
- the stories help make Margaret's arguments much more clear and specific.
What such stories lack in scientific precision they more than make up for
in effective teaching and readability. It's also good to see a concise and
accurate summary of the heuristics traps (thanks for the citation). Even
though my heuristics work remains preliminary, I'm glad it continues to be
a helpful construct for recognizing human factors in both women & men.

Anyway, this is a great article and I very much look forward to reading
it in its final form. Feel free to pass my comments on to Margaret, and my
congratulations and encouragement for an article that is sure to be of great
interest to most TAR readers!

I hope you are well and enjoying plenty of skiing,
-Ian
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crown profiles

A Classic San

Juan Cycle

West Riverside— This classic San Juan path is on the north side of Red Mountain Pass on Highway 550; it comes out to the creek and the road just uphill (south) of the snow shed, which protects the road from the infamous East Riverside. This path has a large and complex starting zone with aspects ranging from 90-180 degrees. In this picture, the left finger, which faces east, runs full track and to the ground. The upper starting zone of the West Riverside sits at 11,840' and runs 2,520' to the creek at 9,320'. This particular event put debris into the creek, but only covered the road with 8" of powder blast.

St. Louis— this path is located in the Ophir Valley and has a history of affecting the county road that leads to the town of Ophir. In fact, it was this slide that closed the road early on Sunday, January 7, during this cycle. The path is generally south-facing, but has southeast and southwest components to it. This slide initiated under a large rock feature in the upper, center, south-facing portion of the path. St. Louis has an uppermost starting zone at approximately 12,400' and runs to the valley floor at approximately 9,450'. This particular event put up to 15' of debris about 350' wide across the road.

West Badger— this path is located in the Ophir Valley and has a history of affecting the county road that leads to the town of Ophir. The path is generally south-facing, but has southeast and southwest components to it. This slide initiated on a crossloaded southeast aspect on the gunner's left side of the path. West Badger has an uppermost starting zone at approximately 12,500' and runs to the valley floor at approximately 9,550'. This particular event brought debris down to the valley flats, but only covered the road with 5" of powder blast.

Story and photos
by Mark Rikkers

We've had an interesting winter so far here in the San Juan mountains in southwest Colorado. We had no snow at all in November, followed by a December with enough snowfall for the record books. The Christmas to New Year's week was brutally cold, which caused significant faceting in the upper snowpack. Then we got a major storm on a strong southwest flow between Saturday, January 5, and Monday, January 7, that brought 3-4.5' of snow and high winds to the mountains.

All major mountain passes were closed as of Saturday evening – Red Mountain, Molas, Coal Bank, Wolf Creek, and Lizard Head – and a good natural cycle on all aspects and at all elevations was underway. A natural avalanche hit the road leading to the small town of Ophir, near Telluride at 9,700', early on the morning of Sunday, January 6. That road stayed closed until late afternoon on Wednesday, January 9.

On Tuesday, January 8, we got a break in the weather, and Telluride HeliTrax and the Colorado Avalanche Information Center teamed up to do explosives mitigation for state highways 550 and 145, as well as for San Miguel County along the road to Ophir. We got significant results; several paths ran full-track and to the ground. Then on Wednesday, January 9, we got another foot of snow and high winds. On Thursday, January 10, we flew again and cleaned out two more major paths along the Ophir road that had stubbornly resisted our efforts on Tuesday.

Prepared on January 21, 2008, by Mark Rikkers, Colorado Avalanche Information Center, Northern San Juan Mountain Zone.

Investigations into Wet Snow

Story by Simon Trautman

Little research exists on wet-snow avalanches. There are several reasons for this, but foremost is that historically, dry-slab avalanches kill more people and have therefore generated more interest. This is not to say that nothing is known about wet snow. Many locales have gained extensive knowledge from a practical perspective, and have applied that knowledge in successfully forecasting and managing terrain during wet-avalanche cycles. What the lack of research does mean, however, is that there is a fundamental gap in terminology, approach to experimentation, and forecasting tools within the avalanche community. By recognizing this gap and encouraging practitioners and researchers to keep it simple and answer questions where answers are needed, we can make significant strides toward a complete and fundamental understanding of wet-snow avalanches.

Wet-snow avalanches occur in two distinct morphologies: 1) wet loose avalanches and 2) wet-slab avalanches. While there are sub-categories within each of these morphologies (i.e. new snow wet loose, old snow wet loose, glide slab avalanches, rain on snow, etc.), it is apparent that all wet-avalanche activity occurs in response to the addition of free water to the snowpack. Forecasting in this realm involves the recognition of a system that is somewhat independent of that encountered in dry, cold snow – a system that revolves around how much water is available and, more specifically, how that water is affecting the snowpack.

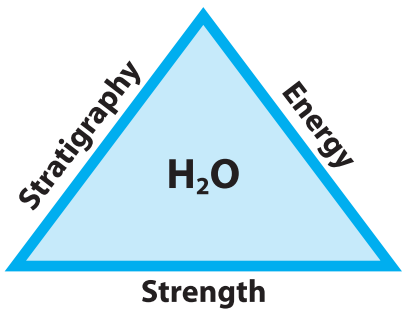


Figure 1: The wet-snow system can be conceptualized using a familiar triangular representation.

The system is defined by energy input and exchange, snowpack stratigraphy, and the change in snowpack mechanics due to the introduction and movement of free water within the snowpack.

Excessive energy input is needed to 1) create free water through melt and/or 2) allow water to move through the snowpack. The amount of energy available in the system is directly related to the amount of free water available for transport.

Stratigraphy controls the rate of infiltration, the pattern of infiltration, and ultimately the concentration of that free water. It also provides the structural starting point, or initial condition, that can be affected in the encounter with free water.

The presence of free water within snowpacks dynamically affects the mechanical properties of that snowpack. Water concentrations below ~7% by volume can in many cases densify and strengthen snow, while higher concentrations (greater than 7%) can break bonds and decrease strength within a given sample.

So exactly how does this relationship relate to avalanches? Well, that is the 59-dollar question. The remainder of this article will give brief discussion of each of these components, and how documentation and study of each can improve our understanding of the wet-avalanche phenomena.

Energy Balance at the Snow Surface

In a general sense, once the temperature of the snow surface is raised to 0oC, further energy input results in the conversion of ice to liquid water. The energy balance at the snow surface can be described as:

Energy Balance = R + H + LE + G + F

Where R is the net radiation input (short-wave and long-wave), H is the sensible heat exchange (conduction in response to temperature gradients, can be increased by wind), LE is the latent heat flux (energy transfer through condensation or sublimation), G is the ground heat flux (energy transfer from temperature gradients at the snow/soil interface), and F is the advective heat flux (mass transfer of energy into snow, i.e. rain on snow). Although all of these factors are considered, radiation is the dominant driver.

Air temperature is used by practitioners as a proxy for the radiation input because it is readily accessible. Unfortunately, it only partially represents both the sensible heat exchange and the radiation input. A more complete picture could be provided with radiation instrumentation, but these instruments are relatively expensive and, thus far, not widely used by avalanche-forecasting operations.

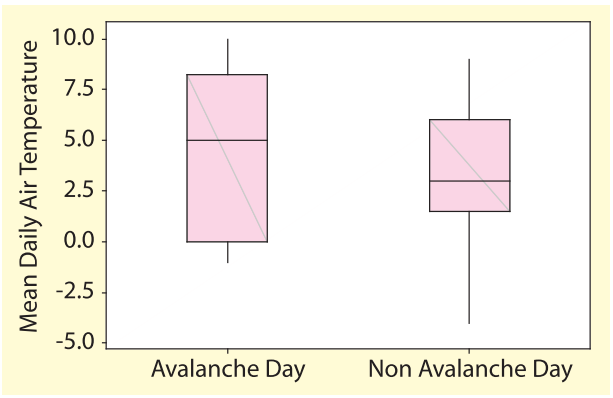


Figure 2: This graphic depicts how the documented mean daily air temperature relates to avalanche days and non-avalanche days. The line on the graph represents the median, the box is the interquartile range, and the whiskers represent the range of the data. Avalanche days have a higher median value than non-avalanche days, but there is obvious overlap between the spread of each data set (Trautman, 2007).

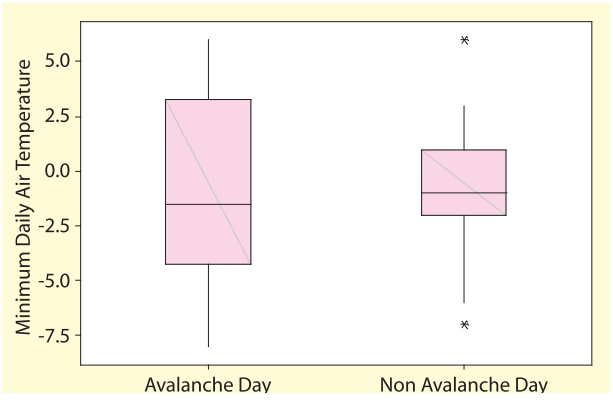


Figure 3. Minimum daily air temperature in relation to avalanche days and non-avalanche days. The line on the graph represents the median, the box is the interquartile range, and the whiskers represent the range of the data. The range of the data presented for non-avalanche days falls completely within that presented for avalanche days (Trautman, 2007).

Experience and research have shown that monitoring air temperature is only partially useful when forecasting wet-snow avalanches. Figures 2 and 3 illustrate this point in regard to wet loose avalanches. In this figure, daily air temperature values show a common range on avalanche days and non-avalanche days. From a scientific perspective, analysis of how the radiation balance relates to free water production, movement, and ultimately wet-avalanche release is needed. From a forecasting perspective, integration of the energy balance (once defined) should be factored into the protocol. In regions where temperature is the only available representation of the energy input,

The wet-snow avalanche at left occurred in mid-May 2001 on the west face of Max's Mountain at Alyeska Resort in Girdwood, Alaska.

The resort had been closed for several weeks. We were sitting out on the back deck when we heard a huge roar like a jet engine. I looked up at Max's and watched the entire event. It was really impressive and seemed to go in slow motion with all the trees wiggling and lots of dirt entrained in the debris. After snapping a few photos from the house I went up to the parking lot at the base of the resort. Quite a crowd had gathered and everyone seemed to be waiting for something else to come down.

There had been a widespread cycle of avalanches on west-facing slopes during the week prior to the release on Max's. Many of these went to the ground, and some failed on a mid-winter layer about halfway down in the snowpack. As I recall, most of the big full-depth wet avalanches during this cycle occurred in areas of groundwater seeps where glide cracks typically develop early in the season before the ground is frozen.

A debris pile of trees mixed with snow covered the service road, visible at the top of the Tanaka lift, and lasted well into August.

Note the glide cracks off to the looker's right of the main slide at about the same elevation.

Peter Thurston, March 11, 2008

special care must be given to monitoring other aspects of the system.

Wet-Snow Stratigraphy

Snowpack stratigraphy is as important in springtime forecasting as it is in the winter. Stratigraphy controls water infiltration rates and provides the mechanical framework behind metamorphism and/or weak-layer formation. It is a factor in both wet loose and wet-slab avalanche release. Research has shown that meltwater accumulates at a variety of stratigraphic boundaries, but documented associations between existing stratigraphy and wet-avalanche activity are sparse. This lack of documentation has made it difficult to make the same associations between structure and hazard that we make in dry-snow forecasting. *Montana State University, the Colorado Avalanche Information Center, the Forest Service Rocky Mountain Research Station and the Forest Service National Avalanche Center have initiated a study looking at wet slabs, and your help (with any wet slab observations) would be appreciated.* The following examples illustrate how these associations can be made.

Example 1 – Wet Loose Avalanche

Wet loose avalanche instability is dependent upon high water content or accumulation in near-surface snow (Note the wetness designation at 119cm). Surficial instabilities such as the one depicted in Figure 4 and 5 typically persist until the stratigraphic boundary has been compromised, at which point water can move freely along established flow paths. It is important to note that the upper layers of the snowpack can be classified as wet and still be stable. It is also important that these avalanches do not always happen at the change between cold and warm snowpacks, but happen regularly in isothermal snowpacks.

Wet loose avalanches are generally not associated with the critical danger and inherent risk found in dry-slab avalanches, but wet loose avalanche hazards do exist and based upon the density and water content of the snow involved, demand respect. Two large wet loose avalanches were documented in the Bridger Range of Montana in 2003 and 2004. In both cases the sliding surface was not the point at which water had been accumulating throughout the early part of the day, but was a lower interface between large (+3mm), very poorly bonded (fist hardness) poly-crystals and an underlying layer of well-bonded melt-freeze rounded grains *(Figure 6 and 7)*. The layer of poly-crystals had very little strength between individual crystals; a handful could be sifted between the fingers. Meltwater accumulation occurred immediately above the poly-crystalline layer, below a well-defined melt-freeze crust that lost much of its integrity immediately prior to both avalanches.

It is not known if the two avalanches described above resulted from a rapid loss of strength in the poly-crystalline layer due to a pulse of meltwater being released from the overlying crust when integrity was lost, or from simple entrainment of the weak poly-crystalline layer following avalanching in the surficial layers once the overlying crust lost strength. Either way, the presence of this poorly bonded layer allowed a much greater amount of snow to be incorporated, resulting in much larger avalanches.

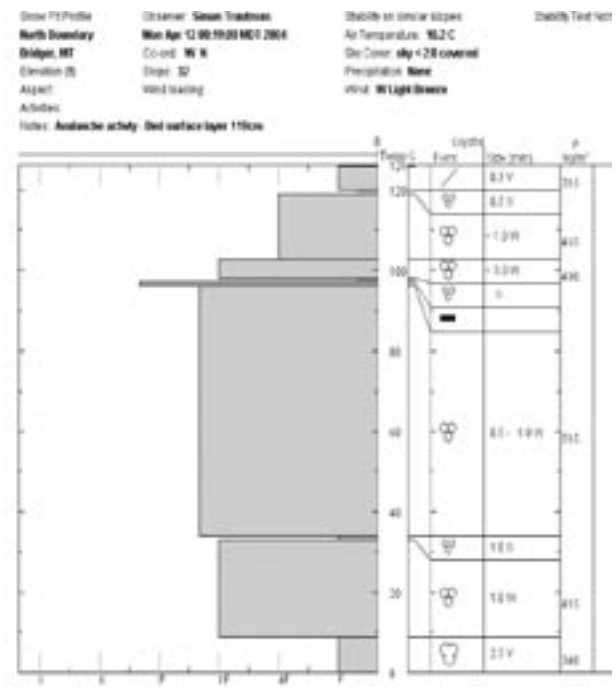


Figure 4: Meltwater accumulation at 119 cm resulted in wet loose avalanche activity. Avalanche days can be identified by a 'slush' layer, or melt-water 'horizon' in the upper layers of the snowpack.

Figure 5: Meltwater accumulation along a surficial stratigraphic interface. Powdered dye was applied to the surface prior to the daily melt cycle.

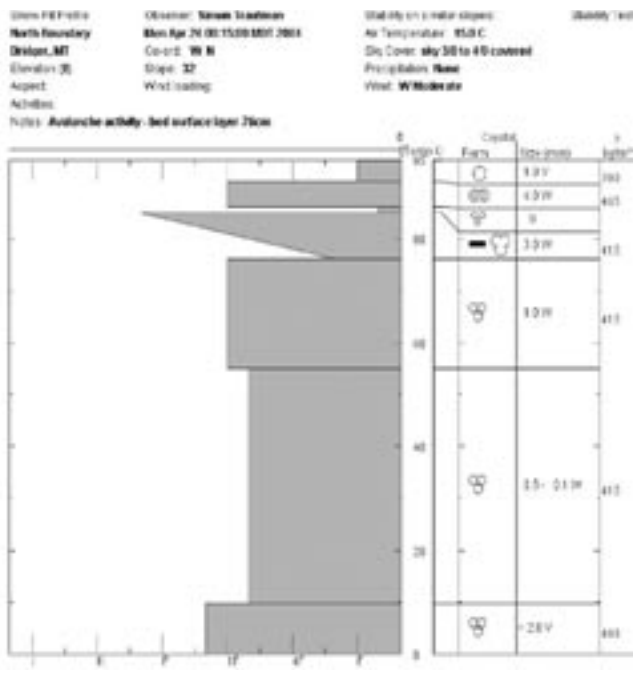


Figure 6: Weak polycrystalline layer involved in an April, 2004 wet loose snow avalanche.

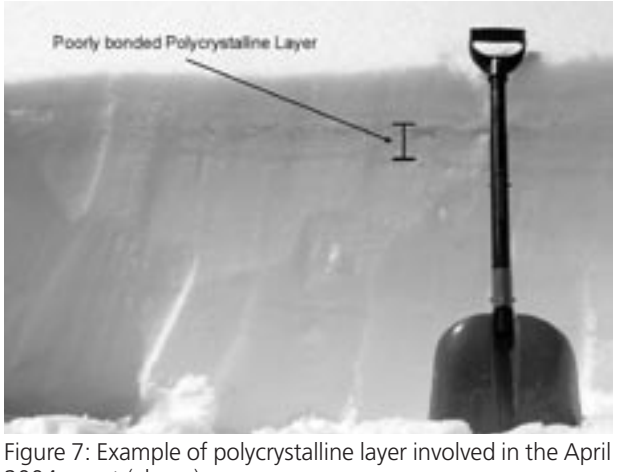


Figure 7: Example of polycrystalline layer involved in the April 2004 event (above).

Wet-Slab Avalanches

Wet-slab avalanche activity is a different animal, and is more extensively covered in an article by Erich Peitzsch in this issue of TAR *(see page 20)*. In my limited experience they appear to happen during significant warming events (or with rain), before the snowpack has lost its wintertime stratigraphy, and when an existing weak layer is activated by the addition of free water. Essentially, the rapid warming (or rain) adds enough water to the cold snowpack to allow flow fingers to form. These flow fingers transport water down to any significant capillary barriers that might exist, while allowing the overlying slab to retain some of the characteristics of a dry slab. As the water runs along the capillary barrier, strength is dramatically decreased, setting the stage for a wet slab avalanche. Lundy and Reardon (2004) described some of these processes for some case studies in Glacier National Park. Obviously, there are many complications along the way, and there are many parts of this process that we do not yet understand.

Implications

Kattelmann (1985) hypothesized that snowpack stability is high when meltwater is passing through the snowpack unhindered or when the input (of melt water) equals the output. In other words, when the amount of meltwater created is consistent with the flow of water through the snowpack, high levels of accumulation do not occur, and weak layers are not present. In terms of forecasting, an assessment of where water is accumulating on a certain day (and how it may affect the existing snowpack) is more important and more practical than where water may accumulate in the future.

Widespread stratigraphic documentation is needed by practitioners in order to develop a theoretical basis for all types of wet-avalanche release. Work in wet snow is very different than that in dry snow, and crystal classification can be tricky. The determination between wet snow, very wet snow, and slush is somewhat ambiguous because the hand-squeeze test does not offer the best resolution for quantifiable results. In order to quantitatively determine the true wetness of individual layers, new technology must be developed for use in a field setting.

The Strength of Wet Snow

Research has repeatedly shown that wet snow loses its strength when its water content reaches about 7% by volume (~14% pore volume). This rapid change in wet-snow strength in relation to water content helps explain why the onset of wet-snow avalanches is often rapid and dramatic.

Continued on page 21 ➡

From TAR to Sam Colbeck—
I do have one wet-snow question I have been pondering: you came up with the terms pendular and funicular, right? To me, they have always have the connotation that the pendular is hanging, in balance but waiting for something to happen, while funicular makes me think of the European trams that quickly carry people (temperature) from one grain to another, one state to another. Was that your intention with those terms?

From Sam Colbeck to TAR—
Pendular and funicular were used in other porous media before I used them. One describes a state of low liquid-water content where the liquid, the wetting fluid, is not continuous throughout the pore space. The continuous fluid in that case is air. The other describes a state of higher liquid-water content where the liquid is continuous, or connected, throughout the pore space. In this state the air exists in isolated bubbles.

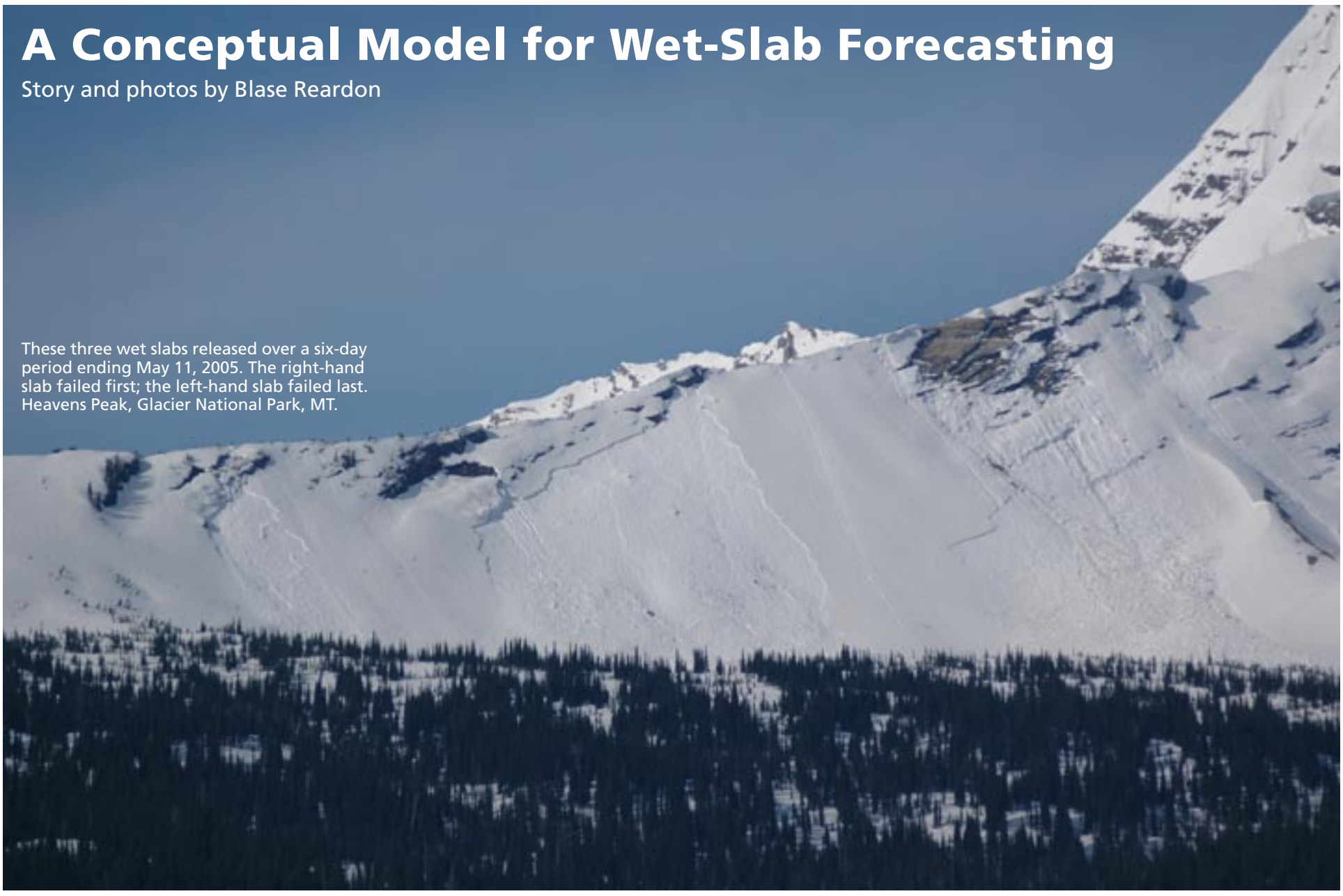
There is a fundamental difference between the thermodynamics of these two states just because of the differences in geometry. At lower liquid contents, the state at which liquid water, water vapor, and ice are in equilibrium requires ice-to-ice bonding. Thus this state has an inherent strength through bonding. On the other hand, at high liquid contents ice-to-ice bonds are unstable. That equilibrium state lacks bonding so slush is weak.

The equilibrium form of wet snow at low saturations is the grain cluster. However, daily melt-freeze cycles usually gives us melt freeze grains instead. The equilibrium form in slush is a well rounded crystal.

There are also differences in permeability to liquid, grain growth, and electromagnetics.

A Conceptual Model for Wet-Slab Forecasting

Story and photos by Blase Reardon



These three wet slabs released over a six-day period ending May 11, 2005. The right-hand slab failed first; the left-hand slab failed last. Heavens Peak, Glacier National Park, MT.

At the 2004 ISSW in Jackson Hole, Chris Lundy and I presented a paper on forecasting for the Going-to-the-Sun Road (GTSR) in Glacier National Park that included a conceptual model of snowpack structure, snowpack processes, and weather conditions that seemed to be conducive to wet-slab avalanches. That model has guided forecasting decisions for the GTSR since, and it has worked well. Which is to say Chris and I or our successors – Mark Dundas and Erich Peitzsch – have been able to explain just about every instance of wet-slab avalanche occurrence – and just as importantly, lack of occurrence – using it.

But adhering to this model, like any model, has its dangers. A model might explain a phenomenon in ever more intricate detail but still be wrong, like medieval cosmology's complex nest of celestial spheres rotating around the Earth. In other cases, a model might be generally accurate, but the world is bigger than you anticipated, and you are unwilling or unable to incorporate new physical evidence. This kind of error leads people to sail west to India and name the first islands they come to the West Indies and the people there Indians, even though they're only part way to India.

Our conceptual model for wet-slab avalanches could be as erroneous as either of these two examples, despite our success using it. In a decade or so, when the avalanche world knows more about how meltwater flows through the snowpack, it might seem quaint. I'll review the model nonetheless, and speculate about some of the questions that using it has raised, in hopes that other avalanche professionals can bring their experiences and ideas to bear on the wet-slab avalanche problem.

A CONCEPTUAL MODEL FOR WET-SLAB AVALANCHE SNOW STRUCTURE

The Water Factory:

The near-surface layers of the snowpack where meltwater is generated by temperature and radiation changes. This component is generally shallow – a half meter or less – and the transition from it to the slab below is distinct.

The Slab:

The bulk of the snowpack. Compared to the other two layers it looks and feels remarkably dry. Meltwater from the water factory drains past the slab without significantly wetting it, despite whatever crusts the slab might contain. The water moves in flow columns, rather than moving down through it in a wetting front. Some evidence for this are the frozen, irregularly shaped ice columns (also known as percolation columns) sometimes found deep in the snowpack after conditions have warmed then cooled.

THE FUNNY BUSINESS—
Weak layer for a wet-slab avalanche triggered by bulldozer, Glacier National Park, MT, May 4, 2005. Note coarse-grained facet and ice crust combination.

The Funny Business:

The weak layer for wet-slab avalanches. It is typically a wet layer of facets that is distinctly softer and coarser-grained than other layers in the snowpack. In both the 2003 and 2005 wet-slab cycles, it was immediately below an ice crust, counterintuitive as that might seem. The Funny Business seems to be formed by dramatic weather events such as early season rain on a shallow snowpack and is therefore often near the base of the snowpack. In 2005, however, a prolonged dry period during February and March was followed by several weeks of sustained spring storms. The mid-winter dry period was one of the longest such events in over a decade in the area. When conditions warmed in early May, a cycle of small- to medium-sized wet-slab avalanches ran on the mid-pack weakness that formed at the snow surface during the dry spell. Our snowpack often contains knife-hard crusts of varying thicknesses, including some that feel like panes of glass, and water sometimes saturates the snow immediately above these crusts. I have not, however, seen wet slabs run on such saturated layers above crusts.

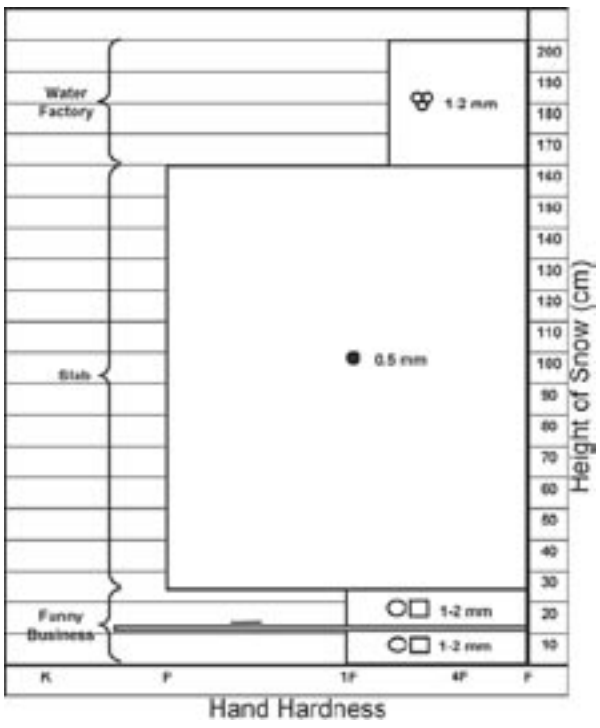
Wet-Slab Avalanche Cycles:

The wet-slab avalanche cycles near the GTSR have occurred within two weeks of the snowpack's peak for the winter. That's the Snow Water Equivalent (SWE) peak, which typically occurs the last week of April for the slopes around the GTSR. The peak depth usually occurs several weeks to a month earlier. A high-pressure system that roughly coincides with the SWE peak can bring a sustained period of sunny, hot weather that generates large amounts of meltwater before the snowpack – which is effectively still a cold, dry winter snowpack – has developed an effective drainage network. The meltwater generated in these conditions can rapidly flood any funny business present in the snowpack, destroying whatever strength or structural integrity it might have maintained. If this process occurs rapidly enough that the slab remains mostly dry, then wet loose slides, cornice falls, and glide avalanches can trigger wet-slab avalanches. This initial flush of meltwater is the best test of whether or not the snow structure necessary for wet-slab avalanches exists; if the snowpack withstands this as well as several successive periods of similar conditions, I start to gain confidence that we're not going to see what slab avalanches, even when conditions seem optimum.

That's the idea anyway. It seems to explain the wet-slab avalanches occurring when the snow structure described above coincided with a sudden, intense warming, as well as others that occurred when the warming was more gradual. It seems to explain the seasons when we had warm, sunny conditions but no funny business and saw no wet-slab avalanches.

Numerous questions remain. Erich Peitzsch is working on one of the most important – how does meltwater move through the snowpack? In particular, how does it percolate through the slab without appreciably wetting the slab? Once it reaches the weak layer, what is the mechanism by which it cases failure?

I've also been wondering if changes in slab properties can either contribute to or inhibit wet-slab avalanching. In early May, 2005, three wet-slab avalanches occurred on a steep but relatively uniform, north-facing slope *(see photo at left)*. They occurred over a six-day period, one every two days. The slope did not directly threaten the GTSR, and we had our hands full elsewhere, so we did not do any crown profiles. Based on a profile from another slide during the cycle, the weak layer was a mix of faceted grains that formed during a prolonged, six-week dry spell in February and March that was subsequently buried by several weeks of late-winter and early spring storms. It looked as if a good-sized glide avalanche triggered the first slide, while the later slides seemed to have been triggered by small cornice falls or glide avalanches.



What interested me most was the fact that the last slide was distinctly smaller than the previous two. The part of the slope on which it ran was subtly but not significantly different than that on which the two previous slides occurred – shorter, lower in elevation, and slightly more northerly, but otherwise the slopes appeared to have very similar slope angles and other characteristics. Why was the last slab smaller? It seemed unlikely that the weak layer was gaining strength, given the continuing warm weather. A variable distribution of the weak layer might account for the differences. Possibly the properties of the slab could have been changing, often below an ice crust, over time – as the slab warmed, its viscosity might have decreased while its fracture toughness and creep rate increased. The mechanism that could drive these changes wasn't clear. Most of the competing effects of rapidly warming temperatures should be limited to the near-surface layers of the snowpack. But the slides occurred over six days, so perhaps the warmer temperatures had time to work down through the snowpack, or the water moving down through snowpack caused these or other mechanical changes. Though I still can't explain that progression of wet-slab avalanches, it's left me wondering if changing, often conflicting slab properties leave only a narrow window for wet-slab avalanches.

Sequencing

In 2003, the sunnier halves of two large, west-facing bowls above the GTSR slid on consecutive days; on the same two days we saw at least nine other class 3-4 wet slabs on similar south- or southwest-facing slopes on the west side of the Continental Divide. Our big concern was the shadier sides of the two large bowls where the snow remained in place. Those slopes likely had snowpacks very similar to the slopes that had avalanched – were they next in line? How much more sun and warming would it take? But the sunny, warm weather ended the following day. And we were left to wonder about sequencing – questioning the concept that springtime avalanche cycles start on the lowest, sunniest, warmest slopes and move to higher, shadier, colder slopes as the season progresses.

After four more seasons, I'm still wondering. Sequencing seems to occur with wet loose slides, but that's a surface process more immediately influenced by radiation and temperature patterns. A review of over 100 glide avalanches in our database suggests some sequencing; perhaps on high, shady, leeward slopes less meltwater is produced at the surface, and it takes that water longer to percolate through the deeper snowpacks typically found on such slopes. With observations of fewer than two-dozen wet slabs, however, the picture is complicated. The wet-slab avalanches on the GTSR have been limited to very specific aspects with each cycle. All but one of the slides in the 2003 cycle occurred on south- to southwest-facing slopes west of the Continental Divide. The exception was an east-facing slope east of the Divide. In 2005, natural wet-slab avalanches ran on some north–facing slopes, while a dozer triggered a wet slab on a west-facing slope, and a natural wet-slab avalanche ran on another west-facing slope much higher in elevation. No wet-slab avalanches occurred on other aspects. Which is more important in these cases: the patterns or the exceptions? Maybe the fact that both exist points to snow structure, once again – sequencing can only occur on the slopes where a prominent, persistent weak layer is present. The test will be that rare season when such a weak layer is distributed across most aspects and elevations and a ridge of high pressure sits over the Divide for two weeks.

Some differences between winter and springtime forecasting

Chris and I used to joke that dry-snow avalanches were better understood than wet-snow avalanches because avalanche geeks prefer skiing powder to mush, gwaunch, breakable crust, and even corn. In addition to different skiing skills, springtime forecasting also seems to require a different mental approach than winter forecasting. As a generalization, in winter or dry snow, unstable conditions are often apparent through direct evidence such as avalanching, shooting cracks and whumpfing, or stability tests. In spring or wet conditions, there are few similar clues to instability, and standard stability tests aren't effective. It's difficult to do conclusive compression tests or Rutschblocks on a weak layer near the base of a snowpack three meters deep. And on the GTSR, the problem is forecasting for natural – not human-triggered – avalanches, and we don't have the option of using explosives.

As an alternative, I've found myself focusing on indirect clues to the processes I'm guessing are taking place in the snowpack. If our conceptual model about snow structure and meltwater generation is accurate, then we need to know whether any meltwater produced at the surface is weakening any funny business deeper in the snowpack. But at present there's no way to image and quantify meltwater moving through the snowpack (Richmond, can you feature that as an option on your avalanche goggles?).

So I look for evidence that meltwater is flowing through the snowpack, such as water running across the road surface, rising streams, and SNOTEL sites reporting a loss of 1" or more of snow-water equivalent. These aren't signs of instability; they happen every spring. They do indicate that water is flushing through the snowpack and flooding a persistent weak layer, if one is present. The formation of glide cracks and the occurrence of glide avalanches also suggest that meltwater is reaching the base of the snowpack. A sustained period of such conditions is a test of the snowpack; if no wet-slab avalanches occur, then either no weak layer is present or it is strong enough to withstand that and any subsequent pulse of meltwater.

On the GTSR, conditions will develop such that meltwater is visibly flowing over mid-slope rockbands and the snow in even the highest starting zones looks "peppered" or "chocolate-chipped" with rocks. The snow surface is often dimpled, with blotches of red algae. At that point, I'm usually confident that wet slabs are no longer a hazard.

Relying on such indirect evidence can be a little disconcerting. It's high entropy data whose range of possible meanings makes interpreting it and evaluating its relevance and significance difficult. I'm hoping for some new tools and new insights that produce lower entropy data. The recently developed tests for fracture propagation might be really helpful. And I'm interested to see what happens to several persistent weak layers this spring.

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Blase Reardon is a masters student at the University of Montana in Missoula, where he is studying glaciology and climate change. He is a former forecaster for the GTSR and for Glacier Country Avalanche Center, past editor of TAR, and current publications chair on the AAA board.

Percolation Columns

Jake Hutchinson of The Canyons, Utah, during an American Avalanche Institute Level 2 course at The Canyons in February, 2004. During pitwork, I managed to excavate two crusts well-connected by percolation columns. The facets that were in between the crusts and columns simply blew out like fine feathers.

Photo by Mike Bartholow, while he was a student on this course. Mike's recent exploits are well-documented in Metamorphism.

WET SLABS: What do we REALLY know about them

Story by Erich Peitzsch

During the American Avalanche Association Professional Development Seminar in Jackson last October, I spoke about the fundamentals of wet-slab avalanches and my current graduate research project. As a young avalanche professional, I was honored to be speaking with the likes of Liam Fitzgerald and Bruce Tremper on this topic. Going into the seminar, I thought the topic of my presentation was a bit remedial for the audience. However, once the panel discussion was underway after the presentations, I was amazed that even the veterans were still speculating on the questions being asked.

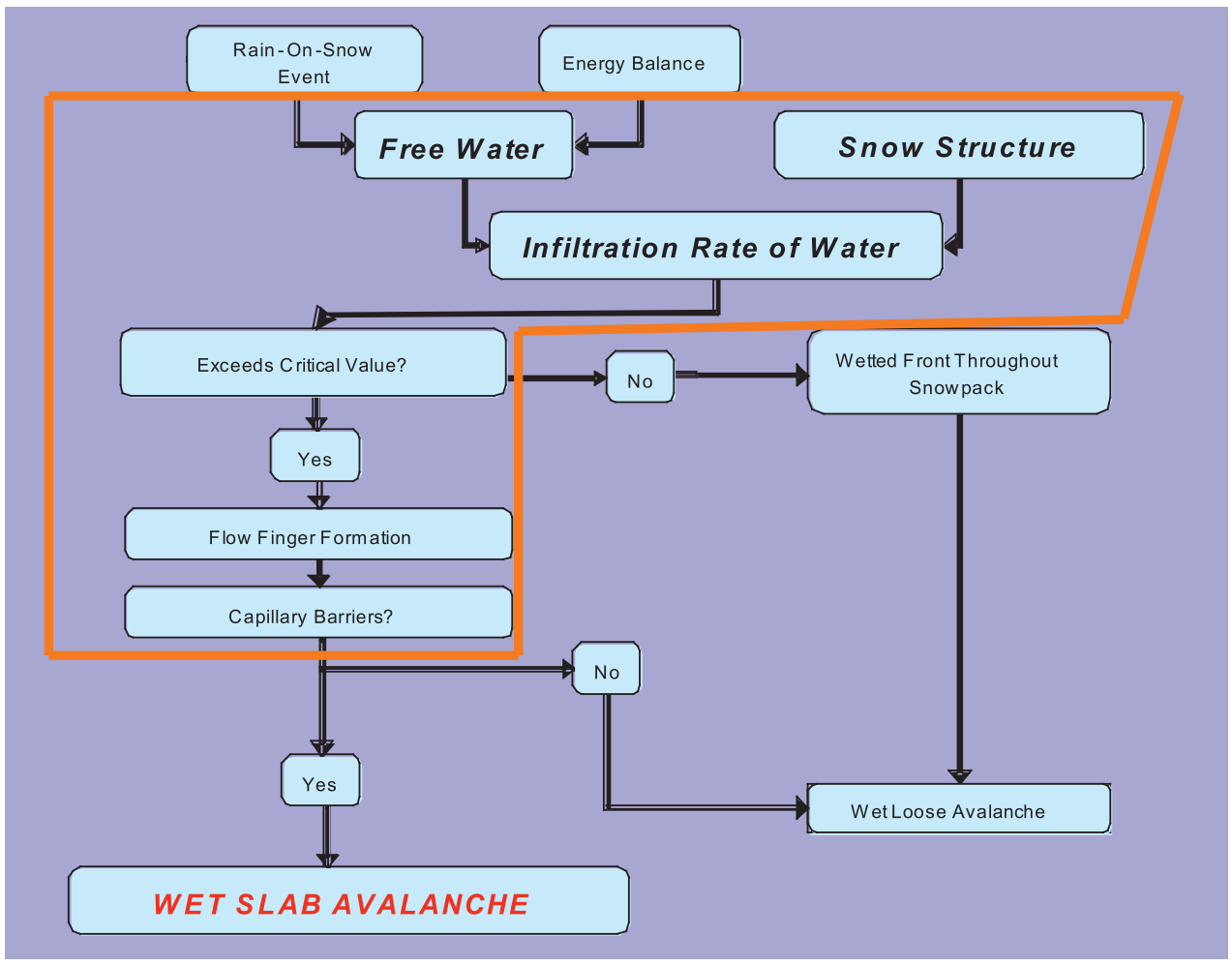
So, why is there so much unexplored territory in the world of wet slabs? Well, they just don't happen that often, and they don't kill as many people as dry slabs. According to numbers compiled by Dale Atkins, only 50 individuals have been killed by wet slabs since 1950. This year alone, there have been 41 fatalities in North America by mid-February, all due to dry-snow avalanches. Clearly, dry-snow avalanches present the most significant hazard to backcountry users. However, within the 50 wet-slab fatalities, 47% were naturally triggered compared to 35% human-triggered slides. This shows that wet-slab avalanches are more likely to be natural slides compared to dry-snow avalanches.

Explosives prove to be relatively ineffective in wet snow because of two reasons. First, shear-fracture propagation in wet snow requires much more energy. Second, the timing of explosives needs to be very precise within a relatively short window, and that window is difficult to predict. This was exemplified when an in-bounds skier was killed by a wet-slab avalanche on a heavily skied slope in the spring of 2005 after a morning of control work. So, even though wet slabs are rare, they are also dangerous and highly unpredictable. Thus, they deserve further attention and research.

Ingredients for a wet slab

Our current understanding of wet slabs comes from years of observations from many avalanche professionals. However, there have been very few quantitative field research studies focusing on wet slabs. Blase Reardon and Chris Lundy presented their observations on wet-slab avalanches along the Going-to-the-Sun Road in Glacier National Park at ISSW 2004. They came up with a conceptual model that includes three major ingredients needed for a wet slab to occur, which they named "the slab," "the water factory," and "the funny business" *(see story on page 18)*.

The slab is the obvious component, but retaining slab-like characteristics in the upper part of the snowpack when water is moving through is not fully understood, and leads to the issue of the water factory. The water factory is produced by either melt at the surface and near surface through radiation or the addition of water through a rain event. With enough water, preferential flow channels – or flow fingers – will form that enable the water to move vertically through the snowpack. These flow fingers also allow the snowpack to retain slab-like properties by forcing water to move through them as opposed to a matrix flow – or wetting front. Matrix flow is when water moves relatively uniformly through the snowpack.



Another piece that is important to the water factory comes from snow structure itself. When fine grains (like small rounds) are over the top of coarse grains (like facets), it can serve as a barrier to water flow through the snowpack. This capillary barrier impedes vertical flow of water and allows it to flow down slope, often great distances, along this layer interface. Crusts buried within the snowpack can also serve as a capillary barrier.

The funny business, as Reardon and Lundy describe it, is usually a section of coarser grains underlying finer grains (i.e., facets under rounds). This potential weak layer is able to support the load above it, but once water enters the equation, funny things begin to happen which, again, are not well understood.

Recent Research

Our research at Montana State University aims to help us better understand the water factory component *(see figure above)*. We are looking at how much water it takes to form flow fingers and also determine what constitutes a capillary barrier. We have our inputs being either a positive energy balance or a rain-on-snow event, both producing free water in the snowpack. Free water interacting with the snowpack structure will give us an infiltration rate that either does or does not produce flow fingers. If flow fingers are formed and a capillary barrier exists, then a wet-slab avalanche may occur. The section delineated by the orange in the figure above indicates the focus of our field work campaign.

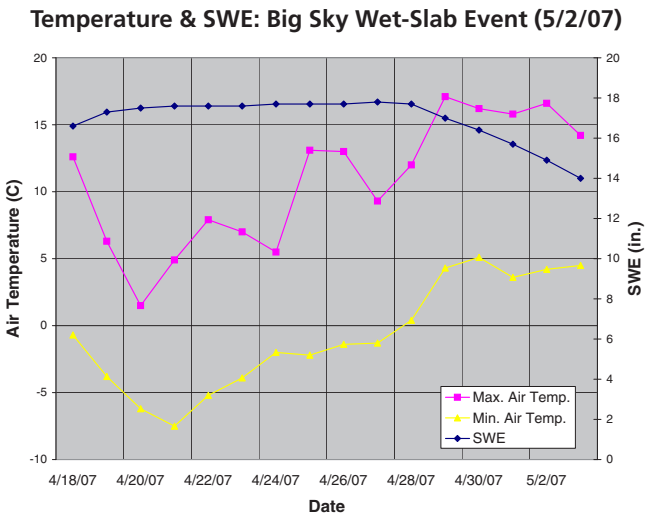


Figure 2. Graph detailing air temperature and SWE from 14 days before to wet-slab event. Data are from the NRCS Lone Mountain SNOTEL site, which is location approximately 400' below the crown of the slide.

Our field work thus far has produced interesting results as to what constitutes a capillary barrier and that water can flow great distances down slope and slightly laterally along this barrier. We will present our findings at ISSW 2008 in Whistler in September. We're currently trying to quantify some of these capillary barriers by using the SnowMicroPen to determine hardness in such subtle layer transitions. This research

Figure 4. Author in Beehive Basin, MT pointing to dyed water coming out the pit wall after running along a capillary barrier located ~7cm from the surface.
Photo by Karl Birkeland, National Avalanche Center

Figure 5. Wet slab in Black Rock Gully/The Bowl area at Big Sky Ski Area (after area was closed for the season). The author can be seen in the middle of the photo below a small tree near the crown.
Photo by Scott Savage, Big Sky Snow Safety

Figure 3. Wet slab in Black Rock Gully/The Bowl area at Big Sky ski area (after area was closed for the season). Debris: 4-6' deep, ~200 m width. Three separate crowns. Max crown depth: 7.5'. Crown to stauchwall 150-200'. Slide started from high on slope above small cliff band (locally known as Butthead) as wet-loose and propagated as WS ~ 3m vertical below. This slab triggered subsequent slabs below cliffs. Crown #1(looker's left in photo): WS-N-R3-D3.5-O. 38o. Alpha angle 30o. Crown #2(looker's right in photo): WS-N-R3.5-D3-O. 50o. Alpha angle 37o. Max. crown depth: 6'. Average crown depth: 4'. Extends up and across skiers left, same bed surface ~130m wide. Crown #3(not visible in photo): WS-N-R2-D2-O. Unable to investigate crown from below.
Photo by Scott Savage, Big Sky Snow Safety

will continue through the winter and spring in southwest Montana and Glacier National Park.

Aside from looking at the water factory, we are also interested in identifying meteorological parameters associated with wet-slab events. To accomplish this, we have set up a wet-slab database that includes meteorological data associated with individual wet-slab events. This portion of the study was set up at six sites around the western US and Alaska that measure air temperature, wind, relative humidity, and net radiation. The net radiation measurements allow for a closer look at how inputs are affecting the water factory.

Case Study

In southwest Montana last year, on May 2, 2007, after Big Sky Ski Area closed for the season, a wet-slab avalanche occurred in-bounds between 12:00 pm and 1:00 pm (Figure 3). Figure 4 shows the air temperature and SWE from the days leading up to the slide. This was the first notable warming event of the spring. This slide occurred on a NNE-facing aspect. In general, it is interesting to look at SWE from nearby SNOTEL sites to determine how much water is being lost from the snowpack, especially if net radiation data is not available. The funny business in this slide consisted of 2-4mm depth-hoar grains.

Final Thoughts and Further Research

As seen through the example at Big Sky, a dry snowpack, fast warming, and a prominent old weak layer are often prerequisites for wet slabs to occur. It also seems that winters that produce persistent depth hoar equate to a spring (or mid-season spring-like warming event) that has wet-slab events. Further research includes investigating the water factory to quantify how much water is needed to form flow fingers and quantitatively identifying capillary barriers.

Acknowledgements

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Erich Peitzsch worked as a patroller at Alpine Meadows in Lake Tahoe before becoming a graduate student at Montana State University. Along with being a student, he works as a forecaster for the Going-to-the-Sun Road in Glacier NP. He especially enjoy the glorious benefits of copious amounts of ice cream after long runs.

Cold Mountain Poem 3

Poem by Han Shan, translated by Gary Snyder. Copyright ©2003 by Gary Snyder from Riprap and Cold Mountain Poems. Reprinted by permission of the publisher.

Dan Powers and Andy Rich on a cold day, looking from Delta Lake up Glacier Gulch towards the Grand Teton, Gunsight Notch, and Mt. Owen.
Photo by Lynne Wolfe

In the mountains it's cold.
Always been cold, not just this year.
Jagged scarps forever snowed in
Woods in the dark ravines spitting mist.
Grass is still sprouting at the end of June,
Leaves begin to fall in early August,
Peering and peering, but I can't even see the sky.

WET-SNOW

continued from page 17

Spatial trends in melt are noticeable in field settings and experience has shown that in many cases, aspect can control which slopes receive sufficient energy to lose strength. Although rocks and other areas of concentrated radiant heat can result in small regions of instability, snow from these areas often releases and slides onto slopes below without producing an avalanche. In most operational settings, hazardous conditions occur when larger and more open slopes lose enough strength to avalanche (either independently or when triggered from above). At the slope scale, the strength of wet, surficial snow is less dependent on spatial variation than on temporal factors (aspect dependent) such as heating and cooling. This relationship is important because it suggests that site selection for strength measurements (of slopes representative of avalanche paths) may be easier than that encountered in dry snow (spatial variability in the slope scale strength of dry snow has been shown to be very high (e.g., Landry et al., 2004; Logan et al., 2005)).

We know that the shear strength of wet snow can change dramatically in as little as 20 minutes. More work is needed that targets how certain parameters of strength (such as shear strength and hardness) respond to temporal change in the energy balance and how those changes relate to snowpack stratigraphy and water content.

Summary

There are many reasons we have a lot to learn about wet snow. The phenomena is transient, it involves some of the most dynamic physics on the planet, it happens in the spring when we are all tired of digging holes in the snow: the snowpit will get you wet, the crystal types are weird and disappear 3 seconds after they hit your card, and they don't make hats that can protect you from standing on a 35-degree slope all day in April. On the other hand, this is a science that's wide open. Small answers can achieve large results. We need practitioners to help fill in the gaps. And remember, just because something is complicated doesn't mean that it's hard!

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Simon grew up running around in the mountains outside of Lander, Wyoming. After maintaining some form of sanity during two deployments with the US Navy, he received a degree in geology from Western Washington University. Recently he has worked as a ski patroller for Moonlight Basin and obtained a master's degree in snow science from Montana State University. Simon is now ready to retire and enjoy quiet time with his beautiful wife, Diesel, and their assorted animals.

So you wanna be a Ski Guide?

Story by Eric Henderson

"So you want to be a ski guide?" I vividly remember Margie Jamison from Ptarmigan Tours asking me as she handed me a large hose and scrub brush. "More than anything," I thought to myself as I filled the water tanks from the reserve and carefully scrubbed the soap and dried skin away from the outdoor hot tubs. I guess this is the way to success. Ironically a few years later while apprenticing in Valdez, one of the senior guides asked the same question as he handed me a mop, plunger, and cleaning supplies. Again I found myself on my knees scrubbing and thinking, "I hope this helps my understanding of the Alaska snowpack." Sure enough, in my case, these simple yet tedious tasks of manual labor did pay off, and now I would consider myself a professional ski guide.

Thinking back on it, those were the golden years. No structure, no guidelines, and no idea where ski guiding was going in the United States. Today we are looking at an ever-increasing business with an expanding clientele and continued support from media and ski areas. No longer can scrubbing bathroom floors, filling water tanks, and holding one's liquor count as a mentorship for ski guiding. These skills are essential and all guides should never feel above them, but some sort of structure beyond those skills needed to be put in place.

In Jackson Hole we have an amazing opportunity to run a professional ski-guide program from the center of Teton Village. Historically the Village has produced some of the field's top snow rangers, avalanche forecasters, ski patrol, and certified ski guides. Many of them have been self-motivated, enduring many long, cold, hard days and cleaned up their fair amount of shit. Today at the Village, the JH Alpine Guides work hand in hand with the BTNF Avalanche Forecast Center and will assist with any rescue needs the patrol might request. As a team of 20 guides, we provide a unique blend of guided backcountry skiing with a mechanical advantage: the aerial tram (to be in place again by winter 2008/09). This allows most clients to ski an average of 12,000' vertical per day. As the industry grows and more people want to explore the "Backside of Beyond," we needed to put in place a sustainable progression that allows new guides to get the training and mentoring needed to prolong their new careers.

This year we have hired a new set of guides who bring a variety of experiences and skill sets to the morning meetings. Some of the staff are purely observers, others work as tail guides, and others had to complete a rigorous checklist before receiving their guide wings. In addition, we have a new observation program where guides from other companies can come and spend a few days shadowing our guide staff in order to learn new skills and techniques. There is little room to hide information in today's guiding industry; we need standards, we need protocol, and we need consistency. This new grid works for the Alpine Guides at Jackson Hole Mountain Resort. It should allow our operation to be transparent to other operations and to our employees and guide aspirants, and hopefully will help to dissolve the myths of becoming a ski guide. It takes hard work, dedication to snow, love of the mountains, and someone to show you how it's done. There are so many mentors in the ski-guide industry who are starting to feel it in their knees and backs; we need to learn from them before they revert to fixing generators and scrubbing hot tubs.

Eric Henderson is Chief Guide for the Alpine Guides at JHMR. He recently achieved his AMGA Ski Guide certification on telemark gear. He also guides at Valdez Heli-ski in the spring. He owns a home south of Victor, Idaho, where he occasionally spends a leisure day.

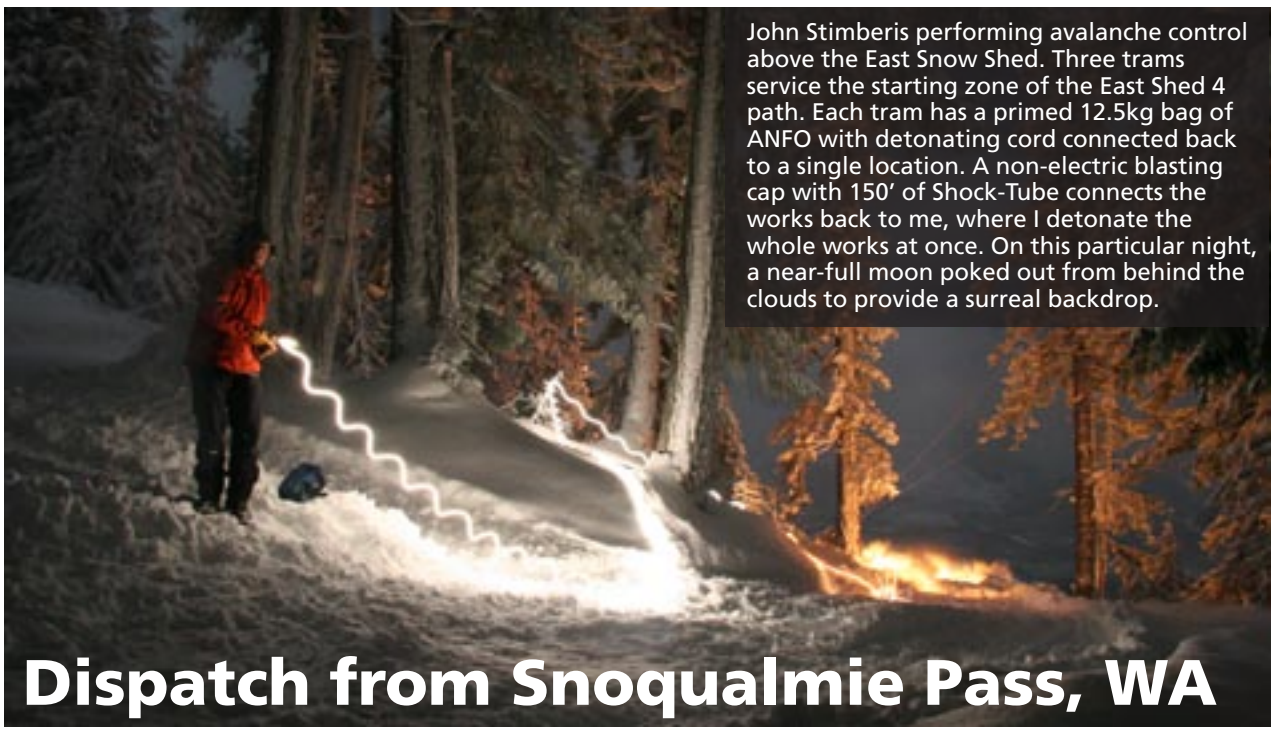
Eric Henderson reaps some of the benefits of becoming a senior guide as he puts first tracks of the season into No Name, JHMR *Photo by David Stubbs / www.davidstubbs.com*

Shadow		Purchase Personal Ticket Prior Planning, Personal Gear Purely an Observer, Sign Release Form	AMGA Track or Ski Guide Experience Letter of reference from guide company	
Aspirant Guide		Complete the season checklist	AMGA Track/Ski Guide Experience Level I or II Avy, Share Field Books 50 days skiing similar terrain, OEC/WFR	10x non-paid tail guide
Affiliate Guide	Teton Pass Days Full Season Pass	Complete Season Checklist Teach Mountain Experience (BCX) In-Season Guide Training Morning Mtgs (pd for days avail or working) Steep Camp and TVR Guide Dbl Guide w/Aspirant Guide or Follow Lead/Auxiary (same route) during Poor Stability	60 days documents ski guiding 3 years or 100 days skiing similar terrain Level II or III Avy, AMGA Ski Guide Course 3 fieldbooks w/profile/Rose diagrams OEC/WFR/CPR Resumé of 2 years Guide Training	2 days/week avg Available through Season-end Peak Period Requirements
Auxiliary Guide	C Status, Teton Pass Days Full Season Pass 15 Pvt Client OB User Days	In-Season Guide Training Morning Meetings (paid for days available or working) Steep Camp and TVR Guide	100 days documents ski guiding 5 years or 150 days skiing similar terrain Level III Avy 3 fieldbooks w/Profile/Rose diagrams OEC/WFR/CPR Resumé of 4 years of Guide Training AMGA Ski Mountaineering Guide Course	2 days/week avg Available through Season-end Peak Period Requirements
Alpine Guide	A, B, C Status			4-5 days/week available or booked with priority Meet hour requirement for status Peak Period Requirements
Emeritus Guide	D, E Status			Request clients or 1day/week available to guide Meet hour requirement Peak Period Requirements

Mark Rikkers wrote:

On a recent tour up on Red Mt. Pass, near Telluride Peak, a group of us saw a great example of something I had seen a handful of times before – the raised tracks from either a coyote or a fox on the snow surface. My first guess is that they are coyote tracks, but I have seen fox up in that exact area before. Chris Landry also thinks they are coyote tracks.

So…fresh snow with little wind…animal is on the prowl…weight of each step causes snow underpaw to sink and become more dense than surrounding snow. Wind picks up; wind scours surrounding higher and less dense snow more easily than sunken and more dense underpaw snow. Snowpack becomes scoured and surrounding snow height drops to below the height of denser under-paw snow. Relative height situation inverts, and paw prints are now "raised" above the surrounding snowpack – differential erosion. The phenomenon is fleeting because continued wind will chisel the raised prints away. *Photos by Chris Landry*



John Stimberis performing avalanche control above the East Snow Shed. Three trams service the starting zone of the East Shed 4 path. Each tram has a primed 12.5kg bag of ANFO with detonating cord connected back to a single location. A non-electric blasting cap with 150' of Shock-Tube connects the works back to me, where I detonate the whole works at once. On this particular night, a near-full moon poked out from behind the clouds to provide a surreal backdrop.

Dispatch from Snoqualmie Pass, WA

Story and photos by John Stimberis

When I was asked to put something together for *The Avalanche Review*, my first thought was, "Our season's not over yet." And yes, our crew here at the Washington State Department of Transportation still has several months of snow and avalanches coming…but I do feel we may have passed a hurdle here in the last few days. The unrelenting precipitation has ended, temperatures have warmed, and the snowpack has begun to settle. This is probably nothing more that a brief respite, though it does provide a chance to review what has transpired this winter and project what could still happen. Our snowpack may be quiet today, but there are layers, deep ones, that still hold the potential for big avalanches.

December arrived and winter began, just like that. We received 91cm of snow on December 2-3 with a water equivalent of 9.53cm. This was followed by nearly 8cm of rain. Avalanches happened, backcountry fatalities occurred, and our highway avalanche control program was in action. Then we had a week off to allow some surface hoar and facets to form.

December 12 began a 35-day stretch during which we would have only three days without new snow. The totals were impressive: 507cm snow (55.25cm SWE), densities that ranged from 4-23% and 19 highway avalanche-control missions during December. Unfortunately, this meant more backcountry avalanche fatalities, as recreational users were slow to adapt to the unique snowpack that was developing.

January arrived and the onslaught continued. By the 15th we finally got a four-day break. 27cm of snow was recorded on the 20th, followed by six days with temperatures in the single digits (F). The snow returned and kept us going right into February; the next 14 days had 371cm of snow (38.5cm SWE), with densities ranging from 4-18% (see graph). We logged 32 highway avalanche-control missions in January.

Surface hoar, facets, and low-density layers were buried deeper and deeper each day. Reports kept coming in about strange events: slopes were hit hard one day without results, only to go deep a day or two later from light charges, skiers, or a temperature change of a few degrees.

On the highway, we watched our control program expand as paths and cut-banks that have rarely been a concern were becoming regular problems. Control work stretched on and on with our crews working around the clock at times. Craig Wilbour, our Avalanche Program Manager on Snoqualmie Pass, usually supervises a day shift of two avalanche forecasters, while I supervise a night shift of two more. At one point we found ourselves in opposite roles, as work and rest cycles had me and my crew working the day and Craig and his crew on at night. By the middle of February we had logged an additional 34 highway control missions. We have used over 7,500 lbs of explosives this winter and fired 99 rounds from our 105mm recoilless rifle. The recoilless hasn't seen action in five years!

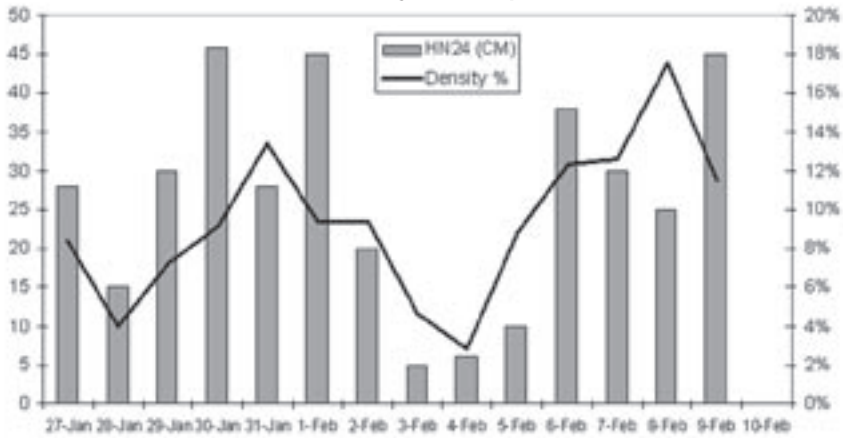
Routine closures became longer as more control work was needed, or our maintenance crews needed more time to clear the snow – they had simply run out of places to put it! At times we couldn't keep up, and closures went from hours into days. We've had around 175 hours of closure time this winter and it is estimated that one hour of closure time costs our regional economy $700,000. The impacts are huge, though I must admit that the pressure from our management to open the highway has not been overwhelming.

Well, that's it for now. I have enclosed a few photos from our area. I'll try to catch up later about the rest of the winter. We still have our spring opener at Chinook Pass to look forward to, as well. Be safe out there and I'll see you at the ISSW.

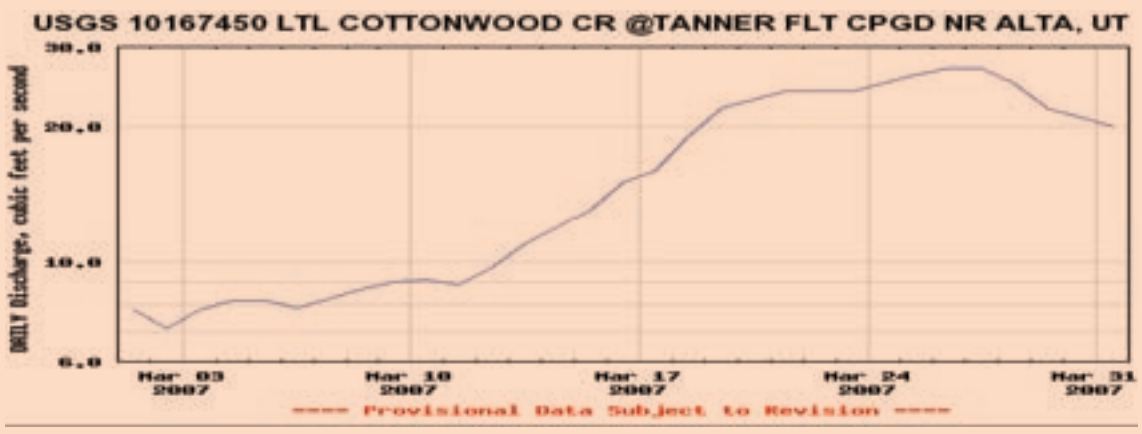
John Stimberis works as an Avalanche Forecaster for the Washington State Department of Transportation on Snoqualmie and Chinook Passes. During the summer he continues to be employed by the WSDOT in the avalanche program. John enjoys live music, photography, and long-distance running.

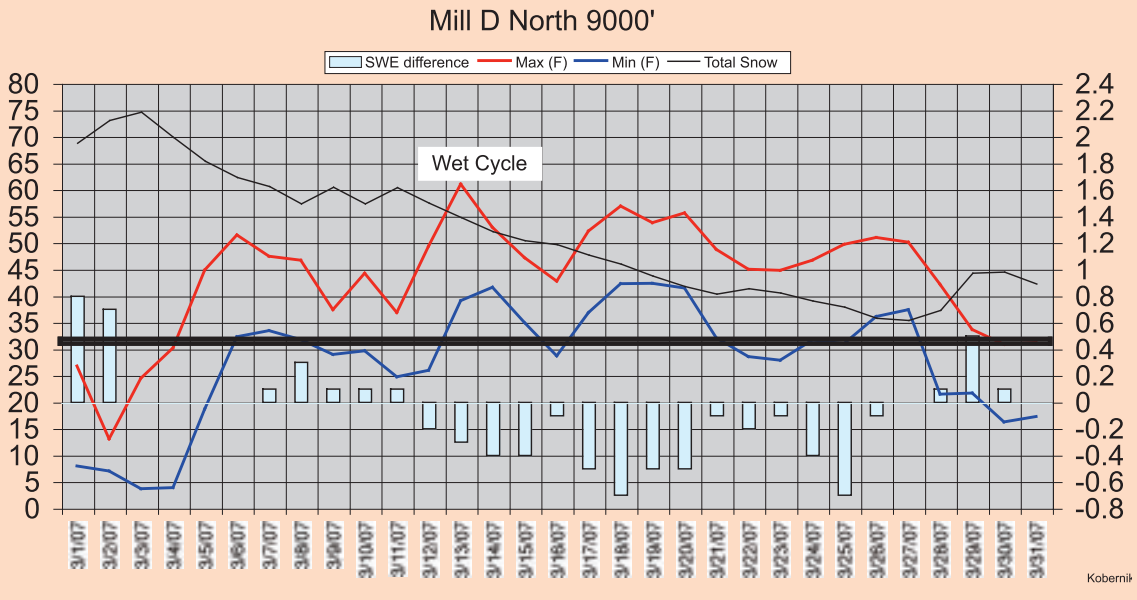
Highway Forecaster Bram Thrift *(above right)*, along with the author and Alpental ski patrollers, investigates a sizeable crown just outside the ski area boundary. The profile revealed a thin layer of low-density snow to be the failure layer *(inset)*. Larger avalanches around Snoqualmie Pass appeared to be failing on this layer as well.

New Snow w/Density for Snoqualmie Pass (3022')



Gobbler's Knob Avalanche: Utah 3/13/07





Bruce Tremper sends TAR a set of Brett Kobernik's graphs from March 2007. *Photo at top by Bruce Tremper*
Note that the wet cycle that culminated with the Gobbler's Knob avalanche on March 13 was directly after the first decrease in SWE coincided with low temps above 32F, and creek levels rising *(see top graph)*.

The Meadow chutes in Big Cottonwood Canyon, November 2004. The Persistent Weak Layer in this incident was depth hoar from a cold early season.

Photo ©2007 Bruce Tremper, www.brucetremper.com

Persistent Weak Layers and the Winter of 2007/08

Story by Karl Klassen • Originally issued: January 30, 2008 • Updated: February 27, 2008 *(see story on next page)*

What's the problem?

A persistent weak layer (PWL) is so called because it does not strengthen over time, and in some cases it even becomes weaker over time. A PWL can remain unstable for weeks or even months and is often the cause of avalanches long after it originally forms and is buried.

A PWL often results in what is referred to as a "deep-slab instability" – a deeply buried weak layer beneath a thick slab or slabs of snow comprised of accumulated snow from numerous storms. Deep-slab avalanches are generally large and highly destructive due to their size and mass. A PWL that formed in the fall of 2002 and the resultant deep-slab instability was the underlying cause of most of the 29 fatalities that occurred in the winter of 2002/03 (the worst avalanche season in recent years), including two large avalanches that each killed seven people in the Selkirk Mountains.

A variety of crystal forms can contribute to a PWL, but the current concern is a "facets-on-crust" layer. Back in the early days of the season, rain saturated the surface of the snowpack (this is called a "rain-on-snow event"). As or shortly after that wet layer froze, facets (sugary snow grains) formed on top of the icy rain crust. Now, that layer of facets has become a PWL.

This year's facets-on-crust PWLs are known or strongly suspected as the cause behind nine of 11 avalanche fatalities to date, spanning a time frame from December 8, 2007, to January 16, 2008, and occurring in the Alberta Rockies, the Cariboo Mountains, and the southern Monashee Mountains. The most active period to date was the first week of January when numerous fatal accidents made avalanches front-page news. The untold story are the many close calls involving this year's PWLs that didn't make the news starting in mid-November and, as of this writing, continuing to January 24 – occurring in practically all the mountain ranges of BC and Alberta. You can see reports about many of these close calls on the Canadian Avalanche Centre's Discussion Forums at www.avalanche.ca/default.aspx?DN=586,558,3,Documents.

Experience has shown that PWLs go through cycles where periods of high avalanche activity are interspersed with periods during which few avalanches occur. When, where, and why these cycles occur can be difficult to predict with a high degree of accuracy and are not fully understood. Unstable periods are often related to changes in weather factors such as increased wind, snowfalls, rain, temperature changes (especially from cold to warm), and solar radiation. A PWL that has produced avalanches and then shows signs of stability is generally treated with scepticism by knowledgeable practitioners, most of whom describe such a layer as dormant rather than stable, the assumption being (as Monty Python once said), "It's not dead; it's only sleeping."

Where is the problem?

One or more rain-on-snow events occurred in pretty much all the mountain ranges of BC and Alberta in the fall of 2007. It is common practice to name a PWL according to the date on which it is buried by subsequent snowfalls. To date this year, rain-on-snow events occurred:

- Near the end of October at most elevations and on all aspects in most BC and Alberta mountain ranges. This layer is generally referred to as October 31 or the Halloween crust, although it is dated as early as October 27 in some areas.
- Around the third week of November at most elevations and all aspects in practically all BC and Alberta mountain ranges. This one is referred to as November 24, plus or minus a few days.
- In early December on all aspects to treeline or just above treeline in most BC ranges. This most recent layer is commonly known as December 5 although it might be anything from December 3 to 10, depending on where you are.

The October layer, while quite widespread in BC and Alberta, is not a great concern in most of BC at this time. It is, however, considered a problem in the Alberta Rockies. The November layer was considered a potential problem in many ranges, but in most areas of BC it seems to no longer be a significant concern. At this time, however, it remains an issue in parts of the Alberta Rockies and perhaps in isolated areas in BC that have a snowpack of less than about 150cm on average. The December layer did not occur in the Alberta Rockies but is widespread in BC. That said, there are numerous areas where these layers either do not exist or, if they do, have shown no signs of instability from the outset.

Following is a breakdown of the regions where this year's facets-on-crust PWLs are more prevalent. I must stress that this is a very general overview, and local anomalies are a certainty. Please note that in areas where a professional avalanche-control program is in place, the problems associated with these layers are significantly or wholly mitigated; this includes, for example, transportation corridors and ski areas.

On a regional scale, October and November PWLs are currently considered prevalent at all elevations in:

- The entire east slope of the Alberta Rockies from the US border to at least Jasper and probably to Grande Cache.
- Limited information indicates the November layer was a concern in the North Rockies, but its current state there is uncertain.

The December layer is considered a greater problem around treeline and in open areas below treeline in:

- The west side of the southern Rockies from around Elkford (and maybe a little farther north) to the US border, including the Fernie area.
- The boundary region east of Osoyoos, west of Kootenay Pass, and south of Castlegar. The mountains around Rossland have been described the "epicentre" of the December PWL.
- The Monashee and Selkirk Mountains south of a line running more or less from Vernon to Nakusp.
- The Purcell Mountains.
- Inland regions of the South Coast Mountains.
- Limited information suggests this layer is of concern in the North Rockies, especially in the eastern parts of the region where the snowpack is shallow.

Even in areas noted above, there are locations where PWLs are less of an issue or perhaps not an issue at all. Knowledgeable local experts (e.g., guides, ski patrollers, and avalanche professionals) who have been tracking and testing the snowpack throughout the winter and use a recognized snow-stability analysis and forecasting process to assess hazard and manage risk will know if PWLs are an issue in their area. Unless you have credible local knowledge and are certain a problem PWL does not exist, it's probably wise to assume there is an issue in the above areas.

The potential for triggering a deep-slab instability on a PWL is greater in:

- Shallow snowpacks (less than 200cm on average).
- Variable-depth snowpack areas (shallow areas interspersed with deep areas on the same slope).
- Rocky slopes.
- Slopes with small, isolated trees sticking out.
- Complex slopes. (see terrain classification at www.avalanche.ca/default.aspx?DN=599,428,4,558,3,Documents)
- Steep, convex, unsupported features.

How do this year's layers look and feel?

A facets-on-crust PWL is characterized by a layer of firm or frozen snow with weaker facets above and/or below it. The firm layer is generally hard to very hard, sometimes even an ice layer, anywhere from perhaps a centimeter or two in thickness to 10cm or more. If you poke the firm layer, it will be difficult or impossible to push a single gloved forefinger into it. The facet layer is soft or very soft, is typically thinner than the crust, and can be

as thin as a few millimeters. It's difficult to assess the hardness of thin facet layers, but they are often relatively easy to see (a darker, sometimes bluish, line in the wall of a hole dug in the snow). Under 8-10x magnification on a dark background, facets look like sugar crystals and the grains separate easily when removed from the snowpack.

A problem PWL, or one that is likely to become a problem, usually displays a certain "fracture character" when tested. The layer will generally produce a "pop" (sudden planar) or "drop" (sudden compression) fracture when tested using the Compression (CT) Test. In Rutschblock (RB) tests it often results in a whole block (WB) or most of block (MB) failure. In the case of PWLs, most avalanche professionals weight the pops and drops or WB/MB fracture characteristic more than the amount of force it takes to create the fracture in the first place. That is, even if it takes a lot of force to make the layer fail, if the layer pops/drops or produces a WB or MB failure, these layers are still considered significant.

One of the problems with the CT and RB tests is they only work when the PWL is less than 150cm below the surface. In many areas, this season's PWLs are already buried deeper than 150cm, and assessing them requires more complex tests that provide less definitive answers. Testing, assessing, analyzing, and predicting the behavior of very deep instabilities falls into the realm of highly experienced professionals who have seen many similar problems in the past, and who can combine technical and scientific information with their broad knowledge and intuition in the analysis of these layers.

Read more about pops, drops, and CT and RB tests at www.mec.ca/Main/content_text.jsp?FOLDER%3C%3Efolder_id=2534374302881865.

How long will these layers persist and what will make the problem go away?

Most PWLs will perform (produce cycles of high avalanche activity) several times throughout a winter, with dormant periods lasting as long as several weeks. However, even in dormant phases, these layers can and do produce large, destructive avalanches.

In my opinion, it's almost certain that, where this year's layers are prevalent, they will persist for the remainder of the season. That said, just because a layer is there, does not necessarily mean it will wake up again and even if it does become active again, it may not produce as widespread a problem as we experienced in early January.

As to what it will take to make these layers go away, there is no definitive answer. A heavy rain event, while it would probably produce a major avalanche cycle in the short term, would likely create a very strong overlying layer of icy snow which, much like a bridge, would support further loads and minimize or eliminate the chance of a PWL below from failing. At the moment however, there is no such event on the horizon according to current long-term weather forecasts. Otherwise, the only thing that will improve this kind of layer is if the crust becomes softer and/or the facets become harder and the whole combo becomes more homogeneous with the surrounding layers. There are some indications that this may be occurring with the December layer in some areas. However, this idea is based on limited data from isolated locations and should not be considered a general trend at this time.

If the layer is dormant, when will it wake up?

First of all, *dormant* is a relative term. A common pattern with PWL avalanche activity is a gradual decline in the frequency of avalanches. However, the avalanches that do occur tend to be larger. When and where the "low-frequency/high-consequence" avalanches will occur during a dormant spell is extremely difficult to predict, and wondering when a dormant layer will reactivate causes sleepless nights for avalanche forecasters worldwide.

In addition to the difficulty of predicting the low-frequency events, it can also be hard to predict when a new cycle of high avalanche activity will start. It's prudent to pull back and wait a few days to see what happens if:

Continued on next page ➡

Persistent Weak Layers: Feb 27 Update

What's happening with the October, November, and December persistent weak layers?

All these layers have been dormant for an extended period of time. The odd isolated event involving the December 5 has been reported recently, usually involving a large trigger like a cornice or a smaller avalanche impacting a slope below. These slides, when they occur, have been large and destructive. It's likely that October 31 or November 24 was a player in a fatal size 3.5 (very large) avalanche in the Rockies that occurred February 18.

These are classic examples of a dormant deep-slab/persistent weak layer (PWL) instability: they're not particularly easy to trigger; the chance of triggering is low; the number of avalanches is few; but the size of avalanches that do occur is large and consequences of being caught are dire.

What's new?

In addition to the facets on crust layers discussed in earlier versions of this paper, there are now two more PWLs of concern in the 2007/08 snowpack. These are January 26 and February 25.

January 26 formed during a clear, cold period that was windy at the outset, then mostly calm for an extended time. Its characteristics are:

- Windcrust in wind-exposed locations at and above treeline. Often there is a thin layer of facets on top of the crust. In some areas, surface hoar formed on these crusts instead of or in addition to the facets.
- In wind-sheltered areas, a layer of facets (up to 10-15cm thick), often with surface hoar on top.
- A thin suncrust on very steep, very sheltered, very sunny slopes. In some areas facets, surface hoar, or both are found on top of the crust, and facets may also exist below the crust.

January 26 is widely distributed and found in most locations throughout BC and Alberta.

February 25 formed during a clear, mostly calm, warm period. Its characteristics are:

- On moderate to steep, sheltered, sunny slopes: a suncrust of varying thickness. In some places, facets probably formed below the suncrust, more likely at higher elevations.
- At low elevations on all aspects: melt-freeze crusts from warm temperatures.
- On many colder, shaded slopes, especially at and above treeline: a layer of facets (up to 10-15cm thick).
- At all elevations and aspects: surface hoar. You'll find it in combination with the facets and crusts or as a discrete layer in locations where facets and crusts are not prominent. This surface hoar is generally larger at lower elevations. Some areas reported sizes to 140mm below treeline in areas sheltered from wind and sun. The surface hoar is generally smaller and/or deformed in wind- and sun-exposed slopes. Surface hoar may have been destroyed on slopes that experienced strong winds, very warm temperatures, or intense solar radiation just prior to the first snowfalls. However, skies were cloudy, temperatures cool, and winds calm in many areas the last day or two before Feb 25 was buried, so I wouldn't bet the farm on the surface hoar being gone unless you have extensive local knowledge.

February 25 is widely distributed and found in most locations throughout BC and Alberta.

Are Jan 26 and Feb 25 performers?

January 26 was initially buried by several cold, dry, light snowfalls under calm conditions. For 7-10 days there was not enough load and/or slabs were not cohesive enough to create a widespread cycle on this layer. Eventually, however, the overlying snow settled or was blown by wind into a slab, and continuing snowfalls added enough load that January 26 began producing good-sized avalanches. In many areas the cycle peaked around mid-February when a wind event triggered a round of large avalanches. Things died down for a few days, and then another cycle occurred on this layer, initiated by warm temperatures and strong solar radiation. This solar-induced cycle often involved cornice triggers and step-down avalanches, which gradually tapered off and ended when temperatures cooled off and skies clouded over. Recently, Jan 26 has become dormant with only the occasional, isolated avalanche occurring. Slides are, however, becoming increasingly large and destructive.

February 25 is being buried as I write. It's starting to perform in areas where there's more than about 25cm of new snow on the layer or where winds and/or warm temperatures have created slabby or stiffer surface layers. Notably, this seems to be occurring in the Northwest and favored, upslope areas on the west side of the northern and central Columbia Mountains. This layer has all the signs of being a performer, so just because you are not seeing anything in your area yet, I'd suggest great care be exercised for the next week or so – we are back in the storm track and ongoing light to locally moderate snowfalls are expected with sunny, dry breaks between systems.

Once there's 30cm or so of new snow and/or a bit of windslab on the Feb 25 layer, I expect a fairly widespread avalanche cycle throughout the province. In many areas, this could occur in the next few days (Feb 29 to Mar 2) if the weather forecast is accurate. Even though Jan 26 and Feb 25 look similar, I will not be surprised if Feb 25 performs more readily and on a more widespread basis than Jan 26 did. Avalanches on the Feb 25 layer also present the potential to step down to the Jan 26 or deeper PWLs. Farther east in Alberta, the problems with Feb 25 might not be as widespread, as snowfalls are expected to be lighter, but I'd be very careful in windy areas where even small amounts of new snow are being drifted into deeper slabs in leeward and crossloaded terrain.

The potential for step-down avalanches

When there are multiple weak layers in the snowpack, a smaller slide involving shallower weak layers could impact an area where a deeper weak layer exists, subsequently triggering a failure in the deep weak layer. While this situation is not limited to PWLs, it's of particular concern when there is a PWL in the snowpack and a deep-slab avalanche is possible, because:

- PWLs are often buried very deeply in the snowpack (January 26 is now about 100cm down in most areas of BC, December 5 is easily 200cm or more, while November and October are even deeper), so there's a lot of mass available to avalanche.
- Deep-slab avalanches usually involve hard to very hard layers of snow that can propagate over very wide areas and across terrain features that are normally considered safe. I clearly recall a PWL from November (1996, I think?) that failed in March and propagated from ridgecrest in one alpine bowl around a very pronounced ridge, then ran down below treeline and back up into the alpine in an adjoining bowl. The entire fracture line cleaned out both bowls as well as the terrain between them and was over 2000m in length. The debris took out mature trees in two separate drainages. You could smell

Continued on next page ➡

PWL FEB 27 UPDATE

continued from previous page

freshly broken timber from the helicopter as we flew over the valley bottom!

- When and where PWLs exist that may provide step-down potential is hard to predict. Unless you are completely familiar with the entire winter's history of a slope, it's impossible to tell whether there's a PWL step-down potential.

In the worst-case scenario, we have four or perhaps even five persistent layers at various depths in some parts of BC. In the best-case scenario, there are probably at least two or three. We are definitely in a winter where step-down avalanche potential currently exists and probably will remain for the rest of the season.

How do I manage my risk with these new persistent weak layers and the potential for step-down avalanches?

While January 26 and February 25 are not facets on crust PWLs like the ones from earlier in the winter, they behave similarly as and after they are buried, and managing risk is more or less the same. *(Refer to "How do I manage risks associated with PWLs and deep-slab instability?" in the main story on page 24).* I'll quickly review some of the factors to keep in mind in terms of potential reactivation or triggering of a typical PWL. This applies to all the PWLs we are currently dealing with.

Deeply buried, dormant, PWLs tend to be triggered or reactivated when:

- Large triggers are applied. Cornice fall triggering is common. Sleds are bigger triggers than skiers. A sledder or skier jumping onto a slope is a bigger trigger than one who is not jumping.
- Step-down avalanche potential exists. Weather factors such as new snow, rain, wind, temperatures, and solar radiation are common triggers for storm snow or surface avalanches, which then step down to PWLs.
- Rapid, significant new snow loads are added. I hesitate to suggest a general rule, but 30cm in 12 hours is certainly something to think carefully about.
- Rainfall adds warmth and load to the snowpack. Any amount of rain is of concern if the existing snow is dry. Things might hold up a bit better if the snowpack is a thick crust or very firm old snow that has been previously warmed or melted and refrozen.
- Wind is loading snow onto a slope. Even relatively small snowfalls can accumulate quickly and deeply when wind starts moving snow around. It's not at all beyond the realm of possibility that a 5cm snowfall could accumulate a 50cm deep slab within a few hours in a windloaded area. Remember that windloading can occur on leeward slopes as well as in pockets on crossloaded or even windward slopes.
- Temperatures rise rapidly. Three degrees C in an hour would be something to watch, especially starting at -10º or warmer and more so if temps are getting close to or going above the freezing point as they rise.
- Strong solar radiation affects a slope. The snow need not feel wet or slushy for it to become unstable. Remember that solar radiation is often stronger and hits earlier on high-elevation slopes. Even on a shaded north- or east-facing slope, solar radiation can be a factor if the backside of a cornice has the sun shining on it at ridgetop.

If more than one factor exists on a slope at any one time, the effect is greater than the sum of its parts.

In my experience, a significant proportion of serious accidents involving PWLs occur in late winter and spring on blue-sky days. I suspect there are a number of factors at play:

- It takes at least several days for PWLs to adjust to stress from new snow or wind events.
- It takes at least a couple of days for most non-persistent, storm-snow instabilities (which might trigger a step-down avalanche) to settle out. People don't wait long after a storm before they push out on a nice day.
- On clear days, warming and solar radiation can quickly destabilize slopes or cornices above, which then trigger a PWL or a step-down avalanche. People don't look up enough, and they tend to underestimate the strength of the sun when assessing warming and solar radiation on slopes or cornices far above, especially if they are in the shade in the valley below or on a "cold" slope such as a north or east aspect.
- There's less tendency to stop and reassess current local conditions in good weather. People miss changes happening around or above them.
- People are more willing to push into bigger, steeper, more complex terrain when the weather is good.
- People ride more aggressively on bluebird days.
- People tend to discount their intuition or "gut feel" more often on bluebird days. If something doesn't feel right, they are more willing to push on a clear, warm day than on a cold, foggy, snowy day.

If any of the above factors is at play, and especially if more than one are a potential, you should very carefully examine your motivation for exposing yourself to slopes where PWLs are known or suspected to exist. It is strongly recommended you back off and go to slopes where PWLs are not an issue. Or choose low-angle, simple terrain that is not exposed to slopes above. If you feel you must expose yourself to slopes that might contain PWLs, give them several days to adjust to new stresses before reconsidering them as an objective. I would suggest you use those several days to obtain as much information as possible from credible local sources about the slope you want to tackle, and continue to question your motivation.

Here are some sobering numbers:

- PWLs are known or suspected to be the failure layer in 11 of 14 fatal accidents so far this year.
- 85% of all reported avalanches reported to the CAC's incident-reporting database to date this year involve PWLs.

This season's snowpack is currently a complex risk-management problem and will likely remain so for some time to come. The snowpack this year is not something to mess with or take for granted.

My intention is not to scare people out of going into the mountains. It is possible to manage risk, maintain reasonable margins of safety, and make informed decisions in these conditions. But my personal approach to a snowpack like this one is very different than when there are fewer or no PWLs involved. Local knowledge of the snowpack and experience with similar conditions are critical components in managing risk this winter. The most important factor in managing risk in these circumstances (and, in my personal opinion, at all times) is understanding and utilizing terrain effectively.

In closing, I thought I'd leave you with some thoughts from some of my mentors that I think are highly are applicable in these times:

"The snowpack is a capricious, erratic acquaintance who you never really get to know very well. The terrain is a steady and predictable friend that you can always depend on."

"When you have low confidence in the snowpack, there are three things that are of the utmost importance in managing risk: terrain, terrain, and terrain."

—Karl Klassen

PERSISTENT WEAK LAYERS

continued from previous page

- It starts raining.
- More than 20-30cm of new snow accumulates in a 24-hour period (perhaps less if the snow feels heavy or is associated with winds and/or warm temperatures).
- Wind is drifting snow onto slopes where PWLs are likely to exist.
- Temperatures rise rapidly (more than 3˚C in a period of one hour), especially if it's -10˚ or warmer.
- Temperatures are near, at, or above 0˚C.
- Solar radiation is strong.
- The snow is softening or becoming moist/mushy.
- Large triggers (e.g., cornice fall, avalanches from above, icefall, etc.) may affect a slope containing a PWL.

It's always a good idea to check the avalanche forecasts issued by the Canadian Avalanche Centre (www.avalanche.ca/default.aspx?DN=5,4,558,3,Documents) regularly to see if there is information indicating that the layer is coming alive or expected to wake up. Another place to look is in the CAC Discussion Forum (www.avalanche.ca/default.aspx?DN=586,558,3,Documents) where people who have been out in the mountains discuss their observations and post incident reports.

Some of the most destructive avalanche incidents in Canadian history are related to the end of a PWL lifespan. This is often in late winter or early spring while a PWL is dormant. After a long period of time with little or no avalanche activity on the PWL, people get lulled into sense of complacency or develop increasing confidence and are then caught by surprise (often in March) when an isolated but very large avalanche event catches the unwary by surprise. I recall a PWL in the 1990s that formed in November, went through several active periods through late spring, then wasn't heard from again until it was suspected as the weak layer in an avalanche that killed a mountaineer in August of the following year.

How do I manage risks associated with PWLs and deep-slab instability?

Deep-slab instabilities associated with PWLs are among the most difficult of all avalanche problems to assess, predict, and manage. Even with extensive training and nearly 30 years professional experience, I struggle with the combination of "low probability-low frequency/high consequence." That is, it's often difficult to trigger a deeply buried instability, and the frequency of avalanches is low, but the consequences if caught in a deep-slab avalanche are very serious due to the size and mass of the slide. The answer lies in making decisions based on what you know about a slope, its history of avalanche activity over the season, slope-use patterns (e.g., compaction), and/or stabilization (avalanche control) measures. In the absence of knowledge, the only reasonable way to manage your risk is by leaving a wide safety margin wherever a PWL is known or suspected.

It's important to be aware of the potential risks so you can make an informed decision when determining whether the risks are acceptable to you and your party. There are a number of steps you can take to ensure you are making an informed decision:

- Examine your own motivation and that of others in your group. Check out this article: www.mec.ca/Main/content_text.jsp?FOLDER%3C%3Efolder_id=2534374302881868
- Assess the training and experience of your party.
- Use a decision-making process or tool like the Avaluator™ to aid in trip planning (www.avalanche.ca/default.aspx?DN=428,4,558,3,Documents).
- Ensure that all members of the party play an active role in all aspects of planning, preparing, and executing the trip.
- Talk to the others in your party. Listen to what they have to say. Respect their concerns. Make sure lines of communication remain open between all members of the party at all times.
- Use the information in this discussion and from regional avalanche forecasts to assess general conditions for the area where you will be.
- Talk to credible local experts such as guides, ski

patrollers, avalanche professionals, etc., to get a handle on local conditions.
- Watch for signs of instability while traveling, such as whumpfing, cracking, and avalanches on similar slopes. These observations give you clear signals that things are at a critical state. However in the case of a known or suspected PWL, the absence of whumpfing or avalanches should never be interpreted as evidence that a layer is not active.

PWLs are associated with high uncertainty and low confidence. With PWLs I don't ask, "Will it slide?" I do ask, "If it slides, what will happen to me or my partners?" This approach leads to greater margins for error, which in my opinion, is the best way to manage risk at times and places where confidence is low. With PWLs and deep-slab instability, I am extremely careful in choosing what terrain I use and how I manage my groups in that terrain. Here are some general tips for managing risk at any time and some specific ideas for dealing with the existing PWL problems identified in this discussion:
- Take a more conservative overall approach in areas where this year's PWLs are more prevalent *(see "Where is the problem?" on page 24)*.
- Use a slope-assessment tool or process like the Avaluator Obvious Clues™ card to assess each slope before you expose yourself to avalanche terrain (www.avalanche.ca/default.aspx?DN=673,428,4,558,3,Documents).
- Take a more conservative approach at elevations from just-above treeline to treeline and in open areas below treeline.
- Avoid travelling in avalanche terrain where the snowpack is shallow (less than 200cm on average).
- Avoid avalanche terrain where the snowpack depth is variable (shallow areas mixed with deep areas).
- Avoid slopes that have rocks and scattered trees sticking out of the snow.
- Avoid steep (steeper than a set of stairs in your house) unsupported terrain features especially if there is a pronounced convexity (roll).
- Eliminate or minimize exposure to terrain traps, such as:
  - ¤ Depressions
  - ¤ Gullies
  - ¤ Creekbeds
  - ¤ Sudden transitions from steep to flat (lakeshores, benches, roadcuts, etc.)
  - ¤ Slopes where an avalanche might carry you:
    - > Over a cliff
    - > Into trees
    - > Against obstructions such as rocks or boulders
- Stay on low-angle slopes that are less than 30° incline (less steep than a set of stairs in your house).
- Stay on simpler terrain (www.avalanche.ca/default.aspx?DN=599,428,4,558,3,Documents).
- Avoid avalanche start zones and tracks if possible.
- If you must travel in or through start zones or tracks, go one at a time from safe spot to safe spot.
- Spread out when travelling in or through avalanche runout zones.
- Regroup only in safe areas where avalanches will not start or run through/over:
  - ¤ High points
  - ¤ Ridges above start zones
  - ¤ Dense timber well away from the track or runout zone

References for further reading

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This avalanche (East Monitor, Utah, 2/11/07) broke out 2-3' deep and nearly 200 yards wide. We skied into the distance along the ridge to see how far the fracture propagated, but visibility was so bad we could not tell how wide it broke out. In a brief clearing, we could see a crown face on the other side of the bowl at least 3' deep, which was a quarter mile from where I initiated the original fracture. It could have run naturally before we arrived. *Photo ©2007 Bruce Tremper, www.brucetremper.com*

Firsthand Account of Avalanche Mechanics

Story by Bill Glude

A few years ago, I had a chance to make firsthand observations of the value of swimming versus protecting airspace when I was run over by a large slab. A fully-developed D3-4 size dry slab broke out 1m thick when it was triggered by a skier uphill of me; I'd conservatively estimate the speed at 40+ m/sec. It was on me at freeway speed, so fast that, as I stood knee deep in fluff on my snowboard, all I had time to do was flatten myself. I was as far up the opposite slope as I had been able to go, but the slide had not yet reacted to the upslope when it hit me.

I got an intimate tour of the dynamics of underside of the leading edge. I felt the powderblast go over me as I stayed safely prone in the snow for a moment, but then the plowing front arrived. I felt like I was about to be ripped apart by the incredible rate of acceleration as my feet flew over my head, and I went into a series of high velocity full-layout flips, rotating so fast that even retracting my outstretched arms was impossible. I would have liked to ball up but could do nothing at all during that phase of the flow.

It was decidedly non-laminar and primarily rotational, faster snow flowing over slower. Periodically during the turbulent rotations, large waves of snow landed on me, feeling like dump trucks unloading. Fortunately, the motion was rapid enough that none of the dump-truck loads of snow stayed on top of me for long.

The moment I felt the slide begin to slow and could finally move, I waited until my head was approaching the top of the rotation and made two full arm and leg strokes upward, retracting the still-attached snowboard and extending it as I stroked. The board was across the flow, toeside downhill, so it was angled to assist my climb, and I popped out on the surface in two strokes of about 0.7 to 1.0m vertical ascent each.

I did not have any sensation of moving to the surface by any mechanism other than my own effort. It felt like swimming to the surface after a long snorkeling dive or getting hammered by a big wave in surf; buoyancy or particle size sorting was just not happening fast enough to matter much. In this phase, the chunks were still bouncing enough to move through but had solidified just enough to give something to push against. That transition phase from flow to solid only lasted long enough for me to make my two strokes, plus possibly one more if I had needed it. Starting at the bottom of the flow, I do not believe I would have come anywhere near the surface if I had just waited for the particles to sort by size.

I broke the surface into fine laminar flow and braced in position as the 0.5 to 0.8m tail of the slide washed by, with my torso and head creating a sizable bow wave. It all passed and left me knee deep in snow and quite sore but otherwise unharmed. That night I felt like I had been wrestling a gorilla!

That's my anecdotal report on avalanche survival strategies, one of many pieces of the puzzle. The curse of being in this damn field is that every time I get caught I am so fascinated by making observations that I have to consciously remember to leave off with it and save myself! Fortunately it does not happen often.

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Up on the Rooftop

Top: "spatial variability"
Right: "bridging and lots of stuff"

Photos by Doug Richmond, along with the cryptic message that "one photo is worth a thousand words; here's two photos and a short caption for each."

GENDER HEURISTICS

continued from page 13

making process was conservative, the expert halo, scarcity, and commitment all contributed to a higher risk acceptance level than we realized at the time.

MIXED GENDER GROUPS:

Day Tour – Slot Couloir, Snoqualmie Pass, WA

This was a simple day trip – a group of friends and acquaintances looking to ski a great couloir. As the day unfolded, our group committed to skiing the couloir – and realized after doing so that the main hazard wasn't avalanche hazard, it was sliding hazard. This day was characterized by:

- Our group was assembled loosely: friends of friends came along for a chance to ski the couloir. As a result, skill levels of each group member were not clear.
- Some folks had skied it before, some had not: those who had skied it were anxious to show the others how great it was; those who hadn't skied it were anxious to do so!
- Members of the group who were better skiers went in first, assuming all would be well. The unknown members of the group then followed, and ended up being in way over their heads, at risk of falling and sliding the whole length of the couloir.

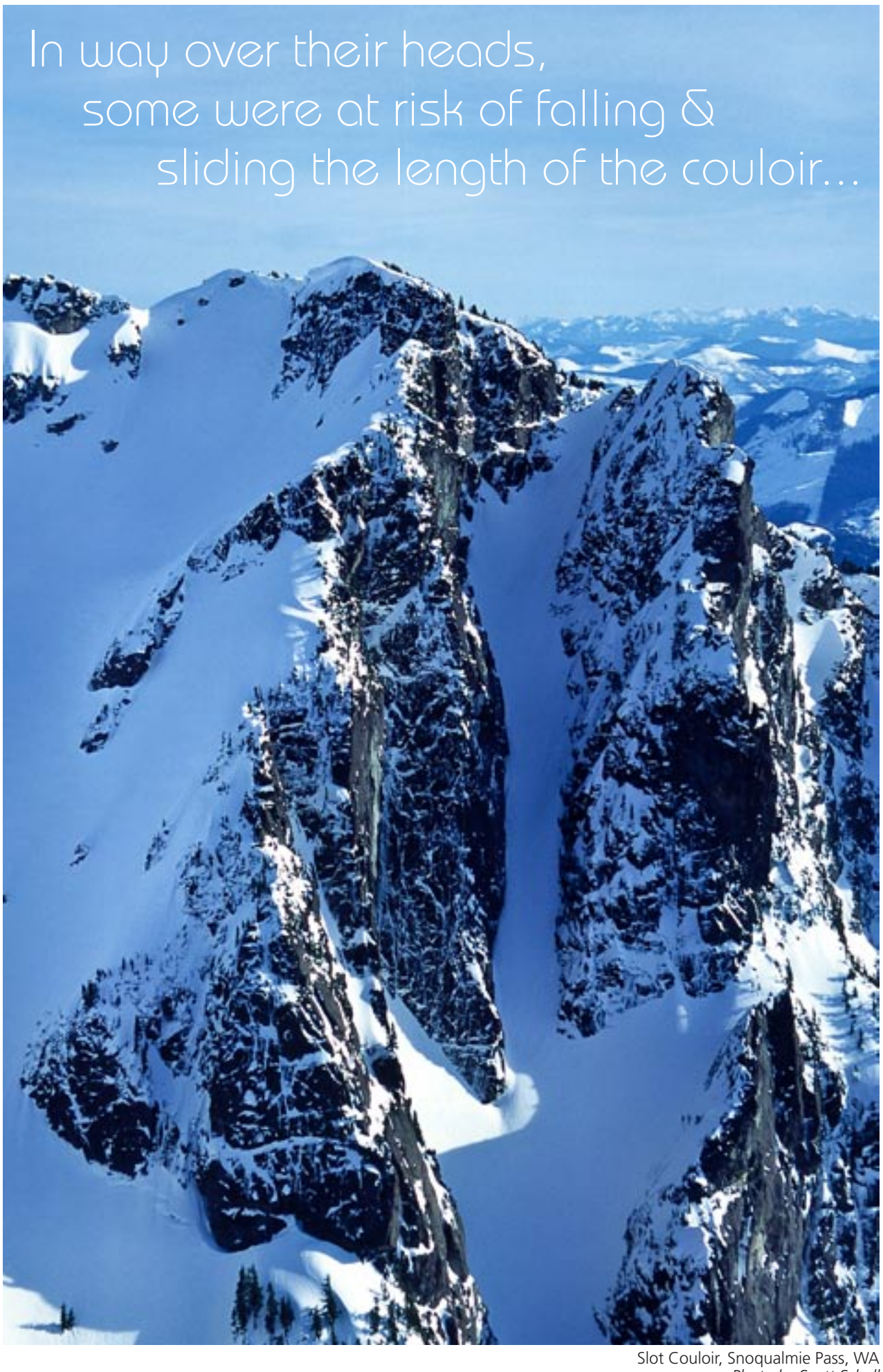
In this mixed group our communication was flawed, but why? Was I less likely to talk to the folks I didn't know because I am female, or because I didn't want to bruise any egos? Was it both, or neither? Again, the waters get muddy fast. But looking at the day from the heuristic perspective offers good insight to the dynamic. Each group member's communication was limited by the desire to have a good time and to be accepted by the group, and the scarcity of a chance to ski the couloir was driving us all to commit to doing so. The expert halo may have been present that day as well: I was an off-duty guide, trained to take responsibility for groups, but not acting in that role on this day.

As I compare these experiences to the original list of perceptions about men and women, some of them are reinforced, and some of them are contradicted. Yet as I go through these stories from the perspective of the heuristic traps, they are all reinforced. What is the take-away, then?

Until science can prove things – definitively – one way or the other, I'm going to rely on what I know about human factors and be very wary of what I think I know about men and women. Because the rules for gender dynamics are not clear – and even if they were, there will be an exception to any rule. Better to think: how do your own perceptions stem from your own experiences? How might they be shaped by them, and how might they be leading you astray? What might your experience level, your training, and your background do to shape your personal mindset, and therefore your decision-making dynamic?

Tune your antennae to what effects gender might be having on any group's dynamic, but make your own observations about how experience levels, age, circumstance, and personality are shaping each interaction. In dealing with human factors related to or exacerbated by gender, don't let your perceptions or stereotypes be a "gender heuristic" trap.

Margaret Wheeler is a professional mountain guide, and the author of the new book from the Mountaineers, Backcountry Skiing: Skills for Ski Touring and Ski Mountaineering. *She is based in the Pacific Northwest, and can be reached at marg@proguiding.com.*



Slot Couloir, Snoqualmie Pass, WA
Photo by Scott Schell

Was I less likely to speak up because I am female or because I didn't want to bruise egos?

Skinning towards high camp below the summit of Hanuman Tibba, Himachal Pradesh, India.
Photo by Margaret Wheeler

Left: Margaret Wheeler gives a PowerPoint presentation of this article at the Northwest Snow and Avalanche Seminar in November, 2007. *Photo by Don Svela*