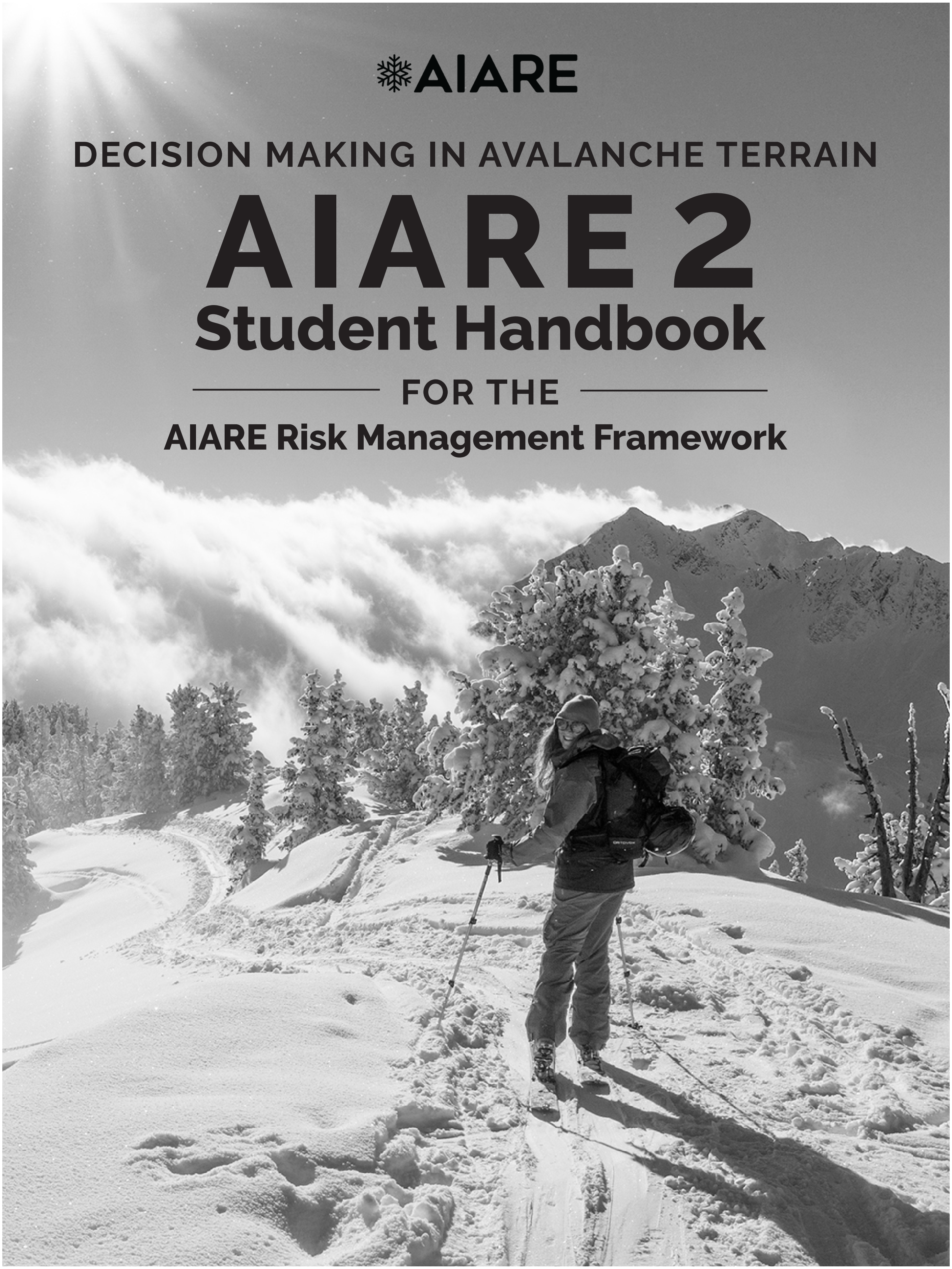
AIARE

DECISION MAKING IN AVALANCHE TERRAIN

AIARE 2
Student Handbook

FOR THE

AIARE Risk Management Framework



The Student Handbook for The AIARE Risk Management Framework

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AIARE
Avalanche Research + Education

AIARE's mission is to "Save lives through avalanche education."

AIARE is a registered 501(c)(3) nonprofit educational organization, which serves as a focal point for the gathering, development, and dissemination of materials, ideas, and curriculum for avalanche educators in the U.S. and select locations across the world. There are currently over 110 course providers and 450 instructors representing AIARE. This handbook was created with input from this community. AIARE is comprised of an advisory Education Committee and professional staff charged with assimilating ideas, materials, and concepts from AIARE members and the avalanche industry to develop teaching tools and materials.

AIARE does not teach, oversee or conduct AIARE 1, AIARE 2 or Avalanche Rescue Courses. It does provide course curriculum and materials to avalanche course providers and qualified instructors to teach AIARE 1, AIARE 2, and Avalanche Rescue courses. All organizations and individuals conducting AIARE act independently of AIARE and are solely responsible for conducting the courses.

Importantly, in choosing to voluntarily engage in avalanche courses or program that operate in the backcountry and/or wilderness settings, individuals must understand that they accept and assume the inherent risks of these activities.

Table of Contents

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INTRODUCTION

The AIARE Risk Management Framework is a step-by-step method travelers use to manage their risk when traveling in the backcountry. This companion manual provides detailed instructions on how to use *The AIARE Risk Management Framework* and the prompts and checklists outlined in *The AIARE Fieldbook.*

The manual is organized to follow the sequence of the steps of *The AIARE Framework* in order to be a useful and easily available reference during your course. Keep this manual handy for reference after your course as you continue to build your decision-making skills and gain proficiency with *The AIARE Framework.*

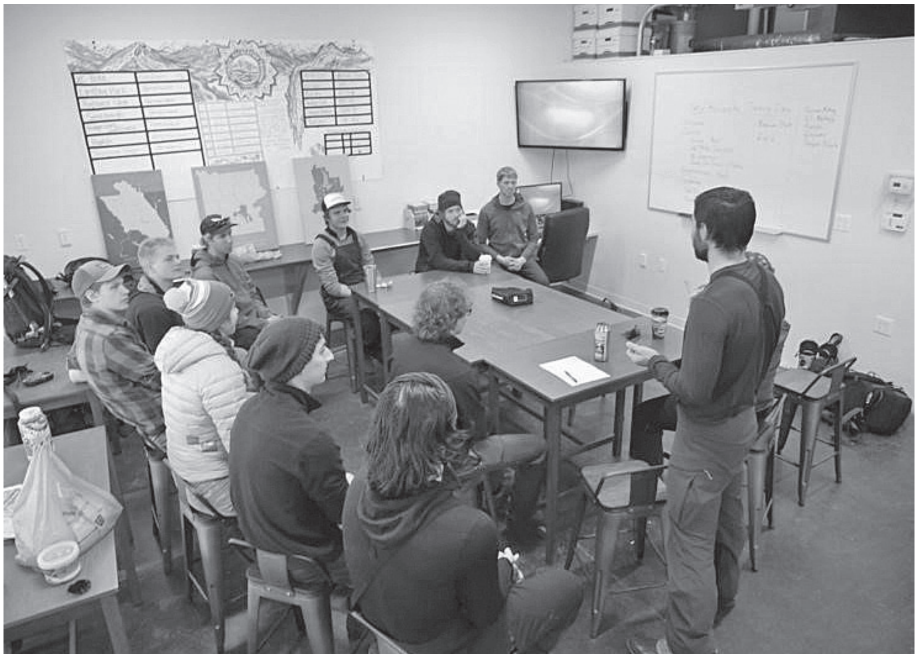
MANAGE YOUR AVALANCHE RISK

Grant Gunderson

Consider your motivation to access backcountry winter terrain. Is it to glide up the skin track and reach untouched powder skiing? To snowshoe throughout the winter on your favorite summer trails? To head deep into mountainous terrain on a snowmobile? Or to leave the lift lines behind and exit the ski area from a backcountry gate?

There are endless recreational opportunities in the backcountry, but regardless of your mode of travel, these pursuits all involve risk.

Some risks, such as the cold and the complexities of backcountry navigation, are easier to understand and manage. Other risks, like those posed by avalanches, are much more complex. Additionally, the consequences of involvement with an avalanche can be deadly. Because the stakes can be so high, staying safe in the backcountry requires humility, methodical assessments, unbiased decision making, and a lifelong dedication to learning about avalanche terrain and the conditions that cause an unstable snowpack.



Chris Pruden

The first step for both you and the people you travel with into the backcountry is to begin your avalanche education. The AIARE program *Decision Making in Avalanche Terrain* is an introduction to a mentored practice that engages backcountry travelers in the lifelong learning process that is an essential part of backcountry recreation. *Decision Making in Avalanche Terrain* introduces backcountry travelers to a repeatable risk management process, *The AIARE Risk Management Framework* or *The AIARE Framework* for short. *The AIARE Framework* helps a team work together to manage avalanche risk and make decisions in avalanche terrain. This program consists of three courses:

AIARE 1

The objective of the AIARE 1 is to learn how to recognize risk in avalanche terrain. This three- day course provides an introduction to using *The AIARE Framework* to manage risk while traveling in avalanche terrain.

AVALANCHE RESCUE

Avalanche Rescue is a one-day intensive course to learn how to manage a small-team avalanche rescue. This course also serves as a regular refresher opportunity to practice seldom-used skills.

AIARE 2

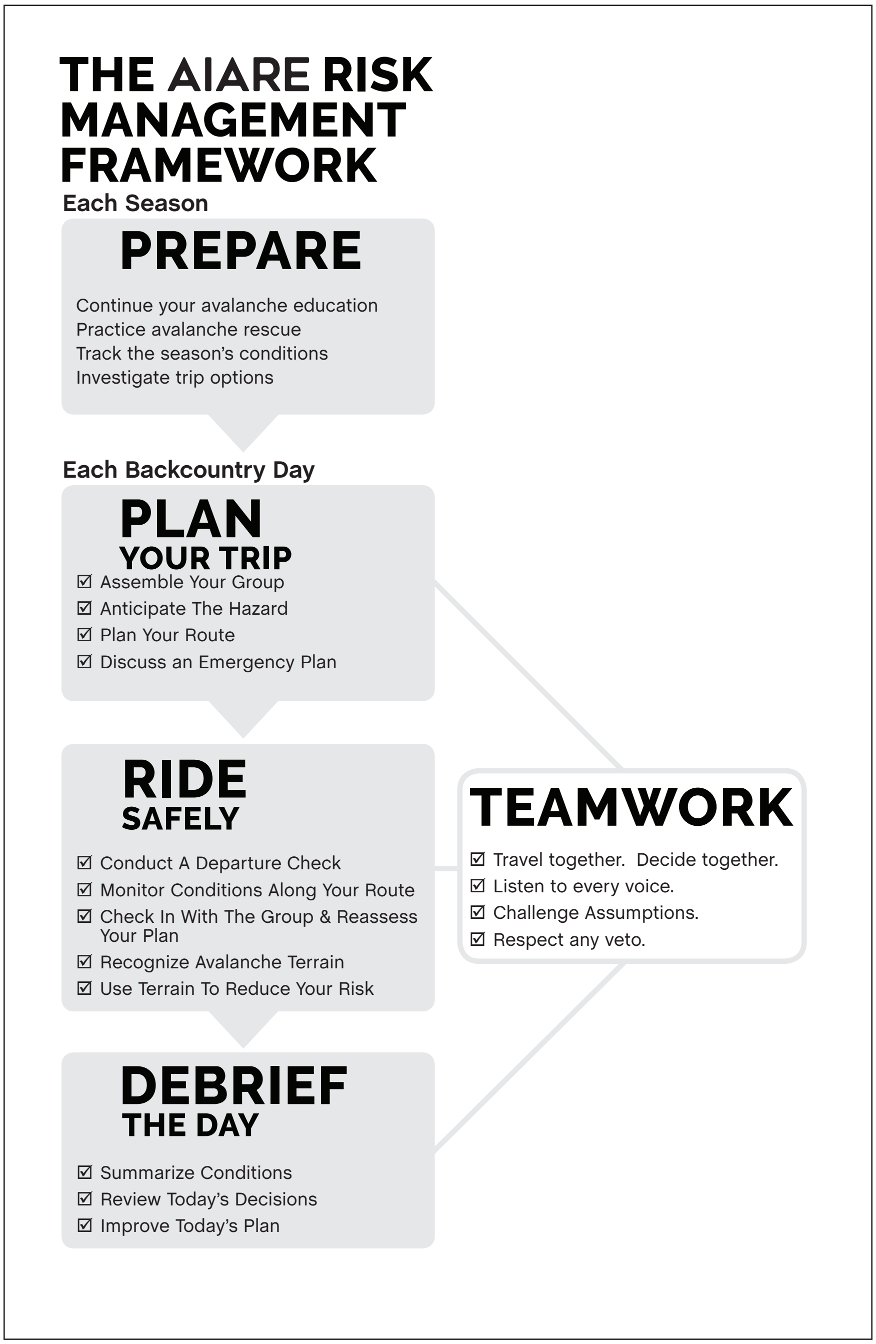
The objective of the AIARE 2 is to learn how to manage uncertainty in avalanche terrain. This three-day course is for those who have taken an AIARE 1, Avalanche Rescue, and have had at least one year of backcountry travel experience. The AIARE 2 provides backcountry coached mentorship in the application of *The AIARE Framework* to new terrain and situations.

Chris Pruden

THE AIARE FRAMEWORK

The AIARE Framework is a risk management tool that combines international standards for managing risk[1] with checklist practices gleaned from fields such as medicine and aviation, similarly complex fields with potential life or death consequences. Humans are humans and often miss steps or behave "irrationally" when trying to make decisions in complex and uncertain situations. Researchers have found that using checklists can significantly reduce the number of accidents by ensuring no steps are missed[2]. *The AIARE Framework* is designed to help recreational travelers develop a lifelong practice of gaining experience managing risk in avalanche terrain.

The AIARE Framework is comprised of five important pieces. Each of these components is an essential piece of the puzzle, and a strong understanding and execution of each is an important part of staying safe in backcountry terrain.



PREPARE

Good decisions start and end with your motivation to PREPARE for each winter season prior to backcountry travel. Engage in a lifelong process of acquiring knowledge and skills through many forms of education. *Practice Avalanche Rescue* to ensure you can respond in an emergency. *Track The Season's Conditions* to identify trends. *Explore Trip Options* suitable for different experience levels or different conditions.

PLAN YOUR TRIP

Each backcountry day, use the PLAN YOUR TRIP checklist with your team to *Assemble Your Group*, use expert advice to *Anticipate The Hazard*, *Plan A Route* appropriate for the conditions, and *Discuss An Emergency Plan* for if something goes wrong.

TEAMWORK

Decisions made with consensus are the only way the rest of this process works. You will see that TEAMWORK isn't the first, last, or middle part of the process. Instead, teamwork is a foundational part of the whole *AIARE Framework*. Just checking the boxes of the checklist is not the goal; instead, the goal is working together as a team and embracing a culture of engagement from every member. TEAMWORK establishes the rules of engagement for every backcountry trip. Choosing a cohesive team is an imperative part of keeping yourself—and the people around you—safe. Backcountry partners share wisdom, challenge assumptions, and decide by consensus.

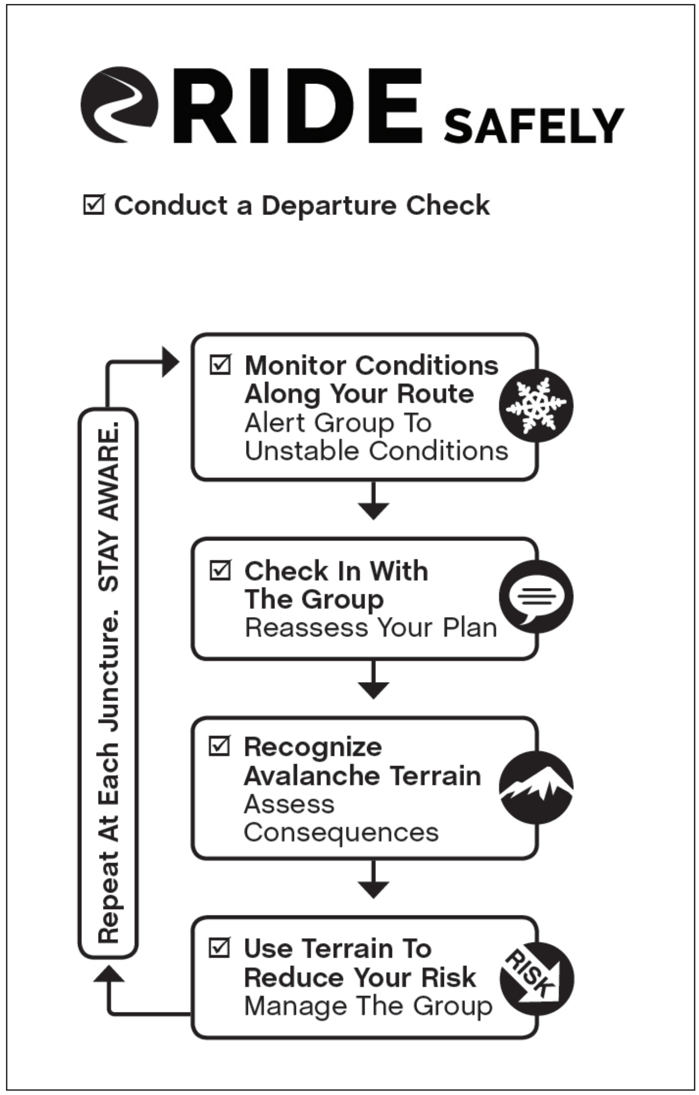
1 See ISO 31000:2018, Risk management – Guidelines: https://www.iso.org/iso-31000-risk-management.html

2 See for example Atul Gawande's *The Checklist Manifesto*

RIDE SAFELY

Enter the backcountry with a well thought out plan in hand and use the RIDE SAFELY checklist, shown here and on each page of *The Fieldbook*, to maintain situational awareness and communicate with your team by asking important questions like: Are we on track? Is anything different than we expected? How best should we manage this terrain?

The checklist prompts these important discussions among teammates that will help you decide not only where to go, but also how to go as you travel in avalanche terrain, which is a key to reducing accidents.



DEBRIEF THE DAY

At the end of every day, there are lessons to learn both from what we did right and what we think we could do better. Nature is notorious for keeping quiet most of the time and providing unforgiving feedback when we want it least. If you fall into a bad habit, debriefing the day can help you recognize and change that habit while you still can. During DEBRIEF THE DAY, the group will discuss what it saw, how it was different from what was predicted and why, when it was most at risk, and what can be done to improve the plan.

The components of *The AIARE Framework* comprise a fairly straightforward checklist that you will learn how to use during the AIARE 1 course and apply in more complex situations on an AIARE 2 course. While the checklist itself may be straightforward, learning the nuances of applying *The AIARE Framework* is a lifelong endeavor. Use this manual as a reference to help you learn how to use T*he AIARE Framework* and your Fieldbook. Continue to refer to this manual as you apply *The AIARE Framework* and gain more experience as a seasoned backcountry traveler.

PART 1:
Each Season

Grant Gunderson

Mike Manuel

A lot of preparation throughout the season goes into providing the foundational knowledge, skills, and experience to help you manage risk on the days you travel in the backcountry. Managing avalanche risk doesn't only happen on the days when you are traveling in the backcountry. Preparation for backcountry travel is a lifelong commitment.

The AIARE Risk Management Framework includes four areas of ongoing and seasonal preparation as a key component of daily risk management: *Continue Your Avalanche Education*, *Practice Avalanche Rescue*, *Track the Season's Conditions*, and *Investigate Trip Options.*

In Part 1, you will learn how to become a lifelong learner when it comes to avalanche safety. It is important to *Continue Your Avalanche Education* throughout the winter and from season to season. You do this by taking more classes, practicing your skills on your own and with your backcountry partners, and seeking out mentors. This part also provides a comprehensive avalanche rescue reference so you can *Practice Avalanche Rescue.* It is imperative to *Track the Season's Conditions* as it progresses to understand how the snowpack is developing. Lastly, you *Investigate Trip Options* by learning how to build a list of potential trips so you can make an educated decision on which routes and objectives are appropriate given the day's weather, snowpack, and other factors such as the group with whom you are traveling.

CHAPTER 1:
Prepare

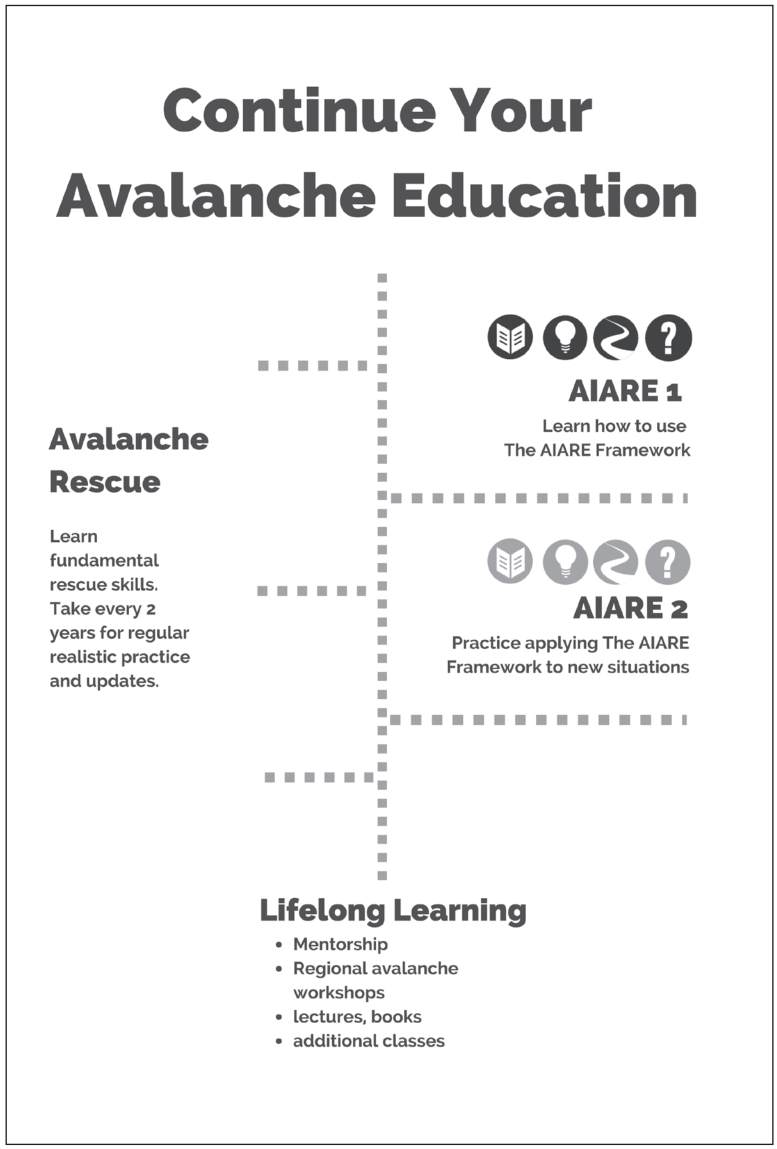
CONTINUE YOUR AVALANCHE EDUCATION

Avalanches are complex natural hazards that make a lifetime of discovery, learning, and practice necessary for any winter backcountry user. The coaching and instruction you receive in a recreational avalanche course will enable you to improve your decision making when you are in or near avalanche terrain, but it is up to you to apply what you learn in class to the real world, and to keep your skills sharp.

As mentioned in the introduction of this manual, the AIARE 1 introduces *The AIARE Framework* to help participants work with a team to make better decisions in the backcountry and manage avalanche risk. The Avalanche Rescue Course gives participants the tools to execute a fast and effective rescue in the event of an incident as well as how to practice those rescue skills between trips.

After participants have completed the AIARE 1 and Avalanche Rescue, they can continue with the AIARE 2. Typically, participants wait a season or two before doing this, as the extra time and mileage in the field will give them enough experience to apply *The AIARE Framework* to new situations and conditions. Participants have the opportunity on an AIARE 2 to receive direct coaching and mentoring from an Instructor. The AIARE 2 builds upon the skills developed in the AIARE 1 and applies them in more complex situations that include unfamiliar terrain, travel partners, snowpack conditions, and/or weather events.

During all of these courses, the Instructors will manage risks and include participants in discussions of how to use the *Fieldbook* and apply it in the field. Once you complete the courses, however, your safety in the mountains lies squarely on your shoulders.



The three courses offered by AIARE are all introductions to the process and craft. It's up to you to hone your skills and continue learning. Your safety in and around avalanche terrain depends on your commitment to practice and feel prepared each time you leave the trailhead or backcountry gate.

Being a backcountry winter traveler also means you are a lifelong student of the mountains and group dynamics. The completion of the *Decision Making in Avalanche Terrain* program is just the first step in preparing yourself for adventures in avalanche terrain. Seek out mentoring opportunities with more experienced friends or hire a professional. Regional snow and avalanche workshops hosted by your local avalanche center or community groups are excellent ways to keep abreast of current best practices and new research regarding decision making and group dynamics. Subscribe to The Avalanche Review published by the American Avalanche Association (A3). Many providers offer advanced travel courses to help you apply and refine traveling and decision-making skills. A myriad of opportunities exist, but it's up to the individual to seek them out.

PRACTICE AVALANCHE RESCUE

Grant Gunderson

Getting caught in an avalanche can be violent, gruesome, and heartbreaking. On average, 53% of fully buried victims die. The chance of surviving a complete burial decreases significantly after 10 minutes. In North America, the chance of survival in an avalanche is further reduced by the increased incidence of major trauma. In fact, one quarter of avalanche fatalities are due to traumatic injuries, not from asphyxiation.[3] The odds aren't good. The best plan is to do everything possible to avoid involvement with an avalanche.

Using *The AIARE Framework* can help your group make good decisions in avalanche terrain and avoid involvement with an avalanche. But traveling in the backcountry is not without risk. Groups can make mistakes in judgment or decision making. If someone from your party is buried in an avalanche, the victim has only minutes before they'll succumb to asphyxia. This means outside help is not an option and the buried partner is relying on you for rescue.

3 From 25 years of Canadian and Swiss statistics on people completely buried in an avalanche. Haegeli, P., M. Falk, H. Brugger, H.-J. Etter, and J. Boyd. "Comparison of Avalanche Survival Patterns in Canada and Switzerland." CMAJ: Canadian Medical Association Journal 183, no. 7 (2011): 789-95. doi:10.1503/cmaj.101435

If the victim is fully buried, consider the following. A three-foot deep burial (which is less than average) requires moving at least 2,500 pounds of snow. A six-foot deep burial requires moving at least 10,000 pounds of snow. Responders have minutes to get the job done, and still have the confounding factors of keeping the rescuers safe, the challenges of communication and access to the debris (with people potentially spread across a mountainside), understanding the technical detail of the transceiver, and the overwhelming stress of having a partner dying beneath the snow. If it is not clear yet, avalanche rescue is not something you want to ever have to do.

Practicing avalanche rescue is rehearsing for an unlikely but possible emergency situation. Learn how to best conduct an avalanche rescue by taking an Avalanche Rescue Course. To keep your skills sharp and make sure you are reinforcing the correct habits, frequently review this avalanche rescue section, practice throughout the season, and regularly retake the Avalanche Rescue Course to gain experience working with others in realistic scenarios and receive coaching from experienced professionals.


Mike Manuel

There are three areas to cover every time you practice avalanche rescue:

- How to respond if caught in an avalanche
- How to organize avalanche rescue with teammates
- How to care for and evacuate an injured party from the backcountry

It is also important to evaluate your avalanche rescue skills to make sure that you are reinforcing correct habits and continuing to improve skills you may infrequently use. You want to be able to employ your skills efficiently and as quickly as possible. As noted earlier, the chance of survival decreases significantly after 10 minutes. Timing your practice gives you an indication of how effective your skills would be in a real-life response situation. Practice and time your skills to ensure you are able to recover a target buried at least three feet deep in 10 minutes or less.

Grant Gunderson

The bottom line is that avalanche rescue is a daunting and challenging task. The upside is that training can improve response outcomes. As an example, the highly-trained guides of heli-ski company Canadian Mountain Holidays have an average response time of 8 minutes. That skill and efficiency comes from regular practice and training.

HOW TO RESPOND IF CAUGHT IN AN AVALANCHE

One of the most important aspects of emergency rescue scenarios is taking care of your own safety first. You are no good to the rescue effort if you are also a victim. Prepare for the worst and know what to do if you are the victim in an avalanche. If you notice the slope beginning to slide, get to safety if possible and then look for the rest of your party.

If you feel yourself getting caught:

- Yell! Call out for attention.
- Your backcountry partners should always have eyes on the person exposed to the avalanche hazard. If your team can establish a last point seen, it will improve your chances of being found quickly.
- Deploy your airbag.
- Don't hesitate to do this. The airbag will not affect your ability to yell or exit to the side of the avalanche.
- Try to exit to the side of the avalanche.
- Slide or roll towards the sides of the avalanche. Snow moves more slowly at the edges of the avalanche and you increase your chances of not being carried as far.
- Try to arrest as you're caught.
- If you fail to escape to the side of an avalanche, grab bushes or trees, or arrest yourself in the bed surface in an effort to slow yourself down. This might allow the moving snow to flow around you and leave you high on the slope.

As the momentum of the avalanche accelerates:

- Discard your equipment.
- Release your skis or snowboard if you can, let go of your poles, and continue to fight and thrash your way to the side of the avalanche.
- Protect yourself.
- Keep your backpack on; it protects your spine and you may need the gear inside during the rescue. If there is no hope of getting to the side of the avalanche, curl into a ball and keep your arms and legs tucked in to protect yourself. Keep your hands in front of your face to protect your airway.

As the snow slows:

- Fight to get to the surface.
- Thrust or kick towards the surface. Your chances of survival increase if you are only partially buried. Try to clear an air pocket in front of your face.
- Try to dig out.
- When the snow stops moving, try to dig yourself out if possible. If you're fully buried and can't move, try to remain calm and slow your breathing.
- Yell to rescuers if you can hear them.
- Remain calm.
- Whatever happens, try to remain calm. As difficult as it sounds, try to slow your breathing to conserve the air in your air pocket.

HOW TO ORGANIZE AVALANCHE RESCUE WITH TEAMMATES

Have the Right Gear and Know How to Use it

The first step of any rescue response is to have the proper equipment and to know how to use it. The basic required equipment for each backcountry traveler includes an avalanche transceiver, probe, shovel, and a communication device with which to contact outside help. These essential tools facilitate the search and rescue of avalanche victims. You should also carry your *AIARE Fieldbook* or *AIARE Rescue Quick Reference Card* with you at all times and use it throughout the rescue process—both when practicing and during an emergency.

Your essential equipment—transceiver, shovel, and probe—can save your life or your group member's life, so it must be in good condition. Whether you own or rent one, your transceiver should be a digital model with three antennas. Purchasing a used transceiver is not recommended, as they are fragile electronic devices requiring care and maintenance. Know the history of your own device: how old it is, if anyone has borrowed it, and when the firmware was last updated. Refer to the user manual for details specific to your transceiver and don't forget to check the battery level each time you enter the backcountry.

Know how to properly wear your transceiver. Keep in mind electronic devices such as cell phones, cameras, radios, and even battery-heated electric gloves can impair your transceiver's ability to transmit or search. Keep these devices at least 30 cm (12 in) away from your transceiver while traveling in the backcountry. Turn off all electronic devices, including phones, digital cameras, and snowmobiles prior to beginning a search.

Additional safety equipment includes airbag packs, Avalung® equipment, and gear with RECCO® technology. An avalanche airbag is designed to reduce the likelihood of burial. According to Swiss statistics from accidents between 1981 and 1998, the most effective means of preventing fatality in an avalanche accident is to avoid complete burial. This study showed that the overall buried victim mortality rate is 52%, but the partly buried victim morality rate is only 4.2%.[4] Avalanche airbag packs and vests are designed to prevent or decrease burial depth, potentially decreasing the chance of mortality. A secondary, but still important, factor to note is that avalanche airbag packs may reduce the chance of trauma. Depending upon the location of the inflated airbag (back, head/neck, or chest) certain types of impacts may be lessened. A helmet and body armor may work with an avalanche airbag to further reduce trauma. An important consideration is that an avalanche airbag pack is not guaranteed to prevent burial, so a transceiver, probe, shovel, and partner are still considered essential equipment regardless of whether an airbag is used.

An Avalung® is designed to help a fully buried victim maintain an airway beneath snow and slow the accumulation of carbon dioxide in the victim's breathing space. Gear and clothing equipped with a RECCO® reflector can make a buried victim easier to find by professionals with the necessary search equipment. The reflector is not a substitute for an avalanche transceiver, probe, and shovel. When someone is buried, it is the combination of the transceiver and reflector that give buried victims the best opportunity to be found faster, whether in a ski area or far in the backcountry.

Adequate clothing and extra insulation, first aid, and an emergency evacuation sled increase the chance of surviving injury and facilitating first aid and evacuation once the recovery has happened.

Conduct a transceiver function check every time prior to entering the backcountry. Assemble your probe and shovel before every trip to ensure everything is working and in order. Each season deploy and repack your airbag according to the manufacturer's recommendation to verify it is functioning properly.

4 Brugger, H., Falk, M. "Analysis of Avalanche Safety Equipment for Backcountry Skiers." Translation of a paper from JAHRBUCH (2002). Published by the Austrian Association for Alpine and High Altitude Medicine. Retrieved from https://s3.amazonaws.com/BackcountryAccess/content/papers/brugger_falk_report_2002.pdf

Small-team avalanche rescue

Small-team avalanche rescue isn't simply practicing with your transceiver, probe, and shovel. It is important to learn not only how to use your equipment, but also how to execute all the components of a rescue under pressure, including taking in the overall scene, making a plan for how to allocate resources, and considering how you will connect to outside help.

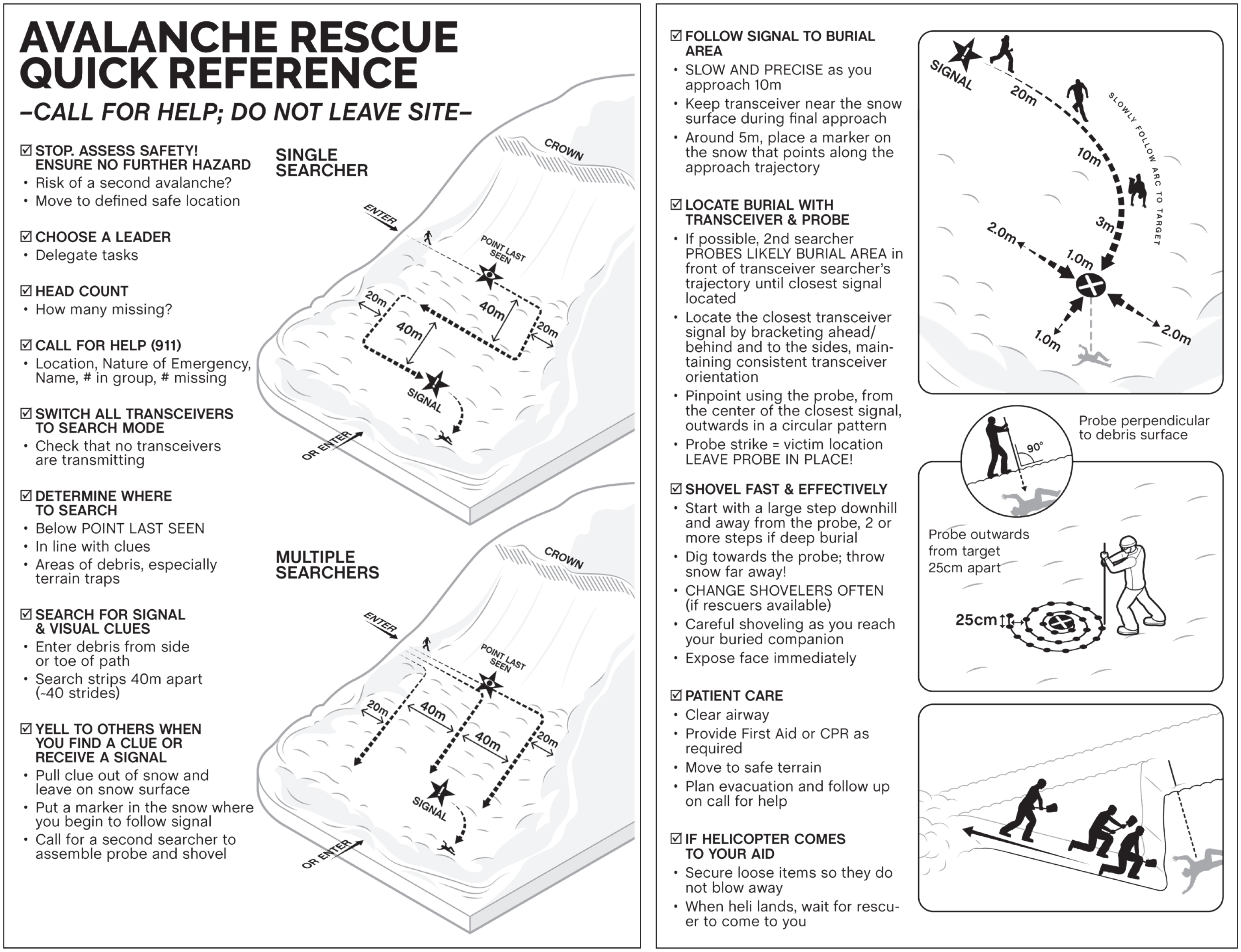


FIGURE 1: AIARE AVALANCHE RESCUE QUICK REFERENCE

There is too much happening in the moment to try to remember all the things you need to do. Always use the *Avalanche Rescue Quick Reference* (Figure 1 and located inside the back cover of your *Fieldbook*) when practicing rescue just as you would in the field.

The process for small-team avalanche rescue should be executed the same way every time. It is important for each backcountry team member to understand how to execute each of the following steps with confidence.

☐ STOP. ASSESS SAFETY! ENSURE NO FURTHER HAZARD

When the emergency first occurs, take a moment to assess the scene. Consider the terrain and resources at hand and decide how your party will best be able effect a fast rescue and contact outside resources.

Before rushing to act, consult with the team to evaluate any remaining avalanche hazard. Is there still unstable snow above the crown of the avalanche? Are there cliffs or crevasses below the team? Your team should also determine and verbalize where it is safe for rescuers and survivors to enter the avalanche area and begin the search.

☐ CHOOSE A LEADER

Designating a leader helps prioritize tasks and minimize confusion. A leader's role is to delegate duties, consult the checklist while others execute tasks, and take a bird's eye view of the overall process.

☐ HEAD COUNT

Determine how many people are missing or unaccounted for and communicate that to the entire rescue party. This will cut down on confusion, particularly when other rescuers arrive.

If there are multiple victims, determine how you will use your resources. The harsh reality is that the team should prioritize the closest buried victim to make at least one rescue. Don't attempt to save everyone and fail to save anyone.

When traveling in avalanche terrain, only one person should be exposed to hazardous areas at a time to decrease the likelihood of a multiple-victim avalanche. In the unlikely event that multiple people are caught, however, concentrate your rescue efforts on the closest buried victim and then move on to the next one.

☐ CALL FOR HELP

Do not leave the site. While you are going to need help from outside resources, you are the first response and the best hope for rescuing your partner.

Determine how best to call for help (to other backcountry travelers, to 911, with a satellite device, or via VHF radio) based on your location. The rescue leader needs to make sure a member of the group immediately checks for a cell signal. Call for help via phone or radio before descending a slope, as you could lose the signal. Whatever communication device you have, take stock of the situation, make a note of your location, the nature of your emergency, the number in your group, and the number of people missing, injured, or buried. Take a moment to think about what you're going to say before calling or radioing for help. Speak clearly and communicate your information as soon as you have contact. You may be cut off or lose battery power, so make sure to explain you have an avalanche and/or medical emergency and your location.

☐ SWITCH ALL TRANSCEIVERS TO SEARCH MODE

The rescue leader or someone tasked with the job should visually verify all rescuers switch their transceivers to search mode. A panicked rescuer who leaves their transceiver in transmit can confuse a search and cost the team valuable minutes. If you are traveling with a new or inexperienced team member, it's worth double-checking their transceiver for them. The rescue leader should remind searchers to turn off cell phones, cameras, radios, and any other electronic devices (including electric gloves).

☐ DETERMINE WHERE TO SEARCH

The rescue leader should determine where the buried victim(s) were last seen. The search starts from that Point down the avalanche path. Note any visual clues of where the victims might be and modify your search based on what you can see and common sense. The leader should communicate a search strategy based on resources, number of burials, and terrain features. Searchers should be sure to cover terrain traps, including piles of debris and the areas uphill of trees or rocks.

☐ SEARCH FOR SIGNAL AND VISUAL CLUES

Rescuers should enter debris from the side or bottom of the avalanche to minimize exposure. The leader or whoever is in charge of the transceiver search must make sure the team searches methodically in 40m (130ft) wide search strips. See the diagrams in Figure 2, noticing the different search patterns for a lone searcher versus multiple searchers. Rescuers should clearly communicate if they see visual clues (poles, backpacks, gloves, or even a hand or ski sticking out of the snow).

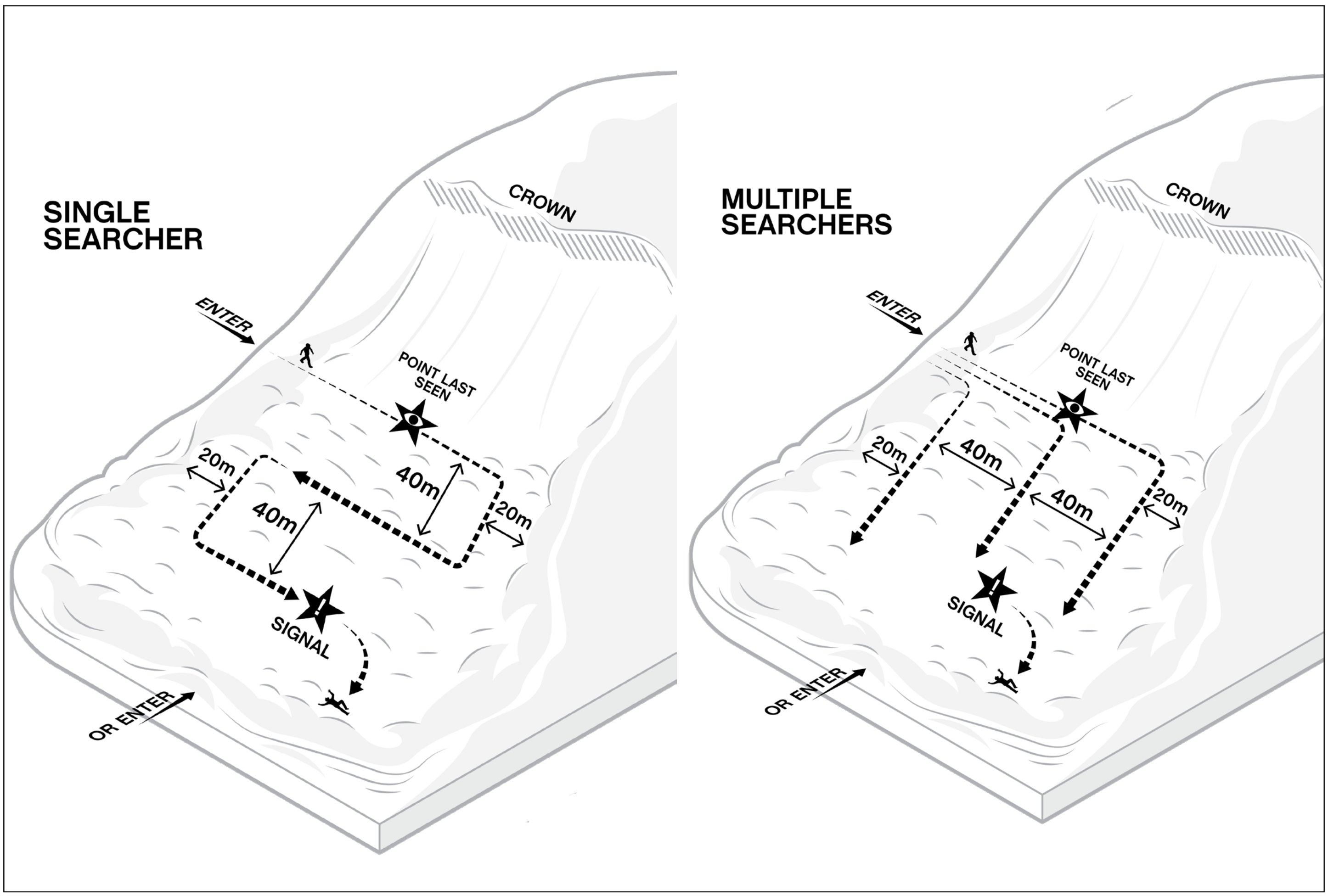


FIGURE 2: SINGLE AND MULTIPLE SIGNAL SEARCH PATTERNS

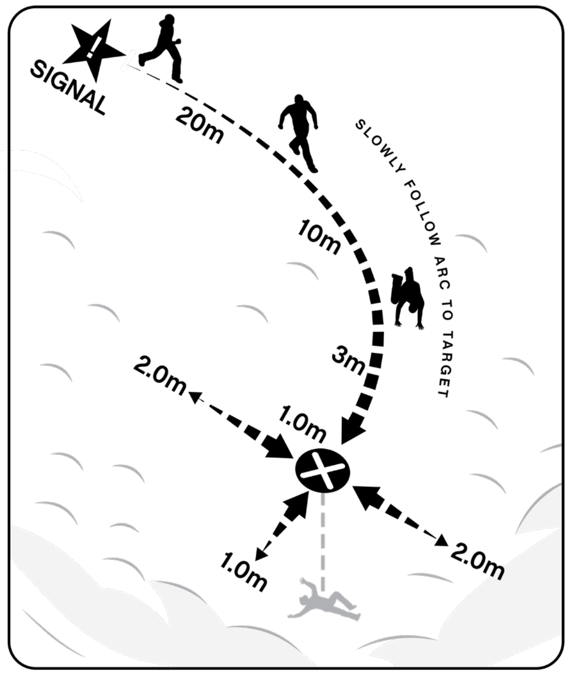
PREPARE

Practice Avalanche Rescue

☐ YELL TO OTHERS WHEN YOU FIND A CLUE OR RECEIVE A SIGNAL

Avoid superfluous talk or shouting, but when you see or find a visual clue, and/or get a regular signal on their transceiver, yell to the team and let them know. Physical clues should be pulled out of the snow and left on the surface. The first rescuer to receive a regular signal should put a marker of some sort (a ski pole is perfect) in the snow to indicate where the signal search began. Once a rescuer is following a transceiver signal, they should yell for others to assemble shovels and a probe.

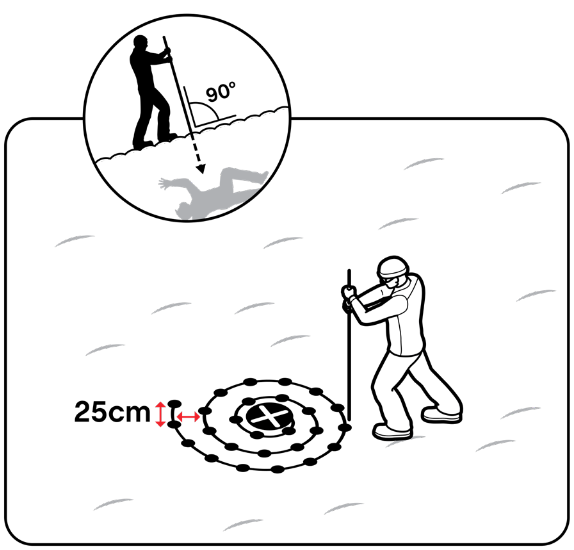
☐ FOLLOW THE TRANSCEIVER SIGNAL TO THE BURIAL AREA



Rescuers should move quickly, following their transceiver's arrow indications and watching the distance units decrease steadily until it drops below 10. Under 10, the rescuers should slow down and check their incoming paths towards the victim. Usually the incoming line will be a curved arc, based upon how the transceiver searches. Occasionally the line may be straighter depending on how the victim is oriented.

When the units drop below 5, the searcher should step out of their skis, snowboard, or snowshoes, leaving them directly in line with their final trajectory, as a physical marker that points towards the victims location. If resources allow for someone to probe ahead of the transceiver search, the rescuer with the transceiver should direct the rescuer probing. The searcher's transceiver should remain along the snow surface and oriented in the same direction for the remainder of the search. Rotating it will change the distance readings and confuse the search.

☐ LOCATE BURIAL WITH TRANSCEIVER AND PROBE

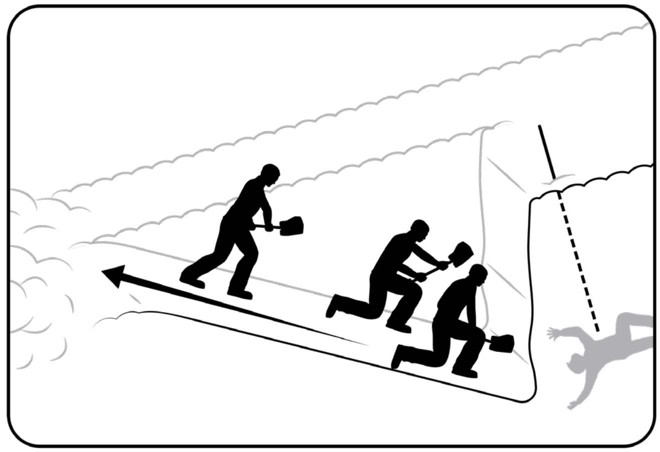


The transceiver searcher moves along the snow surface until their numbers begin to go up. At this point, mark the snow and without rotating or turning their transceiver, move backwards along the same line until the numbers go up again. At this point, the rescuer marks the point at which the transceiver displayed the lowest distance. Then, assemble the probe and begin probing in an outward spiral at 25cm (10in) intervals.

When multiple rescuers are present, the person who isn't conducting a transceiver search can assemble their probe and shovel. Once the transceiver searcher is slowing down on "final approach," the prober can get ahead of that person along the final approach trajectory and begin probing ahead of the transceiver searcher. This is called "pinpointing on a line." A well-practiced team can often get a probe strike in this way, saving valuable seconds in the rescue.

When you strike the victim with your probe, leave it in the snow and begin shoveling.

☐ SHOVEL FAST AND EFFECTIVELY



If a larger rescue team is on hand, other rescuers should assemble their shovels as the transceiver searcher and prober finish their tasks. Do not leave skis, packs, or other equipment downhill of the probe—these items will be buried and lost when the shoveling begins, which will only create more problems for the team as the rescue continues.

If the probe strike is less than 1m (3ft) deep, shovelers take one step downhill and begin digging towards the victim. If the victim is buried deeper than 1m, shovelers take two steps downhill and dig straight down and then inwards towards the victim. With three or more shovelers, two should be in the front, with additional shovelers moving snow downhill.

Shoveling as a team saves energy and time. The team should rotate out the two primary shovelers in front at 75-90 second intervals. Shovelers in the rear may choose to convert their shovels into hoe mode, if applicable. This speeds up clearing shoveled snow. As soon as rescuers reach the victim, care should be given to not injure the victim with shovels, and the victim's airway should be cleared immediately.

☐ PATIENT CARE

The patient's airway takes precedence over other issues. As soon as snow is cleared from the victim's face and their airway cleared, rescuers with first aid or medical training should check the patient, providing first aid and CPR as necessary. The victim will likely need medical attention for serious injuries sustained in the avalanche. If in exposed terrain, the team should move the patient to a safe zone, away from avalanche and weather hazards. Meanwhile, the rescue leader should plan an evacuation and coordinate with outside resources if possible. If you want to be fully prepared for an injury in the backcountry, consider investing in a commercial rescue sled or learning how to build a stretcher out of ski equipment.

☐ IF A HELICOPTER COMES TO YOUR AID

The team should prepare a landing zone, if possible, by removing any loose debris and instructing team members to secure personal packs and clothing. Protect the patient from blowing snow when the helicopter arrives. Don't approach the helicopter until instructed to do so by the pilot.

HOW TO CARE FOR AND EVACUATE AN INJURED PARTY


Jeff Moskowitz

Once you've excavated a buried victim and ensured your patient has a clear airway, is breathing, and has a pulse, your team still has a serious medical and logistical issue to deal with. Patient care is first and foremost. Ensure the patient is treated for or protected against hypothermia and other environmental threats and then perform a complete head to toe physical assessment for injuries. If you don't have adequate first aid training, take a wilderness first aid course from a reputable provider in your area. Consider the first aid training and skills of you and your partners when *Assembling Your Group*. Just as you practice your rescue skills regularly, keep your skills sharp and up to date through regular training.

You may have sought out the backcountry for the solitude and remote lines. The reality of what this means, however, can be terrifyingly clear when having to move an injured party to a place where you can meet professional rescuers. Even if a helicopter can come to your aid, you may need to move the patient to a suitable location. At a minimum, carry enough equipment and know how to assemble an improvised a litter or buy a commercial sled or tarp. Refresh your skills by practicing assembling it each season.

While you won't learn first aid or evacuation skills on an AIARE course, these skills are just as important as avalanche rescue skills. What you would do after you've excavated a fully buried victim should be considered every time you practice avalanche rescue. It's important to consider these additional required skills and equipment both when you *Assemble Your Group* and *Discuss Your Emergency Plan*.

PRACTICE AND EVALUATE YOUR SKILLS


Joseph Osterman

Rescue skills are a last resort when everything else goes wrong. Hopefully they are skills you rarely or never have to employ. But skills that aren't used expire. In order to master and maintain the skills necessary to execute a fast, efficient rescue, you need to practice avalanche rescue regularly.

At the beginning of each season and then monthly throughout the winter, *Practice a Rescue Response* with a team. Pre-event rehearsal is a proven strategy to reduce stress and focus on actions during critical, lifesaving situations. Practice not just avalanche rescue, but also review what to do if you are caught and the skills required to evacuate an injured person from the backcountry. Always practice with the *Avalanche Rescue Quick Reference*. How you practice is how you will respond in an emergency.

The Rescue Practice Checklist is a tool designed to help you ensure you and your partners are practicing correctly and not building bad habits. It is used during an AIARE Avalanche Rescue Course and is included at the end of this section for reference. Have a partner use it when you practice to give you feedback to ensure you are creating the right habits instead of reinforcing poor skills.

Ben Mirkin

Use *The Practice Checklist* to debrief each scenario. Identify what you are doing well so you continue to do it. Identify where you would like to improve the next time you practice. Create practice strategies that target specific skills. Consider videoing your team's response and reviewing it together, identifying moments of confusion and places for improvement.

Another critical piece of evaluating your rescue skills is to time your response from the moment the team begins its search to the moment you've extracted a transceiver and turned it off. Your group should strive to extract two buried transceivers, both 1m (3ft) deep, in less than 10 minutes.

Hailey Littleton

Why is the time component so critical? The quicker you can rescue the avalanche victim, the better their chances of survival. While the probability of survival is 80% for those buried for 10 minutes, the probability drops to 40% after 15 minutes and then 10% after 35 minutes. In North America, these probabilities of survival in an avalanche are further reduced by the increased incidence of major trauma. Minutes can make the difference between life and death. Timed practice helps your team measure the improvements in speed and efficiency, so you can feel confident you are responding as quickly as possible.[5]

5 Haegeli, P. et al. "Comparison of Avalanche Survival Patterns in Canada and Switzerland." Canadian Medical Association Journal 183.7 (2011): 789–795. Crossref. Web. DOI:10.1503 /cmaj.101435

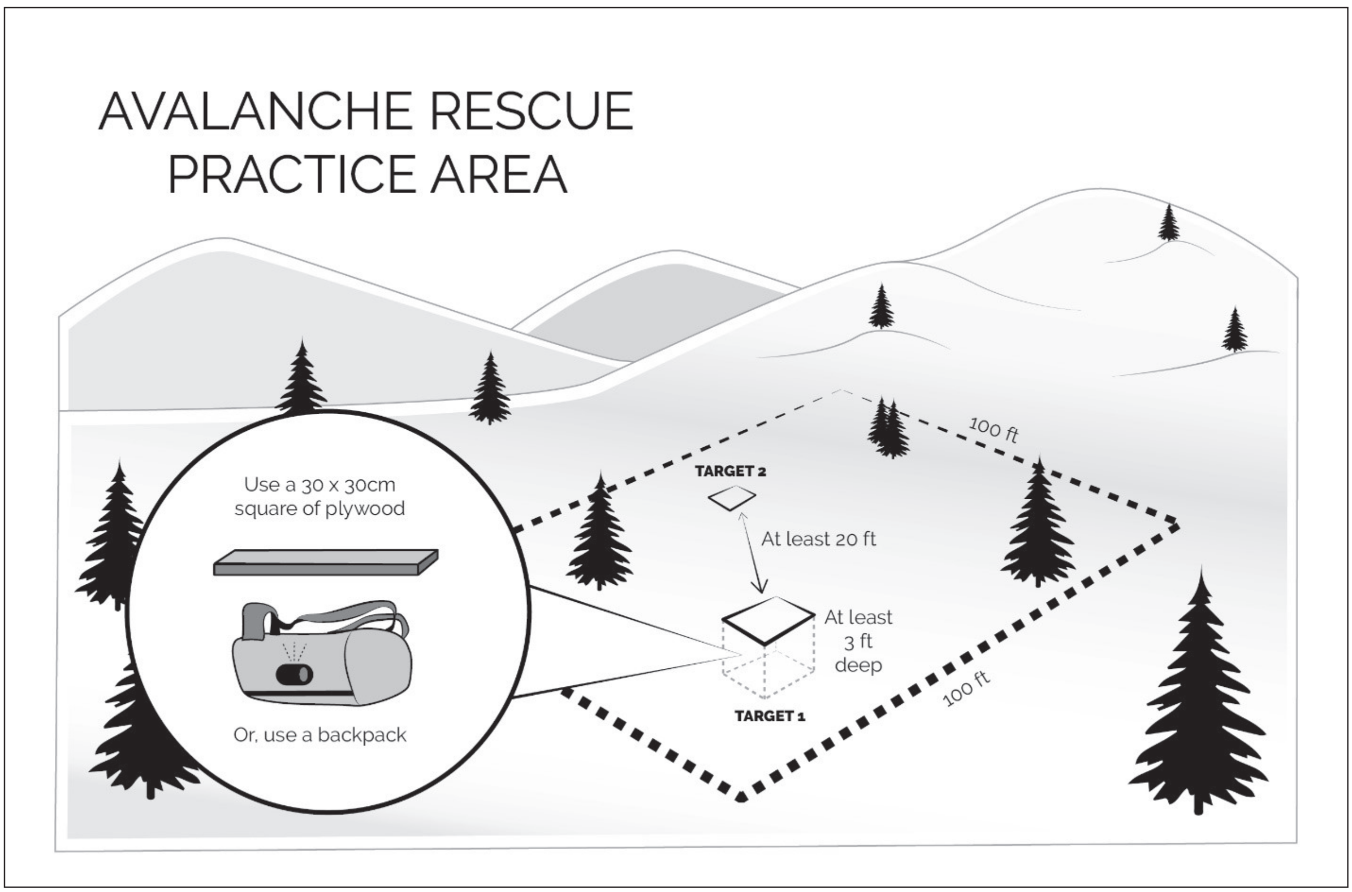
How to Practice Small Team Avalanche Rescue

Imagine the gut-wrenching emotions of helplessly watching and avalanche engulf a loved one as they rag doll over a convex roll and out of sight.. It's a gruesome worst-case scenario, but one where in order to offer the best possible chance of a good outcomes we've got to stop, think, and step into action decisively, without making another mistake.

Perfect practice makes perfect performance. Pre-event rehearsal is a proven strategy to reduce stress and improve competence in completely critical life-saving actions in sequence. It is not just practicing but also how you practice that will improve your skills.

Set up your practice area in a realistic scenario; not a parking lot or flat snow slope, but an area with varied terrain and deep snow that is safe from avalanches. Choose a tracked-up area free of noise and electrical interference like power lines, buildings, or other permanent infrastructure.

Start by burying just one transceiver in a 30 x 30m (100 x 100ft) area, at a minimum of 1m (3ft) deep—this is the average burial depth of an avalanche victim. You can put a 30 x 30cm (12 x 12in) square of plywood over the transceiver to give you a larger target and to protect the transceiver from probe strikes.



As your skills improve, bury two transceivers approximately 6m (20ft) apart. Practice using your transceiver to find each target on your own as well as in teams. Having two buried targets requires a systematic, calm approach to differentiate the signals. Make sure to bury the transceivers at least 1m (3ft) deep, as this facilitates realistic probing and shoveling practice.

Practice with your backcountry partners, rotating tasks and sharing responsibilities. Always use the *Avalanche Rescue Quick Reference* in *The Fieldbook.* Have one member of the team observe and use *The Rescue Practice Checklist* (at the end of this Chapter). Communicate clearly amongst teammates while practicing, clearly verbalizing what each member is doing. This will translate into clear, calm communications in the event of a real emergency, and this will save valuable minutes in the field.

Rescue skills have an expiration date.

While rescue is only a backup plan for when everything goes wrong, you want to make sure that you can quickly and competently perform a rescue under stress. In order to do this:

- **Practice avalanche rescue with your team regularly.**
- **Use *The Rescue Practice Checklist*. Time your practice.**
- **Acquire and maintain the additional skills required to provide first aid and extricate the injured party from the backcountry.**
- **Take an Avalanche Rescue Course regularly.**

TRACK THE SEASON'S CONDITIONS

BCA

Experienced backcountry travelers track weather events and trends throughout the season in order to build a mental image of the mountain snowpack and the events that formed the current snow conditions at various elevations. This involves keeping tabs on season-long weather and snowfall events, avalanche events, and danger trends.

You might be able to do this by reading the daily avalanche advisory or keeping a log of weather and avalanche information from local experts. Whatever you do, keep an eye on conditions from the time the mountains begin accumulating snow.

As you track the winter season and layers in the snowpack, recognize that certain weather patterns and events push avalanche danger up and down. Identifying these patterns, particularly the ones that cause the danger to rise, is valuable because it shows you the relationship between weather and avalanche danger.

When your local avalanche center begins issuing advisories, read them daily. If your center can email you the daily advisory every morning or send you alerts via social media, sign up for the service. Read the daily advisory and discuss it with your partners, as well as local experts. Ask for their perspectives on current conditions, how the season has developed, how it compares to past years, and whether or not they're worried about seasonal or recent trends.

Soon you'll begin to notice correlations in weather and danger. As you develop this skill, relate these patterns to different locations and terrain. Where will snowfall and wind create avalanches? Which slopes will be affected? What types of terrain are avalanching? Which slopes, in terms of their relation to sun and wind, are problematic? Which drainages have been affected by recent events or the seasonal history?

Reading the bulletin each day will allow you to take of note of increasing or decreasing avalanche danger, which in turn will help you begin to recognize how timing can help reduce your risk during travel. For example, being off sunny slopes by late morning might keep you out of harm's way in the spring. Perhaps waiting a day or two to ride on lee slopes will help you avoid avalanches after a major wind event.

You will soon notice persistent avalanche problems in the bulletin. Some problems might linger for days, weeks, or even months. The experts will be discussing these types of problems and urging caution, and it's up to you to listen. Be especially disciplined and take their advice when they warn of low-likelihood, high-consequence events. These can be near impossible to predict and days or weeks can go by without an avalanche incident, but if the experts warn of these types of avalanche problems, take heed. Don't get complacent.

Other riders' trip reports can let you know what types of terrain people are choosing. Talk to people in your community who have been out in the backcountry. By learning what terrain they're choosing, as well as what they're avoiding, you can learn about making appropriate choices for your own backcountry trip. Investigate why others are choosing or avoiding specific slopes and learn from it. You can also learn plenty from an Avalanche Center's accident databases and analyses such as *The Snowy Torrents* published by The American Avalanche Association. Without judgment, read how others made mistakes and learn from them.

Paying attention to local advisories, avalanche experts, and other riders will also help you recognize when conditions are generally stable and the avalanche danger is low. Often this happens in the deep spring snowpack, but not always. Notice when other riders have gained confidence and are increasing their exposure to avalanche terrain. Then compare this to your experiences and assessments. Do they match? Why are others doing something you're not?

INVESTIGATE TRIP OPTIONS

Prior to creating a plan for each trip, you need to be familiar with trip options in the area. Recognize quality trips that you are interested in and catalog this knowledge as part of an ongoing process of becoming familiar with when and where you can travel in any given season. Choosing the right trip is the first step in reducing the likelihood of a problem or accident.

Ruby Mt. Heli

Begin studying and paying attention to trip options in your area. It won't take long to discover there are a variety of outings in terms of quality, complexity, exposure, difficulty, and length. Some routes are once-in-a-lifetime outings, ones that only get done in certain conditions or are so difficult you will have to train for them, while others might be short trips reserved for a dawn patrol, when you have less-fit partners, or on a day when avalanche danger is increased and you're traveling carefully. Recognize what options you have and create a catalog of these with notes describing when certain outings will be appropriate.

PREPARE

Investigate Trip Options

Your trip option catalog should have simple, low-angle terrain options for when conditions are unstable. Identify shorter trips suitable for challenging or slow travel conditions, shorter early season days, and days when you will practice your skills. Develop a range of trips for different travel abilities. Keep a list of longer, more strenuous, and more challenging trips for when snow conditions, a solid group, weather, and skills all align.

Guidebooks can be helpful in identifying terrain, but so can other riders and your own experience and observation skills. Begin taking photos of terrain that interests you, both in winter and summer. Even while driving along the road, you can always pull over and snap a few photos. Later you can compare these to guidebooks, maps, and the notes of others. Use the photos and maps to identify avalanche slopes and features you will encounter on each trip.

The more you pay attention to the season's weather history and avalanche conditions, the more you will start to notice trends and patterns regarding where people go and when. Knowing when other backcountry travelers choose a specific trip will supplement your own understanding of appropriate avalanche conditions. Comparing their decisions to the database and knowledge compiled in your trip options catalog will ultimately help you make safer terrain choices.

Share your opinion, your observations, and trip options with your partners. Soon you and your team will have a good catalog of outings you'd like to do and an understanding of what sort of conditions you'll need to pull them off safely.

AIARE

Avalanche Rescue Practice Checklist

Name: ____________________ **Time:** __________

Assess Safety
- ☐ Rescuer verbalized assessing exposure to a second avalanche
- ☐ Rescuer defined a safe location for spotters and survivors

Choose a Leader
- ☐ Rescuer verbalized assigning a leader or took charge and delegated tasks

Head Count
- ☐ Rescuer asked for and communicated number of victims to rescue party
- ☐ (Multiple Burial) Rescuer verbalized basic strategy for multiple victims

Call for Help
- ☐ Rescuer verbalized when to call for help, selected method of communication, and communicated appropriate information (at a minimum location and that an avalanche involvement has occurred)

Switch all Transceivers to Search Mode
- ☐ Rescuer asked group to turn off electronic devices and turn transceivers to search mode

Determine Where to Search
- ☐ Rescuer determined where to begin searching based on point last seen
- ☐ Rescuer communicated search strategy based on resources, number of burials, terrain features present, location of debris, etc.

Comments on Initial Avalanche Response:

Search for Signal & Visual Clues
- ☐ Rescuer used a pattern (not greater than 40 m search strips) appropriate to mode and direction of travel to search debris, entering from the side or the toe, while moving quickly
- ☐ Rescuer looked for visual clues (or delegated the task) while searching for a signal

Yell to Others When Finding Clue or Signal
- ☐ Rescuer pulled clues out of the snow and left it on the snow surface
- ☐ Rescuer left a marker on the snow when beginning to follow a signal
- ☐ Rescuer notified rescue party when finding visual clues or a signal
- ☐ Rescuer called for a second searcher to assemble probe (and shovel)

Follow Signal to (1st) Burial Area
- ☐ Rescuer slowed down while approaching 10 m ensuring an assistant with probe accompanied search
- ☐ Rescuer communicated to allocate all team resources (including prober) at burial site
- ☐ Rescuer placed a marker on the snow or removed skis/board to visualize trajectory at 5 m
- ☐ Rescuer moved slowly and directed assistant to effectively probe ahead

Comments on Signal and Visual Clues Search:

Locate Burial with Transceiver

- ☐ Rescuer used an appropriate and efficient method (bracketing and/or probing in front of searching transceiver) to locate the closest signal
- ☐ Rescuer kept transceiver as close to the snow surface as possible while locating the closest signal
- ☐ Rescuer maintained consistent transceiver orientation while locating the closest signal
- ☐ Rescuer moves slowly enough to allow their transceiver to correctly process signals

Comments on Transceiver Search:

Locate Burial with Probe

- ☐ Rescuer used a consistent probing method (on a line or pinpointing with square or spiral pattern) with spacing no more than 25 cm
- ☐ Rescuer probed perpendicular to the debris surface
- ☐ Rescuer left probe in place on probe strike

Shovel Fast and Effectively

- ☐ Rescuer used probe to identify and verbalize depth of burial
- ☐ Rescuer moved appropriate distance downhill from probe to begin shoveling
- ☐ Rescuer used appropriate shoveling configuration based on number of available rescuers
- ☐ Rescuer dug a ramp towards the victim throwing snow far away
- ☐ Rescuer changed shovelers often (if possible)
- ☐ Rescuer shoveled carefully when nearing the victim

Comments on Probing and Shoveling:

(Multiple Burial) Locate 2nd Burial With Transceiver

- ☐ Rescuer switched 1st buried transceiver to search
- ☐ Rescuer intentionally moved away from 1st burial towards marked point of multiple transceiver signals.
- ☐ Rescuer uses repeatable method to detect 2nd transceiver signal (marking, micro-strip, 3-circle, etc) if needed.
- ☐ Rescuer repeated steps from “Follow signal to burial area” through “Shovel fast and effectively” for 2nd burial

Comments on Locating and Extracting 2nd Burial:

Patient Care

- ☐ Rescuer verbalized clearing patient airway and assessing need for CPR
- ☐ Rescuer defined safe location to move patient and rescuers
- ☐ Rescuer formulated evacuation plan based on available resources

Call for Help

- ☐ If complete call for help was not made initially, rescuer revisited call for help, selected method of communication, and communicated appropriate information

If a Helicopter Comes to Your Aid

- ☐ Rescuer verbalized securing loose items and waiting for helicopter to land and rescuer to come to them

Comments on Post-Extraction:

CHAPTER 1:
Summary

PREPARE

Continue your avalanche education
Practice avalanche rescue
Track the season's conditions
Investigate trip options

Backcountry travel is something that requires preparation throughout the season. In order to be fully prepared, you should be refreshing your knowledge and honing your skills regularly. The best way to do this is to focus on four components highlighted below in this chapter's summary.

CHAPTER 1 QUESTIONS

Continue your avalanche education

1. How will you continue your avalanche education? List two steps you will take to continue to learn and gain experience after this course.

2. What are three qualities, in addition to avalanche expertise, that make a good backcountry mentor?

Practice avalanche rescue

3. Why is it so important to practice avalanche rescue several times each winter?

4. If you have multiple rescuers and burials, should your team rescue the closest, shallowest burial first? Or should you divide your searchers and excavate two sites at once?

Track the season's conditions

5. When we monitor the season's conditions, what should we watch for and why?

Investigate trip options

6. It is helpful to have a catalog of trip options for you to reference and add to throughout the season as you plan your trips. What factors should be considered when choosing a trip from this list?

See Page 97 for answers


LIVE.
SKI.
REPEAT.
In the early days, Black Diamond employee Alex Lowe brought an infectious stoke to backcountry skiing. Lowe inspired his coworkers to create equipment that could keep up with the hard-charging skiers of the Wasatch. Today, we're still bringing that same spirit of ingenuity to the game. See you out there.
BD Athlete Mike Barney Jeff Cricco
BLACKDIAMONDEQUIPMENT.COM
Black Diamond

Part 2:
Each Backcountry Day

A TALE OF TWO GROUPS

Jenna, Kelli, and Evan were a group of friends who were somewhat new to backcountry skiing. The trio had gone out together on weekend day-trips a few times so far this season. It had been snowing all week and Saturday was the first clear day with a partly sunny forecast. The trio decided to head to Grizzly Mountain, an outing they had been on before, to get some powder turns.

Steve and Luis were longtime backcountry snowboarders who grew up strapping their snowboards to their backpack and climbing uphill through deep snow with snowshoes. They were also heading to Grizzly Mountain to celebrate Luis's promotion and enjoy some much needed weekend time after a hard week at work.

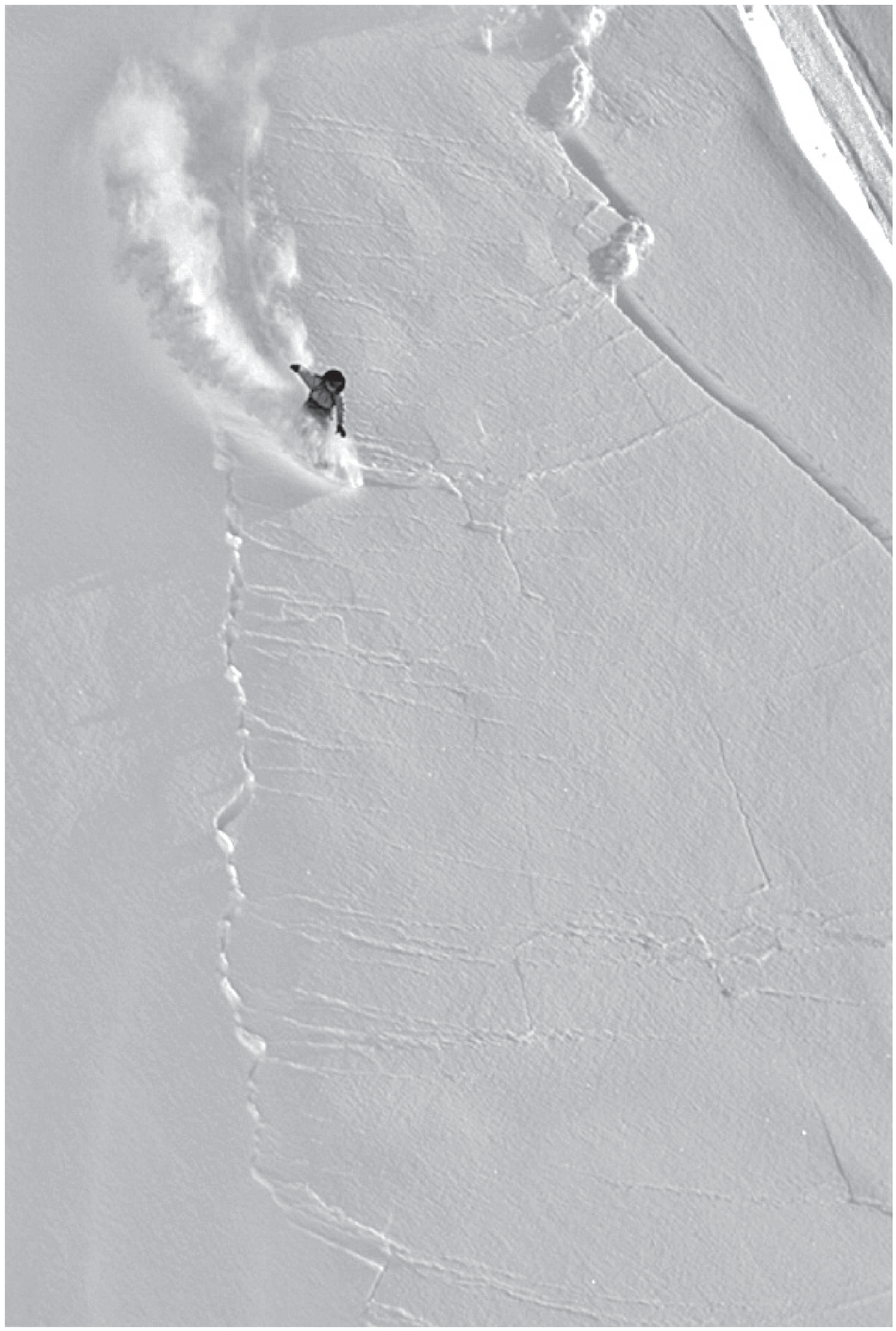
Felipe Inostroza

At the top of the mountain, Jenna, Kelli, and Even ran into Steve and Luis as they were transitioning to head downhill. The groups made small talk and then the trio headed down the mellower south side of the mountain, while Steve and Luis worked their way over to the steeper east face.

The trio enjoyed some great turns and made a couple more laps before calling it a day. They ran into Steve and Luis again in the parking lot. Both looked shaken. Luis was super disheveled and wet. A snowboard with one of its bindings ripped off lay at his feet.

Steve recounted their story to the trio: from the top of the mountain, they began their descent down the east face going one at a time and leap frogging positions. Steve rode one pitch and stopped above a place where pitch of the slope changed. Luis then came down and rode past Steve. About a hundred feet below Steve, as the pitch got a little steeper, cracks shot out from Luis's board and what looked like a large island of snow began to move downhill and took Luis with it. Luis was able to fight to stay on top and moved off to the side of the moving snow, but not before the force of the snow had ripped one of his bindings off and wrenched his ankle in the process. The pair has spent the rest of the day trying to get back to the parking lot. Luckily neither were seriously hurt, both just had the wits scared out of them.

Jenna thought about her group's choices that day. They had checked their local avalanche center's advisory. The danger rating was Considerable, but she hadn't read much more beyond that. She'd like to think that they chose Grizzly because the terrain was mellow, but she wasn't sure if it was "mellow" enough. They had talked about skiing the east face, but opted for the south side because the snow looked better. Jenna thought about how easily they could have been in Luis and Steve's situation. Jenna, Kelli, and Even didn't really have a plan that was any different from Steve and Luis's, they just happened to take different descent lines. She wasn't sure if her group actually made better decisions. What if they just got lucky? How would they ever know?


L. Kennen

Ben Pritchett

Grant Gunderson

BUILDING EXPERIENCE

How does one gain experience? Generally we take some step or action based on our baseline knowledge. If something doesn't work, we make note of it, assimilate it into our baseline knowledge and take a different action the next time. But what if, in the case of backcountry travel and avalanches, our baseline knowledge is rather thin and the consequences of not doing it right can be fatal?

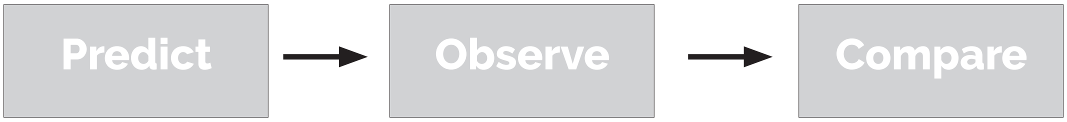
What if our only feedback is either being involved in an avalanche or not being involved in an avalanche? In our tale of two groups, Jenna pondered this exact question. In the case of avalanches, the consequences are too steep to seek out feedback by getting involved with an avalanche. But not getting involved with an avalanche might just be a form of non-event feedback, where we don't experience the potential consequences of our actions. We might just be getting lucky and while still actually making really bad decisions.

When we use involvement with avalanches as our only metric for feedback and learning, we set up a wicked learning environment.[6] These are settings where feedback on our actions is poor, misleading, or even missing. To build experience as backcountry travelers, we want to set up a more responsive learning environment, one where feedback links the outcomes directly to the appropriate actions or judgments. As recreational travelers, we can create a kind learning environment by pulling from a process avalanche professionals use on a daily basis.

Before starting, professionals identify what they expect will happen, actively engage in a process to continually assess what is happening, and then compare what actually happened to what they thought would happen.

6 Hogarth, Robin M., Tomás Lejarraga, and Emre Soyer. "The Two Settings of Kind and Wicked Learning Environments." Current Directions in Psychological Science 24, no. 5 (2015): 379-85. doi:10.1177/0963721415591878.

At the beginning of the day, professionals identify and quantify the hazard they think they will encounter. Then during the day, they make targeted observations, continually engage in conversation with their colleagues, and reassess the hazard if necessary. At the end of the day, they summarize what they observed and compare the summary to their predictions.



The process of comparing predications and observations sets up a feedback-rich learning environment. It considers the many factors that affect the hazard, such as group decision making, instead of solely focusing on events. Did they encounter anything unexpected? Were their findings in line with what they anticipated? Was everyone from the group engaged?

By using this comparison process, group members are able to figure out what they did well and what they could do better. This builds the knowledge base from which they make their predictions. In short, they are learning from their intentional experience.

The AIARE Framework sets up a similar experiential learning cycle with a daily routine for each day you are in the backcountry. Using the baseline knowledge gained while Preparing for travel in avalanche terrain, groups anticipate the hazard and then make a plan to address the hazard during PLAN. During RIDE, groups make observations, engage with their group, and adjust as necessary. During DEBRIEF, group members summarize what they found while traveling and compare it to what they anticipated. They note where they were right and where they were wrong, which feeds into additional preparation and learning they may seek out.

The AIARE Fieldbook contains the essential tools designed to maintain awareness and help manage human factors that can challenge an individual's or group's backcountry decisions.

Pages 1-5 of *The Fieldbook* contain step-by-step checklists[7] of *The AIARE Framework* which helps groups to use the blank PLAN, RIDE, and DEBRIEF pages of *The Fieldbook*. More detailed explanations of these checklists are contained in this handbook.

7 Checklists are a foundational tool in organizational risk management and in so-called Highly Reliable Organizations. For an example, see Atul Gawande's The Checlist Manifesto: How to Get Things Right.

TEAMWORK

☑ Travel together. Decide together.

☑ Listen to every voice.

☑ Challenge assumptions.

☑ Respect any veto.

THE BACKCOUNTRY RULES OF ENGAGEMENT

In order to plan and execute a successful trip in the backcountry, a group must agree to abide by certain backcountry "rules of engagement." TEAMWORK lists the responsibilities of each group member essential to ensuring the group uses *The AIARE Framework.*

The team dynamic is critical to planning, traveling in the field, and debriefing. Ensure that all members of your team actively contribute to your decision-making process. From the planning stage to making choices in the backcountry, listen to every group member and make sure each person is actively contributing to the conversation. Ask quieter group members to speak up if necessary. Backcountry travel is not a place for passive friends to hang out at the back of the pack. Active engagement by all members is crucial for the process to work. When every person is participating, it is possible to challenge assumptions to ensure all points are considered, protect against group think and the will of the majority. When all voices are listened to and assumptions are challenged, every group member has the opportunity to voice their veto. Respecting any veto is the more important aspect of TEAMWORK which prevents the enthusiasm of the majority from pressuring the group into a bad decision.

Lucas Mouttet

Rather than letting your emotions or desires guide your trip plans, you need a process that engages the group, anticipates the hazards you face, and chooses a mindset that facilitates good decisions in the field. Critical decisions, including where you go and how you go, are made prior to the start of any trip.

This chapter walks through the step-by-step checklists you will use as you PLAN YOUR TRIP.

Chapter 2:
Plan Your Trip

PLAN YOUR TRIP

☑ Assemble Your Group **Date:**

Group Check In.
Group names, cell#

Discuss
- Compatible goals
- Your risk tolerance
- All agree to ride & decide together
- An optimal group size (3-5)
- Any health issues

☑ Anticipate The Hazard Read the local avalanche advisory. Seek expert opinion.

Discuss current & forecast weather factors that can affect travel or hazard.
Consider snowfall, wind, drifting snow, and warming.

Identify the avalanche problem and location. Discuss the danger trend and timing.

List primary problem first eg. Wind Slab	Size	Elevation	Aspect	Terrain Features	Danger Trend & Timing
#1					
#2					

Discuss the advisory's key message.
Highlight recent avalanches and travel advice.

☑ Plan Your Route Voice all concerns. Respect any veto. Decide by consensus.

Preview terrain.
- Turn to page 3 and choose a strategy to limit your exposure.
- Use maps, photos and guidebooks to identify a route plan that considers conditions.
- Identify avalanche slopes along the route. Avoid potential hazards.
- Note observation locations & group check in stops.
- Note your turn around point & time.

When uncertain discuss a less exposed alternate route.
- Agree upon where the group will travel to reduce exposure if the day isn't unfolding according to plan.

☑ Discuss Your Emergency Plan Assign group gear.

- Who else has our itinerary?
- Adequate food/water/warm layers
- S.O.S device (cell or satellite unit), emergency numbers
- Lightweight tarp/rescue sled
- First Aid Kit
- Repair Kit
- Navigation tools

Discuss, given our experience, why we think we can safely & effectively carry out this plan?
Invite the devil's advocate into the conversation. Try to identify any holes and what's necessary to carry out the plan.

The members of a group play a critical role in contributing to sound decision making. The step *Assemble Your Group* checks that goals are shared and the members of the group can work together.

Then use the local advisory or expert opinion to *Anticipate the Hazard* by discussing weather and snow conditions.

Armed with information about your group, the avalanche hazard, and the weather forecast, you will *Plan Your Route* and *Discuss Your Emergency Plan*.

On pages 2-3 in *The AIARE Fieldbook*, you will find prompts to help you fill out your trip plan. In this section, you will find a sample filled out trip plan as you follow the prompts. Starting on page 6 of *The AIARE Fieldbook*, there is ample space for you to take your own notes as you use *The AIARE Framework* to PLAN YOUR TRIP. Keeping these notes in one place will be helpful as you gain more experience in the backcountry.

ASSEMBLE YOUR GROUP

Almost every avalanche accident involves a poor decision made by a human. Pre-conditioned biases, an individual's tendencies, habits, and behavior patterns are described as human factors or heuristics. Even in the face of ominous signs of elevated avalanche danger, human factors can cause individuals to make poor decisions in the backcountry that go against their better judgment. These human factors influence us unconsciously and subtly, leading us to make decisions that in hindsight we clearly regret. We're all vulnerable to human factors.

Using a checklist process helps us fight the inclination to support a bad decision, but the checklists are only useful if they are used by a functioning team. A thoughtfully formed group that listens to each team member's observations and motivations makes better decisions in avalanche terrain.


Lucas Mouttet

Assembling a strong, well rounded group that adheres to *The AIARE Framework* means that each individual agrees to travel together, decide together, listen to all voices, challenge assumptions, and respect any veto. This can short-circuit detrimental human factors and help everyone make smarter, safer decisions.

A systematic *Group Check In* helps identify potential problems and human factors in the group, as well as strengths. Use the prompts on page 2 of *The AIARE Fieldbook* to check in with your group every time you travel.

THE GROUP CHECK-IN

☑ **Assemble Your Group** **Date:** Feb. 26, 2018

Group Check In.
John M—970-123-5555
Chris W—970-555-2345
Anya B—250-123-4567

-No medical/health issues in group.
-Risk Tolerance Check: All on same page
-Goals:Good turns and fun storm day riding

All team members agree to:
Ride together
Decide together
Listen to every voice
Challenge assumptions
Respect any veto

The group should make sure members have compatible goals. First off, does everybody get along? Friction between team members hinders open and honest discussions. Team members should make sure they share similar objectives and ambitions. If one person wants to build a kicker, while another wants to get in a tour after a long week at work, these two probably won't have a particularly fun time together.

Other questions to discuss regarding compatible goals:

- *Is anyone familiar with the proposed trip?*
- *Is anyone an expert with current conditions?*
- *Are all group members skilled and fit enough for the trip?*
- *Is everyone familiar with their gear and how to use it?*
- *Will any of these issues affect the group's ability to make decisions?*

Risk tolerance is an often overlooked, but extremely important topic to discuss. Risk tolerance may be a function of age or experience but really it is just as varied and unique as personalities are from one individual to the next. While discussing this issue can yield insight, observing a partner's behavior in the field can be equally revealing.

Questions to discuss regarding risk tolerance:

- *Do members perceive the day's risks similarly?*
- *Are there different levels of risk tolerance within the group?*
- *Will the group need, or feel the need, to reach its objective despite the conditions or risks?*
- *Will the team consider a more cautious approach given today's avalanche or group conditions?*

Many avalanche incidents could be avoided if the individuals in the groups involved all agreed to ride together and decide together. Implicit in this agreement is consensus, meaning that everyone has a voice and everyone has a veto. This means that if one person feels the terrain is unsafe, the whole group will turn back or choose another line. If a group cannot ensure everyone's opinion is equally respected and that all vetoes are valued, it is a sign of an incompatible group dynamic that must be addressed.

Keys to achieving group consensus:

- *Prior to making key decisions, agree that—regardless of experience—all opinions are respected, and any one group member can veto the team's choice or exposure to avalanche terrain.*
- *Allow an individual to challenge assumptions. The voice of the devil's advocate is important and encourages us to identify what we know and what we are assuming is fact.*
- *Explicitly agree that the group is committed to consensus rather than majority rule.*
- *Agree that at each stop—which can be built into travel plans—the team considers local experience, familiarity with conditions, new observations made in the field, judgment versus desire, individual intuition, and common sense.*
- *Agree that no one gets left behind or out of sight, for any reason.*

Other questions to ask regarding consensus:

- *Is someone silent at the back of the group?*
- *Do one or two team members tend to overwhelm others with strong opinions?*
- *Do certain teammates seem willing to just go with the flow and cede decision making to others?*

Research[8] and experience indicate an optimal group size is three to five people. Individuals or groups of two may not benefit from collective experience and wisdom. A small group might also lack an abundance of opinions and experience to offer alternative opinions and perspective. A smaller team sacrifices human power for self-rescue and backcountry evacuation, as well. Groups larger than five can work, but often require expert facilitation to ensure all voices are heard, lines of communication are maintained, experience is recognized, and that discussions achieve true consensus.

Team members should be transparent about any personal health issues. For example, discovering your teammate has ACL surgery scheduled might be a bit of a shock considering you are trusting them with your own life in the event of an emergency in the backcountry. So can learning that your previously fit partner is nervous about exerting themselves at elevation and logging the planned mileage in the time allotted. Anything as simple as a common cold, especially when compounded by fatigue, cold, and hunger, can affect a person's ability to make good decisions. An open, thoughtful discussion amongst team members can appropriately modify the day's objectives.

A solid, well-functioning team can address issues with flexibility and consensus. A team that lacks the ability to discuss and solve problems isn't much of a team at all. If any of the above discussions introduce unresolved debate, you should question the group's viability as a backcountry team. If consensus cannot be reached, agree upon a simpler terrain, smaller objectives, and/or terrain closer to the trailhead and rescue services.

After assembling your group and agreeing on an objective that works for everyone, jot each member's name and emergency contact information in your *Fieldbook*. During an emergency, an accurate head count is critical. Referring to your notes helps to ensure a calm response with no mistakes. Take note if a team member leaves or joins the group during the day.

8 Research used to form the backcountry decision aid, the Nivotest, (R. Bolognesi, http://arc.lib.montana.edu/snow-science/item/791) is based on avalanche accident reports and suggests that 3, 4 or 5 persons is an optimal group size.

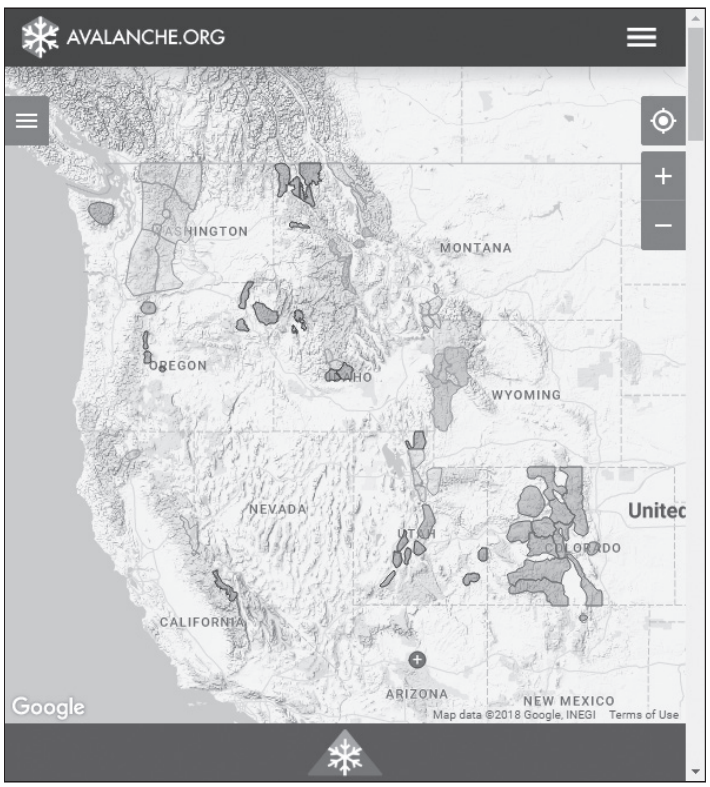
ANTICIPATE THE HAZARD

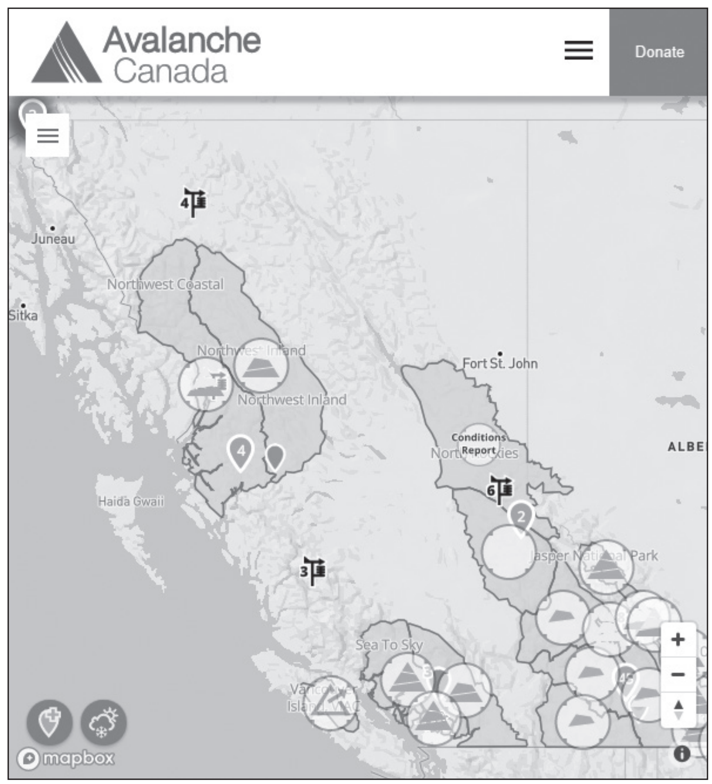
After assembling a cohesive, well-matched group, the group needs to *Anticipate the Hazard*. This is the first step in the process of gaining intentional experience by making a prediction about the hazard in order to compare it to actual findings at the end of the day. Anticipating the Hazard will also inform the travel plan so that decisions are made when we are able to slow down our thinking and engage the deliberate and rational side of our brain rather than relying on the reactive, intuitive side in the heat of the moment.

Anticipating the hazard first requires identifying and accessing reliable sources for the current and forecasted weather and then discussing key factors that contribute to the hazard and affect travel. Once this information is gathered, identify and locate the avalanche problem(s) in the terrain and determine if they impact the proposed plan. Finally, discuss the avalanche danger trends and summarize the key message for the day.

IDENTIFY A RELIABLE SOURCE FOR WEATHER AND AVALANCHE INFORMATION

Reliable, regularly updated weather information can be found on a variety of websites. A popular choice is the National Weather Service's website, weather.gov. It allows users to customize a point forecast to specific backcountry regions, look at in-depth text forecast discussions, and check hourly forecasts.





Find your local avalanche center by starting at avalanche.org in the US and avalanche.ca in Canada. Local avalanche centers issue regular avalanche advisories with daily danger ratings and an indication of the avalanche problems for a particular region. The advisory will also include essential information about the danger trend, recent avalanche activity, the developing snowpack, and the mountain weather forecast. Appendix A includes definitions and explanations of terminology you will encounter in a North American avalanche advisory.

Local experts—ski patrol, mountain guides, avalanche educators, conscientious backcountry travelers—can augment your knowledge and complement the avalanche advisory. If you live in an area without a local avalanche advisory, finding reliable expert opinions is essential.

DISCUSS CURRENT AND FORECAST WEATHER FACTORS THAT CAN AFFECT TRAVEL OR HAZARD

☑ **Anticipate The Hazard** Read the local avalanche advisory. Seek expert opinion.

Discuss current & forecast weather factors that can affect travel or hazard.

8-10" new snow overnight. 2-4" expected today. Winds were calm overnight but are supposed to increase today—West Winds 15-25 mph in forecast. Overcast skies and low visibility expected today. Cold temperatures—High of 20F in forecast.

Identify the avalanche problem and location. Discuss the danger trend and timing.

Discuss the advisory's key message.

Once you have weather and advisory information, discuss the weather trends and weather factors that might affect travel as well as the team's ability to communicate and/or travel together. Discuss how the timing of those factors and trends impacts the group's travel plans. Every member should have an idea of the trend and how it will affect travel in the terrain.

Ask yourself:

- Are weather or conditions causing the increasing or decreasing trends in the hazard?
- Are there any key factors that have been observed or forecasted that might affect travel or the ability to communicate and make decisions as a group?

Recognize Unstable Conditions

Page 5 of *The AIARE Fieldbook* provides a reminder of unstable weather and snowpack conditions for a quick reference while traveling. Use this reference when planning to talk about the impacts of the weather forecast and conditions reported in the avalanche advisory.

Unstable conditions refer to particular events or observations that increase the likelihood of avalanches such as a significant amount of wind or snowfall. Observing and verbally identifying weather conditions that grab your attention will alert you that avalanche danger may be increasing. If any of these conditions are present, they are the first thing to discuss when talking about weather factors that will affect travel or the hazard.

Step 1: Monitor Conditions Along Your Route.

⚠ **Alert Group To Unstable Conditions.**

WEATHER

- **Heavy snowfall**: 30cm (12") in the past 2 days (even less with wind). Watch out for rapid accumulation (>2cm or 1"/hr.)
- **Recent drifting snow** means windslabs can form downwind of ridge lines.
- **Rapid warming** from sunshine or rain can make unstable snow. Extra caution with warming right after a storm.

SNOWPACK

- **Signs of avalanche activity** from today or yesterday.
- **Whumph!** This sound is a warning that weak layers are collapsing in the snowpack.
- **Cracks** in the snow surface that shoot out from skis or track.
- Overhanging or drooping cornices.
- A **slab above a weak layer** (reported or observed in tests).

FIGURE 3: EXCERPT ON UNSTABLE CONDITIONS FROM THE AIARE FIELDBOOK.

PLAN
Anticipate The Hazard

These factors are relevant when anticipating the conditions of the day serve as basic field observation criteria that should be flagged for the whole group to acknowledge and discuss.

Possible signs of weather-related unstable conditions include:

- Heavy snowfall: 30cm (12in) over two days, or snowfall rates of more than 2cm (1in) per hour.
- Snow plus wind: When any snow, whether falling from the sky or on the ground and available for transport, is combined with moderate to strong winds, wind drifting or loading is likely. This forms wind slabs (a specific avalanche problem, see page 85) on the lee sides of ridges and features.
- Rapid warming: Either sunshine or rain can warm the snowpack rapidly, creating instability. Exercise additional caution when temperatures rise after a storm and any amount of rain falls on dry winter snow.

Recognize Unstable Snow

You should also be looking at instabilities in the snowpack itself, not just weather events. Read advisories and reports from other backcountry travelers carefully for reports of unstable snow.

- **Signs of avalanche activity** on day of your trip or from the day before
- **Whumph!** An audible sound and serves as a warning that weak layers are collapsing in the snowpack, often from the weight of a rider
- **Cracks** in the snow surface that shoot out from skis or track
- Overhanging or drooping cornices
- A slab above a weak layer (reported)

Recognize When Weather and Conditions Can Affect Travel

Weather conditions directly impact the avalanche danger rating, but they also impact your travel through the terrain. Be flexible in your plan and if the conditions are unsafe, turn around and come back on a safer day or pick another line.

Examples of how weather can negatively impact your safety include:

Low clouds, fog, or heavy snowfall can all obscure your view. You won't be able to see start zones far above you and it's easier to miss a critical observation, such as a recent avalanche or blowing snow along a ridgetop. Poor visibility can also reduce your ability to estimate slope incline, see terrain features or terrain traps, and navigate safely around steep slopes. Never underestimate how much information you lose in poor light.

Kevin Krill

Don Svela

Heavy winds can create blowing snow and disorienting whiteout conditions that obscure visibility at or near ridgetops, when moving through passes, and in any normal alpine setting. Wind, cold, and blowing snow encourages you to keep hoods and helmets on, which can affect the group ability to converse and discuss important decisions. It's hard to achieve consensus when the whole group would just like to get out of the cold and wind.

Kevin Krill

Clear weather means easy observations. Mountain summits and start zones are easily visible, but the clarity increases the likelihood of sunburn and snow blindness. It's easy to get caught up in the moment on a bluebird day after a long period of storm or clouds, but don't let new snow and clear skies lure you into overlooking any red flags or rushing your observations of the terrain.

PLAN
Anticipate The Hazard

IDENTIFY THE AVALANCHE PROBLEM AND LOCATION

☑ **Anticipate The Hazard** Read the local avalanche advisory. Seek expert opinion.

Discuss current & forecast weather factors that can affect travel or hazard.
8-10" new snow overnight. 2-4" expected today. Winds were calm overnight but are supposed to increase today—West Winds 15-25 mph in forecast. Overcast skies and low visibility expected today. Cold temperatures—High of 20F in forecast.

Identify the avalanche problem and location. Discuss the danger trend and timing.

	size	elev	aspect	terrain features	danger trend/timing
Wind Slab	Small to Large	Near and above TL	NE-E-SE	Below ridgetops and in cross-terrain features	Increasing as the day goes on and snow/winds pick up
Dry Loose	Small	all	all	All slopes >35 degrees	Increasing as the day goes on and as more snow accumulates on sheltered slopes

Discuss the advisory's key message.

Your local avalanche center discusses the danger in your area in light of the principle concern or avalanche problem. Avalanche problems refer to the different types of avalanches as well as where, how big, and how likely they will be. Thinking of each avalanche problem as a distinct challenge gives us an idea of where and when to expect each one, how destructive they might be, and how to best avoid them. Identifying the specific problem allows you to apply a specific solution. Appendix A of this manual provides explanations and illustrations of the avalanche problem types used in North America.

When reading the advisory you need to understand:

- The avalanche problems that are forecasted for the day. (Ex: large Wind Slabs)
- How destructive these problems are.
- Where the problems are located. This includes aspect, elevation, terrain features. (Ex: Problem exists on NW through NE aspects at 11,000-12, 500 feet in elevation. It's found on steep lee slopes below the ridgetop in the Berthoud Pass zone. Exercise caution on all slopes over 35 degrees, on convex slopes, and on any "fat" looking loaded pillows).
- If the danger is improving or getting worse.

These factors and questions must be considered when anticipating the day's risk and making a plan to avoid the problems and where they appear in the landscape. It is imperative that you and your backcountry partners relate the problem from the advisory to the specific location where you plan to travel.

To assist with relating the avalanche problem to terrain and to identify relevant observations, *The AIARE Fieldbook* contains the Avalanches and Observations Reference on 56-58. The reference can also be found in Appendix B of this handbook. Use this reference when you are planning your trip into the backcountry and when you are out in the field. The table gives signs of unstable conditions for each problem and how observations and snowpack tests can complement the avalanche advisory. It can also be used to apply an advisory made for a whole mountain range scale to a specific slope in front of you. Use this tool when creating a travel plan and to make observations related to the primary avalanche problem out in the backcountry.

DISCUSS THE DANGER TREND AND TIMING

Avalanche centers use the North American Public Avalanche Danger Scale to help communicate the potential for avalanches to cause harm or injury to backcountry travelers.[9]

North American Public Avalanche Danger Scale

Avalanche danger is determined by the likelihood, size and distribution of avalanches.

Danger Level		Travel Advice	Likelihood of Avalanches	Avalanche Size and Distribution
5 Extreme	4 5	Avoid all avalanche terrain.	Natural and human-triggered avalanches certain.	Large to very large avalanches in many areas.
4 High	4 5	Very dangerous avalanche conditions. Travel in avalanche terrain <u>not</u> recommended.	Natural avalanches likely; human-triggered avalanches very likely.	Large avalanches in many areas; or very large avalanches in specific areas.
3 Considerable	3	Dangerous avalanche conditions. Careful snowpack evaluation, cautious route-finding and conservative decision-making essential.	Natural avalanches possible; human-triggered avalanches likely.	Small avalanches in many areas; or large avalanches in specific areas; or very large avalanches in isolated areas.
2 Moderate	2	Heightened avalanche conditions on specific terrain features. Evaluate snow and terrain carefully; identify features of concern.	Natural avalanches unlikely; human-triggered avalanches possible.	Small avalanches in specific areas; or large avalanches in isolated areas.
1 Low	1	Generally safe avalanche conditions. Watch for unstable snow on isolated terrain features.	Natural and human-triggered avalanches unlikely.	Small avalanches in isolated areas or extreme terrain.

Safe backcountry travel requires training and experience. You control your own risk by choosing where, when and how you travel.

The avalanche danger combines the likelihood that an avalanche may be triggered with the destructive size of the avalanche as well as the distribution and extent of the avalanche problem across the terrain. In general, the higher the danger rating, the greater the likelihood of a larger, more destructive avalanche.

Current statistics tell us that most North American fatal accidents occur when the danger is rated Moderate, Considerable, or High—with the percentage of fatalities being similar in each of those ratings.[10] This suggests that messaging is effective when the avalanche danger is Low or Extreme. It also suggests that there is still a great deal of uncertainty associated with the Moderate, Considerable, and High danger ratings. This may be because of the terrain understanding, judgment, and decision-making skills required of a group. Danger scale descriptors (i.e. Moderate) alone are not enough to be a useful risk management tool.

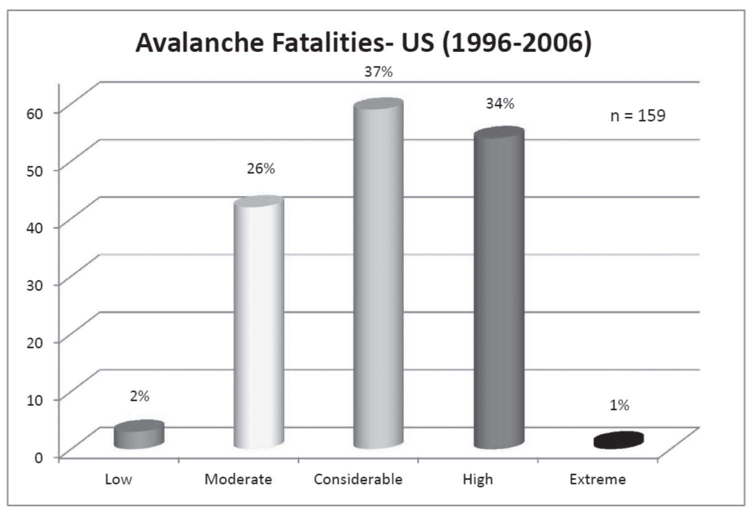


FIGURE 4: FATAL AVALANCHE ACCIDENTS AND FORECASTED DANGER LEVEL

9 Statham, Grant, Bruce McMahon, and Ian Tomm. "The Avalanche Terrain Exposure Scale." Montana State University Library, ISSW (2006): 491-497. http://arc.lib.montana.edu/snow-science/item/970

10 Greene, E. et al. "Fatal Avalanche Accidents and Forecasted Danger Levels: Patterns in the United States, Canada, Switzerland and France." Montana State University Library, ISSW (2006): 640-649. Telluride, CO.

PLAN
Anticipate The Hazard

Backcountry travelers also need to have an understanding of avalanche terrain, knowledge of the terrain in which they are traveling, and a high-performing group in order to make sound decisions together in avalanche terrain.

The most successful risk management strategy involves knowing where the problem terrain lies and ensuring your route plan avoids it. The daily danger rating from the advisory helps to quickly compare conditions with nearby regions. Monitoring the danger each day can reveal the trend, suggesting in a general sense whether conditions are improving, staying the same, or getting worse.

When reading the advisory, you need to understand:
What is the danger trend?
Ex: "Getting worse. Tuesday: Moderate in alpine; Today: Considerable in Alpine

How do timing and/or forecasted weather events factor in?
Ex: "Wind picking up in afternoon, and could make new wind slabs and conditions worse"

DISCUSS THE ADVISORY'S KEY MESSAGE

☑ **Anticipate The Hazard** Read the local avalanche advisory. Seek expert opinion.

Discuss current & forecast weather factors that can affect travel or hazard.
8-10" new snow overnight. 2-4" expected today. Winds were calm overnight but are supposed to increase today—West Winds 15-25 mph in forecast. Overcast skies and low visibility expected today. Cold temperatures—High of 20F in forecast.

Identify the avalanche problem and location. Discuss the danger trend and timing.

	size	elev	aspect	terrain features	danger trend/timing
Wind Slab	Small to Large	Near and above TL	NE-E-SE	Below ridgetops and in cross-terrain features	Increasing as the day goes on and snow/winds pick up
Dry Loose	Small	all	all	All slopes >35 degrees	Increasing as the day goes on and as more snow accumulates on sheltered slopes

Discuss the advisory's key message. MODERATE danger at all elevations. Forecasters expect all avalanche activity to be confined to recent storm snow resting on top of the 2/15 crust. Avoid slopes where the wind has transported the storm snow into slabs. Expect conditions to change as the day goes on. Defer to safer options as blowing snow and low visibility increase uncertainty.

The advisory's key messages and travel advice (sometimes referred to as the bottom line or summary) is important advice not to be missed. These summaries may provide a brief synopsis describing the day's main concerns, and what clues may make them identifiable in the field. With your backcountry partners, discuss the advisory's key message. Your travel plan needs to account for and provide a solution to each of the hazards and problems the summary describes, along with any additional ones your group may identify. The key message also serves as the summary to which you will compare your end of day summary as you DEBRIEF THE DAY in the process of gaining intentional experience.

Example of a Key Message: "Storm slabs, persistent slabs, and weak cornices make for a complex snowpack. I'd continue to choose conservative terrain and limit my exposure to overhead hazards."

PLAN YOUR ROUTE

It is now time to *Plan Your Route* in response to the group you assessed during *Assemble Your Group*, and the hazards your group identified during *Anticipate the Hazard*. Your group will consider the goals and abilities of the group, while also considering the conditions to identify where your group will travel and which terrain your group will want to avoid.

As stressed earlier, teamwork and consensus are the foundation of *The AIARE Framework*. *Planning Your Route* means reaching group consensus on where and how you will travel in the backcountry. If team members can't all agree on a safe, fun route, it indicates unfamiliarity or uncertainty with conditions or terrain—a sign that the group may be in over its head.

But how do you achieve consensus, in specific terms?

Voice all concerns. Each member of the group should read the advisory and have an opinion on the day's conditions and what sort of terrain is safe. Other hazards should be considered, too—weather, intense cold, group preparedness, etc. Everyone's voice must be heard to truly reach consensus. On some days this is easy, while on others it can be contentious. If members don't feel heard, the group's communication is off.

Challenge assumptions. Avoid groupthink by naming or acknowledging any assumptions made by the group or individuals. Play the devil's advocate when the group is in agreement to ensure all points and sides have been considered.

Respect any veto. If you put the necessary work into finding backcountry partners who you trust, then their veto should get your attention. One teammate's mind might be changed upon respectful discussion, but in the end, a veto is a veto. Often, accident victims remember wanting to voice concerns or veto a decision, only to hold their tongue because of social pressure, lack of confidence, or other stressful group dynamics. When any team member's veto or concerns will be considered without backlash or judgment, it reduces the chances of someone's misgivings going unheeded.

Decide by consensus. Consensus means everyone, not just the majority, agrees to a decision. If consensus can't be reached, it's a clear signal that there are enough red flags in the day's conditions or route selection that the plan might be a bad idea. The group's discussions should address the day's danger rating, avalanche problems, the proposed routes, and whether or not the team is willing to be exposed to the risks involved.

PLAN

Plan Your Route

PREVIEW TERRAIN

Utilize the prompts on page 2 of *The AIARE Fieldbook* as your group uses maps, photos, and local knowledge to identify a route that considers the makeup of the group and the conditions.

> ☑ **Plan Your Route** Voice all concerns. Respect any veto. Decide by consensus.
>
> **Preview terrain.** LIMIT EXPOSURE. No Name Gulch Tour.
> Open Areas: No Name Trees, Green Monster Glade, Mr. Toad's Wild Ride.
> Closed Areas: Chutes & Ladders, Big Boy Bowl, Dream Line.
>
> Put skin track on left side of creek until 10,850 ft, and then cross creek to avoid steep gulley. Avoid traveling under wind loaded convexity on Big Boy Bowl. Cross slope on bench at 11,400 ft to get to top of Green Monster Glade.
> Observation Locations: 1. TH; 2;. Bench at 11,400 ft; 3. Top of Green Monster Glade on ascent;
> Group Check-In Spots: 1. Creek Crossing; 2. Top of Green Monster Glade; 3. Top of Mr. Toad's Wild Ride.
>
> **When uncertain discuss a less exposed alternate route.**

Plan to Limit your Avalanche Exposure

Before discussing the specifics of the plan, the group should agree to a strategy for limiting avalanche exposure. The table shown here and on page 3 of *The Fieldbook* can help the group choose the best strategy that accounts for sources of uncertainty or lack of familiarity.

Plan to Limit Your Avalanche Exposure

- When the danger increases, choose simpler terrain
- When the trip or conditions are unfamiliar, choose simpler terrain
- Assess each slope. Apply normal travel precautions
- Consider traveling with an expert capable of managing challenging and complex terrain

Group Confidence	Today's Strategy	Avalanche Terrain Exposure Scale
Less Confidence	**Keep it simple** and **avoid avalanche terrain.** If necessary, cross the run out zone one at a time.	Simple - Exposure to low angle or primarily forested terrain. Some forest openings may involve the run-out zones of infrequent avalanches. Many options to reduce or eliminate exposure.
↕ Identify sources of uncertainty	**Limit exposure by avoiding the obvious paths, steepest slopes and trigger zones.** Consider entering slopes below start zones or lower in the track. Or if in doubt, avoid avalanche terrain.	Challenging - Exposure to well defined avalanche paths, starting zones or terrain traps; options exist to reduce or eliminate exposure with careful route-finding.
More Confidence	**Step it out cautiously and reduce risk by choosing terrain with less consequence.** Low or no chance of avalanches today.	Complex - Exposure to multiple overlapping avalanche paths or large expanses of steep, open terrain; multiple avalanche starting zones and terrain traps below; minimal options to reduce exposure.

Start by identifying the sources of uncertainty in the group or with the conditions:

- Are there new partners?
- Are there any health or fitness issues?
- Are there other sources of stress or preoccupation that would detract a group member from fully engaging in the decision-making process?
- Is the terrain new or unfamiliar?
- Do all group members have experience with today's conditions?
- Is the weather forecast a sure bet, or might conditions change during the day?

The more sources of uncertainty, the lower the group confidence. The lower the group confidence, the more conservative the terrain choices should be. The Avalanche Terrain Exposure Scale developed by Parks Canada provides three general categories of terrain (Simple, Challenging, and Complex) to match the group's strategy to limit avalanche exposure. The types of the terrain found in each category are described in the second column of the table.

When uncertainty is highest and group confidence is lowest, the group should choose the strategy to keep it simple by avoiding avalanche terrain. New partners, the first time in an area, or lack of familiarity with conditions, such as a particular avalanche problem type, all warrant opting for Simple Terrain.

Simple Terrain features low angle or primarily forested terrain. Some forest openings may involve the runout zones of infrequent avalanches, but offer many options to reduce or eliminate exposure.

The photo in Figure 5 shows two peaks near the tree line that feature sheltered and partly forested slopes. The arrows indicate possible routes. These slopes are inclined 25 degrees or less; avalanches are unlikely, even in unstable conditions.

Monashee Power Cats

FIGURE 5: SIMPLE TERRAIN IN THE SOUTHERN MONASHEE MOUNTAINS, BC

As sources of uncertainty decrease, such as traveling in familiar terrain and/or in conditions your group has experienced before, your group might choose to advance on to steeper slopes and more Challenging Terrain.

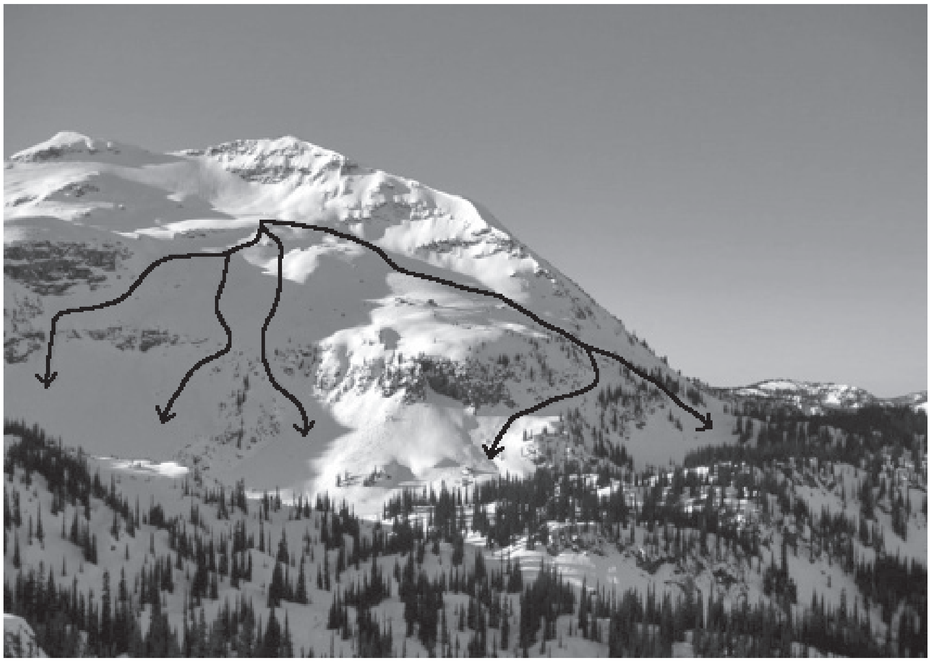
The photos in Figures 6 and 7 illustrate Challenging Terrain where the group may have exposure to well defined avalanche paths, start zones, or terrain traps, but options exist to reduce or eliminate exposure with careful route finding. This requires a group with strong communication, management, and the ability to carefully select terrain, as it is easy to find yourselves in steep avalanche terrain.

Monashee Power Cats

FIGURE 6. CHALLENGING TERRAIN IN THE SOUTHERN MONASHEE MOUNTAINS, BC

Monashee Power Cats

FIGURE 7: CHALLENGING TERRAIN IN THE SOUTHERN MONASHEE MOUNTAINS, BC



Monashee Power Cats

FIGURE 8: COMPLEX TERRAIN IN THE SOUTHERN MONASHEE MOUNTAINS, BC

On a day when everything aligns, sources of uncertainty are low and group confidence is high. The group may choose to ***step it out cautiously*** and reduce risk by choosing terrain with less consequence. This may mean choosing Complex Terrain that has exposure to multiple overlapping avalanche paths or large expanses of steep, open terrain. There may be multiple avalanche start zones and terrain traps below with minimal options to reduce exposure.

Figure 8 illustrates Complex Terrain, which features few or no options you can take to limit your exposure to avalanche prone slopes. Even the lowest angled slopes are still exposed to serious avalanche terrain. Riders venture on this terrain only when they have the experience to assess that the snow is stable, the local hazard is low, and avalanches are unlikely.

The group should only choose *Complex Terrain* when partners, conditions, and terrain familiarity align. Anytime the group observes something about conditions or the group that is unexpected, the group should default to simpler terrain. If observations indicate danger is increasing, choose simpler terrain. If the conditions or the terrain proves to be unfamiliar, choose simpler terrain. The group may consider traveling with an expert capable of managing Challenging and Complex Terrain for them if the conditions or the terrain are unfamiliar.

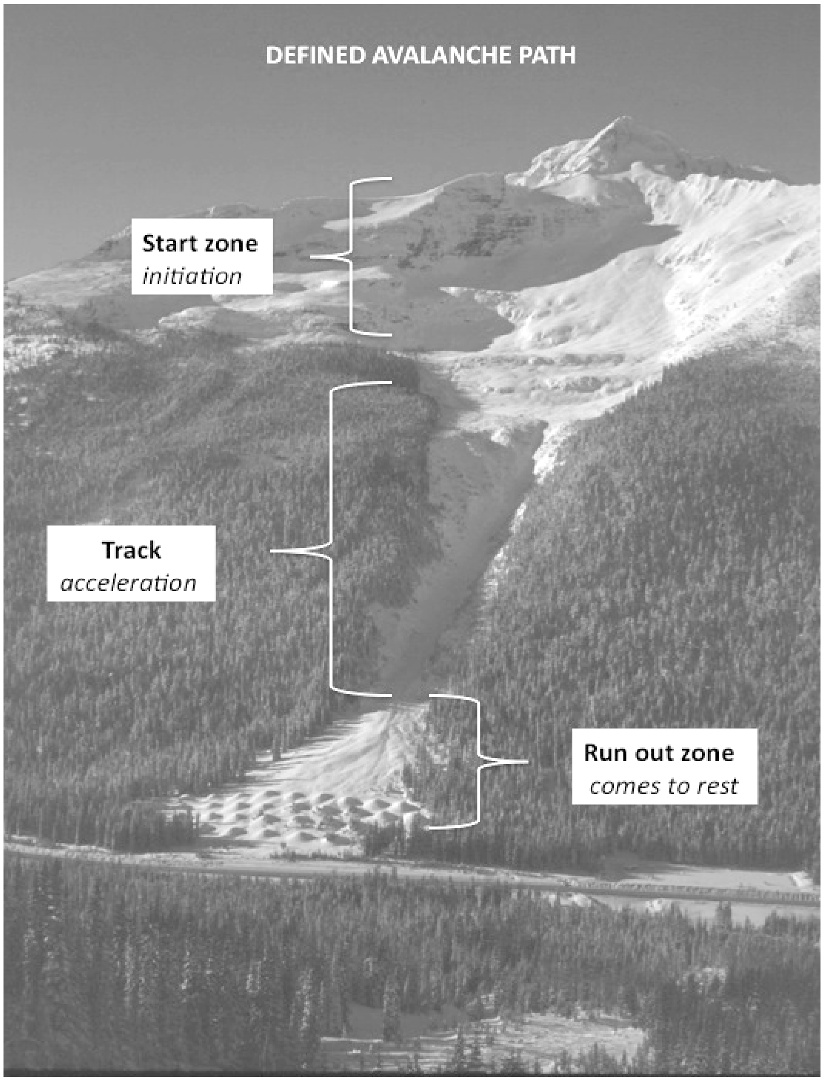
Whatever strategy the group chooses, and whatever the type of terrain the group will travel in, each slope should be assessed and normal travel precautions should be applied, as will be discussed in the next chapter: RIDE SAFELY.

Use Maps, Photos, and Guidebooks to Identify a Route Plan that Considers Conditions

As a part of PREPARE, you have developed a catalog of trip options that can help you match appropriate trips to the group and the day's conditions. The catalog should include references to guidebooks and maps and photos that can help your group plan a trip.

Start by identifying an area that would be appropriate for the group and the conditions. The size of this area will depend on the length of the trip and the mode of transport. Skiers and snowboarders will most likely cover more ground than snowshoers. People on snowmobiles or snowbikes will cover significantly more area than any human-powered travelers.

Within that area, identify a couple of routes, or a route with a few other options or variants. This route should match the group's goals and objectives discussed during *Assemble Your Group*.



Colin Zacharias

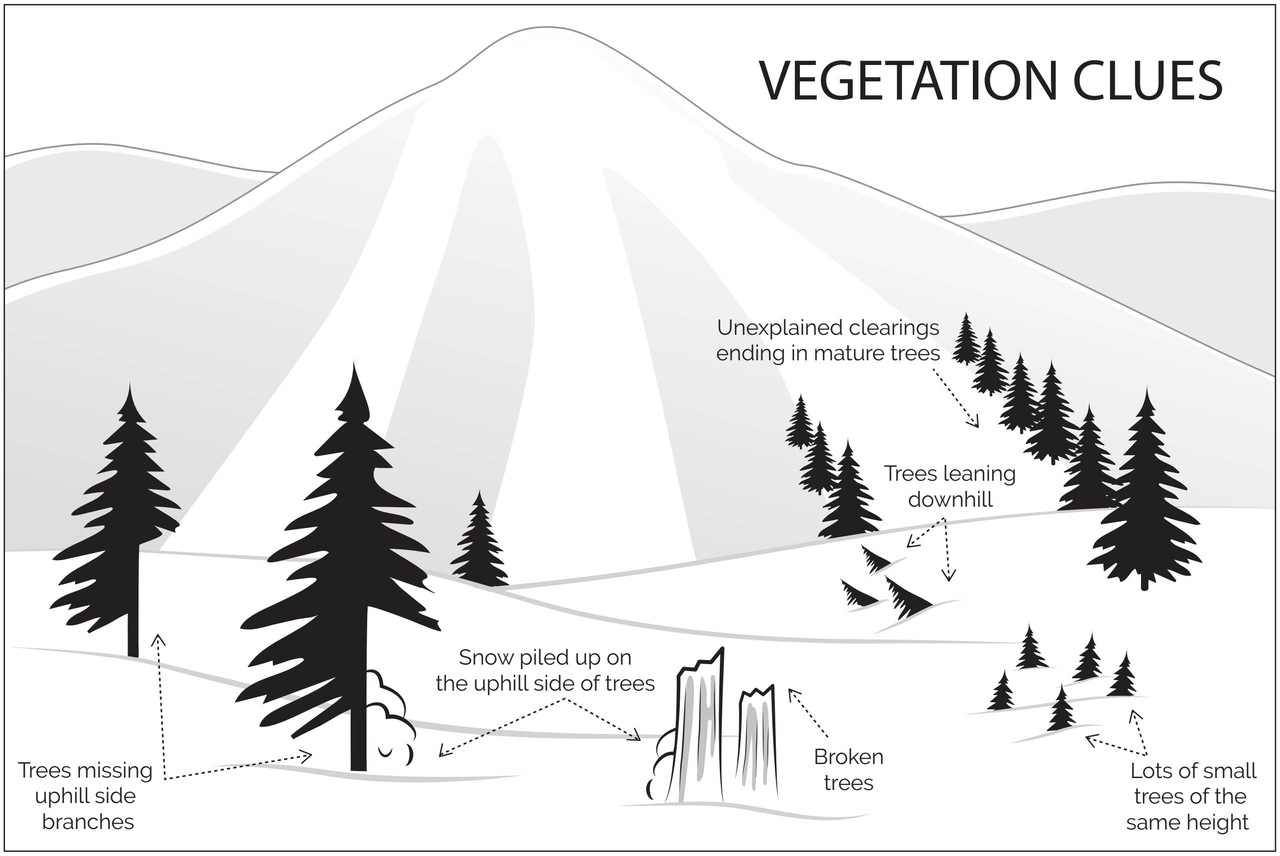
Identify Avalanche Slopes Along the Route. Avoid Potential Hazards.

Once you agree upon a route, dive further into the details of your plan. Identify slopes along your route where avalanches are possible. This entails identifying where avalanches have historically occurred and what terrain has the potential to avalanche given the conditions.

Defined avalanche paths are specific locations where avalanches repetitively occur and are the clearest indicator of where avalanches have historically occurred.

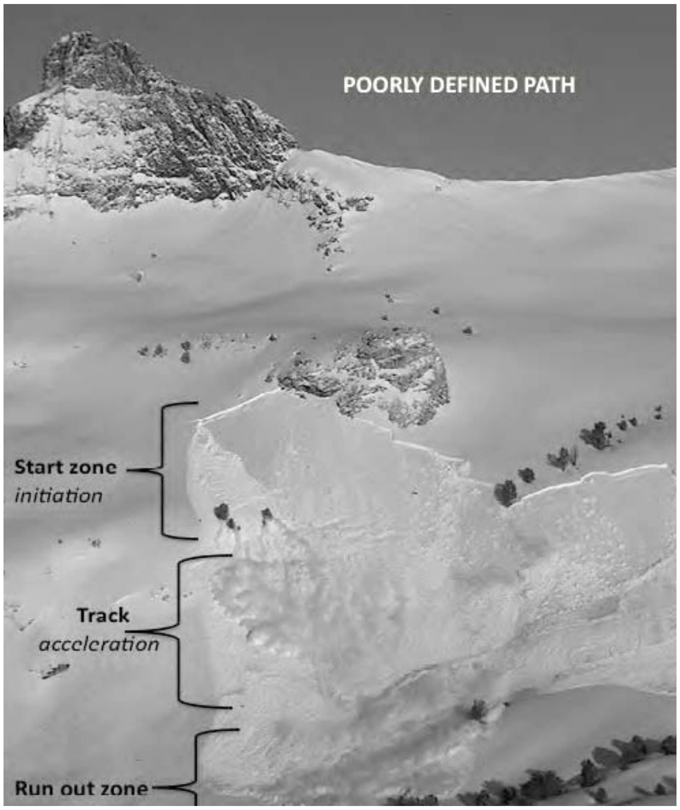
In some cases, avalanche paths are well defined by trim lines where vegetation does not grow and contain three recognizable features:

- *The start zone*, where avalanches typically start. Slopes are 30-45 degrees for slab avalanches, possibly steeper for loose snow avalanches.
- *The track*, where the avalanche typically gains mass and speed as it picks up snow and other debris on its descent.
- *The run out zone*, where the avalanche begins to slow down and lose mass as snow and debris are deposited.



In addition to defined paths, avalanches that have previously run through an area leave physical clues. In photos and in the field look for:

- Unexplained forest openings in steep terrain
- A group of trees broken above a certain height
- Flagged trees, where the branches have been stripped off the on uphill side
- Lumps or chunks in a deposit zone
- Snow plastered to the uphill side of trees or rocks



T. Carter

Be wary of assuming too much about the somewhat arbitrary definition of start zone, track, and runout zone or the idea that slides start only at the top of the mountain in the steepest part of the start zone. It can be harder to identify avalanche paths in alpine terrain. In many cases, the start zone, track, and runout zone are indistinguishable from one another, and the avalanche path is almost indistinguishable from the surrounding terrain. In the most unstable conditions, any slope steep enough to slide down is steep enough to avalanche.

Small, less obvious avalanche paths include steep ravines or creeks. Boulder or talus fields, or glades with widely spaced trees are likely open enough for avalanches to release and run. Logging clear cuts that have been deforested and are exposed to wind and sun can avalanche, particularly on the artificially steepened slopes above roads.

After reading the avalanche advisory, you should have a good understanding of the slopes, aspects, and elevations that may have elevated danger. Highlight those areas and identify them clearly on your proposed route. You can shade this section on your paper, digital topo maps, or markup photos of where you are traveling—anything to clearly identify where you'll find the avalanche problems or aspects described in the advisory.

Once you've done this, determine if your route avoids these slopes and avalanche paths. Can you minimize exposure to these features while traveling? Can you alter your path to provide more options or minimize exposure? Drawing out your route on a topo map will help you determine if it's more or less exposed to these problems areas, and avalanche terrain in general. You might also lay out your proposed route on an online map or mapping app for smartphones. Many mapping websites and apps will shade slopes by angle, so you can see where steeper terrain lies and judge your route's exposure to it.

If you find yourself having trouble devising a route that avoids avalanche-prone slopes described in the advisory and identified on the maps and photos--the solution is a simple one. Default to simpler, less exposed terrain. Plans should be flexible and always favor simpler, less exposed terrain as unfamiliarity and uncertainty increases. Use the same maps and photos to identify terrain with less avalanche exposure and build your route from there.

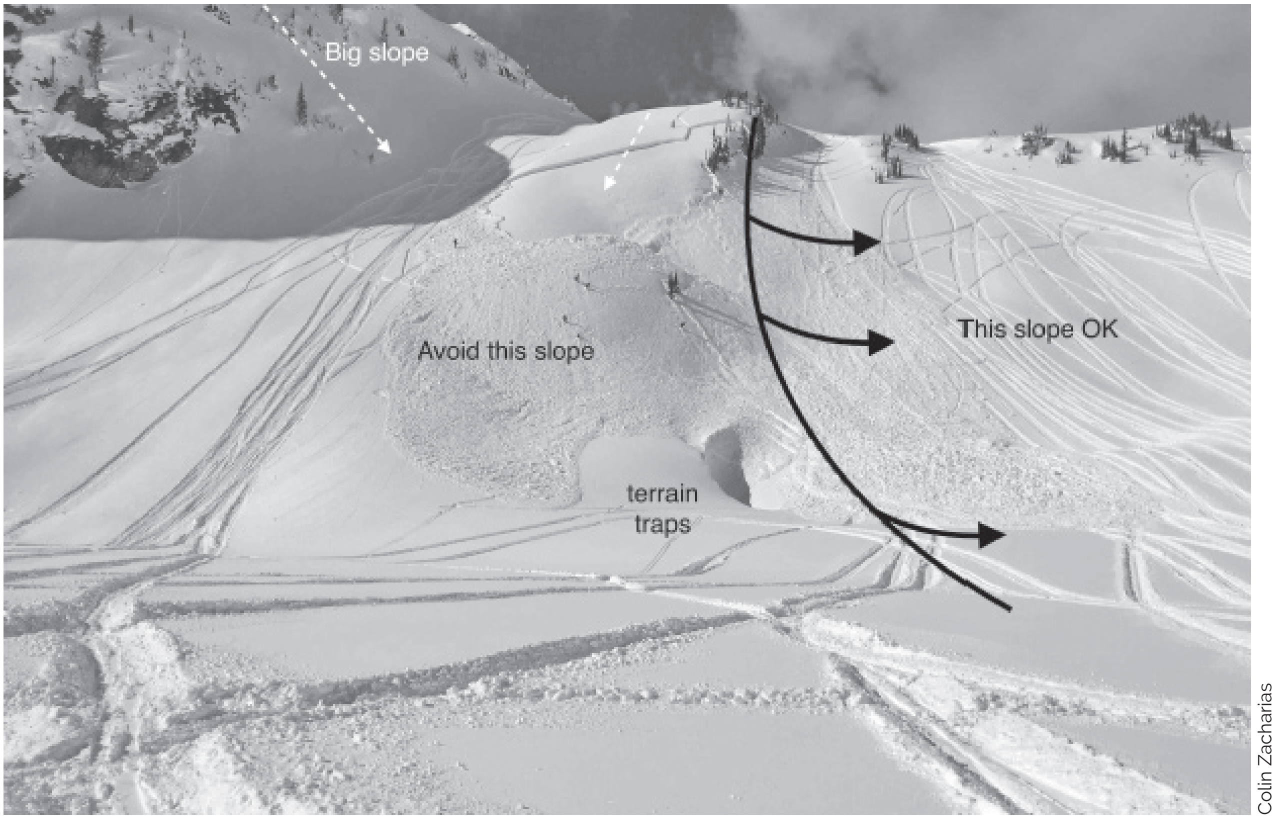


FIGURE 9: EXAMPLE OF USING AN OLD PHOTO FROM A POPULAR SNOWMOBILING AREA.
The avalanche and debris help to define the hazard for future discussions. A rider triggered an avalanche that had a 1m deep fracture and a 2-3 m deep debris pile. It could have buried both sled and rider.

You can annotate photos by printing and drawing on them or digitally marking them up and saving them as part of the information in your trip options catalog.

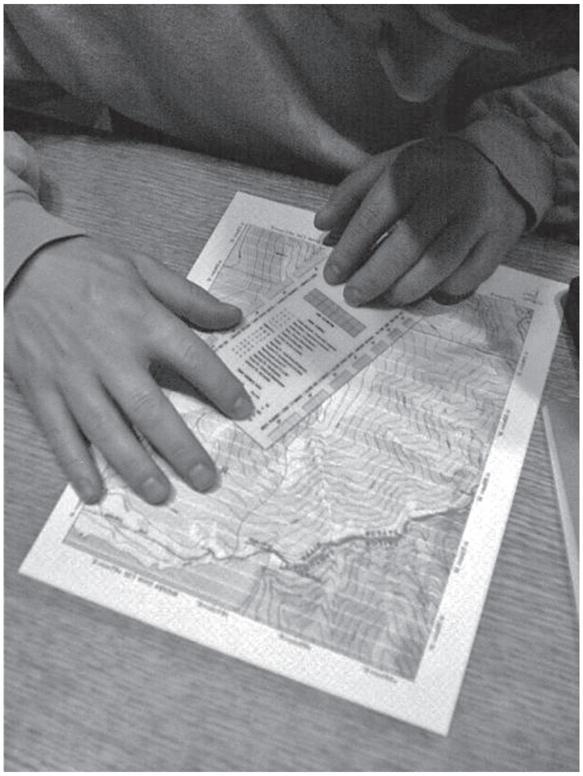
Pulling up terrain images on your phone or laptop will also help you discuss specific features in the context of the day's hazard. Technology provides so many options to clearly and visually communicate while talking about terrain and route options. Pictures snapped on a phone on a previous trip can be easily marked up and shared with others. Multiple map websites and mobile apps with visualization features make it easier for you to visualize terrain and talk about specific terrain features with the group.

Once your group has identified a route and the avalanche prone slopes along it, highlight what slopes should be appropriate given the day's conditions. The advisory gives you an indication of what slopes may be avalanche prone, but don't forget to highlight slopes that should be appropriate options for the day's hazard, or open, given the day's hazard rating and snow conditions.

Likewise, the group should identify and agree not to ride certain slopes, routes, and runs based on conditions the group summarized in *Anticipate the Hazard*. If the advisory identifies the primary avalanche problem with a high likelihood on north-facing, steep terrain, the team should identify and agree not to ride this terrain before leaving the trailhead. This process of closing terrain before the group goes into the field is one of the most important tools for mitigating human factors.

This practice of closing terrain derails our natural tendency to talk ourselves into something in the moment. It ensures we make a reasoned, rational decision, rather than a knee-jerk, emotional one. At the top of an untracked slope on a bluebird day it's easy to get caught up in the moment and feel the urge to just go for it. By applying a group decision to rule out avalanche-prone terrain and noting it in *The Fieldbook*, we are less likely to be overcome by emotion and give in to temptation.

Note Observation Locations and Group Check-in Stops



Tom Murphy

Plan specific locations along the route the group has chosen, where it can regroup, preview upcoming terrain, and discuss options. By identifying observation points along the way, the group will have ample opportunity to *Monitor the Conditions Along Your Route* (which is discussed Chapter 4: RIDE SAFELY). This gives the group the chance to observe any avalanche activity, note any changes in weather and its associated hazards, and discuss observations with the team.

As part of *The AIARE Framework*, the group agrees to travel together and decide together. Implicit in that commitment is actually being together. The group can't have a real discussion if everyone is spread out while traveling. Define what "being together" means for your group for the day. Designate exact spots where the group will come together, compare notes, and *Check in With the Group & Reassess Your Plan*. If the last person in the group has serious doubts about conditions or your objective, the team needs to hear these thoughts and discuss them. This means waiting for everyone to regroup and taking the time to discuss conditions.

Note Your Turnaround Point and Time

Integral in planning a trip is estimating how much time the team will take to travel through the terrain and back to the trailhead. There are several methods for doing this, including online resources for trip planning. Gauge the time it will take the team to cover each leg of the trip and make note of it in the *Plan Your Route* section in your *Fieldbook*. Compare your estimated times to your actual times to refine and improve your planning skills.

After building a travel plan with time estimates, note a turnaround point and the time the team should return to the trailhead. A good rule of thumb is to leave an hour of daylight as a buffer, in case of issues with equipment, slow travel, or an error in navigation. That extra hour of daylight may mean the difference between debriefing somewhere warm and safe and a stressful trip back to the trailhead in the dark.

When Uncertain Select an Alternate Route with Less Exposure

☑ **Plan Your Route** Voice all concerns. Respect any veto. Decide by consensus.

Preview terrain. LIMIT EXPOSURE. No Name Gulch Tour.
Open Areas: No Name Trees, Green Monster Glade, Mr. Toad's Wild Ride.
Closed Areas: Chutes & Ladders, Big Boy Bowl, Dream Line.

Put skin track on left side of creek until 10,850 ft, and then cross creek to avoid steep gulley. Avoid traveling under wind loaded convexity on Big Boy Bowl. Cross slope on bench at 11,400 ft to get to top of Green Monster Glade.
Observation Locations: 1. TH; 2;. Bench at 11,400 ft; 3. Top of Green Monster Glade on ascent;
Group Check-In Spots: 1. Creek Crossing; 2. Top of Green Monster Glade; 3. Top of Mr. Toad's Wild Ride.

When uncertain discuss a less exposed alternate route.

The plan allows us to choose simpler terrain if conditions change. Plenty of low visibility options that avoid avalanche terrain if our uncertainty increases throughout the day.

After consulting maps, terrain images, and guidebooks the team should have a pretty good idea of an appropriate route given the day's hazard rating and the overall compatibility of the group.

If the team finds itself unable to answer questions prompted by the checklists, building consensus, or has difficulty executing the risk management process, it's a sign of uncertainty. Whether it's because of the group, conditions, a particular avalanche problem, a weather pattern, or even just logistics like locating the trailhead or a backcountry hut, it's a clear sign that the team should opt for a simpler route.

Remember: As uncertainty increases, defer to simpler terrain.

Some examples of uncertainty:

- *Lack of current weather and snow information. For example, you don't know how much snow fell overnight, or how much wind blew at ridgetop, or how the local weather forecast compares to other drainages. Visiting a zone without an avalanche forecast, or a week-long backcountry trip without connectivity can put you in this situation.*
- *Few or no recent avalanche observations in the area you plan to travel.*
- *Unfamiliar terrain: no group member has completed the proposed trip, or the group lacks a good map, guidebook, and/or terrain photos.*
- *New group member: the group seems great but is newly formed. Perhaps the group has one or two new members, whose strengths and weaknesses are unknown.*

Teams who plan to venture out with each other several days in a row can consider using day one as a shakedown tour. During a *shakedown tour*, the team chooses a shorter, simpler objective to verify the group works well together and everyone's equipment functions as needed. Meanwhile, the team can gather more snowpack and weather information, increase terrain familiarity, and take photos to use on future outings.

DISCUSS YOUR EMERGENCY PLAN

Travel in the backcountry and eventually you will encounter the unexpected. Gear failure, a major navigation error, an injury, an unexpected storm—these are just a few potential problems that can all turn into serious emergencies without proper planning and preparation. Just as it is important to practice avalanche rescue and for the worst, it is also vital to have a plan and gear for other backcountry emergencies.

An important part of the trip planning process is discussing an emergency plan. Take notes on the discussion in *The AIARE Fieldbook*. Use the prompts from page 2 of *The Fieldbook* to discuss and record your team's contact information, what gear and devices each person has readily available, etc.

☑ Discuss Your Emergency Plan Assign group gear.

Anya B. has itinerary
Gear Assignments:
John M—Sled/Tarp
Chris W—Repair Kit

Anya B—First Aid
John M —PLB and Nav. Kit
(hard copy of map, compass
and altimeter)

Everybody: Emergency #s
Tour Plan/Map on phone
Food/Water
Extra layers

Discuss, given our experience, why we think we can safely & effectively carry out this plan?

Review Advisory's message: This tour is appropriate for the day's weather, snowpack and avalanche conditions. Anya B. toured in area yesterday and verified the advisory. John M. checked local weather stations; he verified the 8-10" overnight and calm winds. Chris W. adds that terrain decisions should be

Who Else Has Your Itinerary?

The first step of this important checklist is sharing the trip plan with someone at home. This person needs to understand what the group is doing and how to get help if the group is not back by a predetermined time. If your backcountry communication strategy breaks down and you're stranded, this step ensures outside help will eventually arrive or at least begin searching in the right area.

Adequate Food, Water, and Warm Layers

When your team plans its trip, consider the weather forecast and the expected duration of the trip. This allows team members to pack adequate food, water, and warm layers. If you lose your way or someone gets injured, does your group have the endurance and supplies to weather the night in the cold? What steps can you take to ensure you can protect yourselves from hypothermia or cold injury (frostbite, etc.)?

SOS Device and Emergency Numbers

The Fieldbook has abundant space to make notes of pertinent information, including team member names and emergency contacts. Write down relevant emergency numbers local to where you are traveling, such as the ski area, government agency dispatch, and search and rescue numbers. Research ahead of time where cell coverage is available or expected in the areas where you will be traveling. For areas without cell coverage, investing in a satellite communication device should be strongly considered. A satellite device, like a Spot or InReach, will send an SOS signal from almost anywhere in the world.

Some backcountry travelers will also take FRS two-way radios (walkie-talkies) and can chat with each other in the field. This is helpful and improves communication when managing difficult terrain.

Gear for Self-rescue

Your group should be capable of self-rescue in the event of an injury in the backcountry. Distribute a lightweight tarp or rescue sled, a first aid kit, a repair kit, and an extra warm jacket among team members before leaving the trailhead.

Practice building and using your rescue sled system regularly.

A functional rescue sled can be assembled from a lightweight tarp and skis and/or poles. Alternatively, you can purchase a rescue sled made specifically for that purpose. For just a couple of extra pounds, your team can have a reasonable system for moving an injured member to a safer/warmer area. **Regardless of which system you choose, you must practice building it.** Just like avalanche rescue, emergency sled building skills should be practiced regularly. Skills left unused expire. Make building sleds for rescue part of your regular practice as a part of PREPARE.

A first aid kit will help you handle cuts, sprains, blisters, and minor illnesses. Purchase a commercially available kit or assemble your own. In either case, make sure your kit includes the basic first aid materials for injuries or illnesses encountered during winter backcountry travel. Consider taking a Wilderness First Aid or Wilderness First Responder Course if you are frequently traveling in the backcountry.

A good repair kit can keep a minor gear problem from becoming an overnight stay. Items like duct tape, bailing wire, a bit driver (with relevant bits), a pole-repair kit, a multi-tool, skin wax, zip ties, ski straps, and a spare pole basket will all get used eventually. A small headlamp stashed in a repair kit may come in handy, as well as fire starter material. You should also try to acquire spare parts specific to your equipment. Spending a few hours collecting all of this material before the season will save you serious headache when it is required in the field.

Navigation Tools

You probably already have some basic navigation skills from planning your trip, but navigating in the field requires a paper map, compass, and probably a GPS.

The paper map and compass function no matter what. Consider printing maps on waterproof paper so they'll withstand snow and moisture. You can also store maps in a sealed plastic bag. Don't skimp on your compass—it should be high quality and have a mirror for more accurate sighting and taking your bearings.

There are several reliable GPS apps available for smartphones. Choose one that works for you and then know its functionalities. If you rely solely on your phone or GPS device, however, your ability to navigate depends solely on your battery life. Keep in mind that batteries of many cell phones and other electronic devices drain faster in the cold.

With a topo map you can get an estimate of your location, but adding an altimeter, which measures your altitude, will give you even more detailed information that will greatly aid your navigation with a map.

Any navigation tool is only as good as the person using it, so practice and familiarize yourself with whatever tools you have at your disposal.

Discuss, Given Your Experience, Why You Think You Can Safely and Effectively Execute This Plan.

☑ Discuss Your Emergency Plan Assign group gear.

Anya B. has itinerary
Gear Assignments:
John M—Sled/Tarp
Chris W—Repair Kit

Anya B—First Aid
John M —PLB and Nav. Kit
(hard copy of map, compass
and altimeter)

Everybody: Emergency #s
Tour Plan/Map on phone
Food/Water
Extra layers

Discuss, given our experience, why we think we can safely & effectively carry out this plan?

Review Advisory's message: This tour is appropriate for the day's weather, snowpack and avalanche conditions. Anya B. toured in area yesterday and verified the advisory. John M. checked local weather stations; he verified the 8-10" overnight and calm winds. Chris W. adds that terrain decisions should be should be simple today due to cold temps and low visibility and No Name Gulch provides lots of options.

Discussing Your Emergency Plan is the last step in planning your trip and is perhaps the most important part of the trip planning process. It serves as a way to double check your team, the conditions, and your route plan. This is the opportunity to find any holes in the plan while the group is still in a place to make rational decisions and plan changes.

Group communication and a solid team dynamic are the keys to managing risk. Discuss the overall plan, the team, the route, and the avalanche danger once more with your team. Try to identify any gaps in the team's knowledge and determine what is necessary to carry out the travel plan safely. Discussions like these offer great opportunities to invite a devil's advocate into the conversation. Look at all angles of the plan and consider what can potentially go wrong.

The pre-mortem (as opposed to a post-mortem) conversation allows you and your teammates to view potentially dangerous scenarios before they happen, giving the team the ability to glean insight into an accident that hasn't occurred yet. Conduct a pre-mortem by imagining a situation where something goes wrong or a part of the plan fails. This can be a powerful tool in exposing gaps in the team's plan, strategy, or mindset. It also gives the group an opportunity to understand how well it is prepared for unexpected events.

A pre-mortem conversation can also be good to have at decision points or during check-ins throughout the day. Gather the group and imagine the worst-case outcome such as an avalanche accident involving your team. Then, discuss what factors in the day's planning and tour could lead to such an outcome. Once you've identified those factors, you can avoid them through terrain selection, an updated route plan, or by making more observations.

Appointing a team member to play the role of a devil's advocate throughout the trip will instigate a conversation about any element that is deemed worthy of discussion. Designating one person to do this, rather than leaving it to anybody to speak up keeps personality and ego out of the process. Rotate the role between trips or even during the day and see if it works for the team.

Chapter 2:
Summary

PLAN YOUR TRIP

- ☑ Assemble Your Group
- ☑ Anticipate The Hazard
- ☑ Plan Your Route
- ☑ Discuss an Emergency Plan

The human brain can justify a lot of bad decisions in the heat of the moment. To avoid letting desires cloud your judgment, it is important to make critical decisions including where to go and where not to go prior to the start of any trip. The PLAN YOUR TRIP portion of the AIARE Framework guides us through intentionally ***Assembling a Group*** with similar risks tolerance and objectives, ***Anticipating the Hazard*** through avalanche advisories and expert advice, ***Planning a Route*** that considers the team and conditions and allows for consensus and ***Discussing an Emergency Plan*** in the event something goes wrong.

CHAPTER 2 QUESTIONS

1. Describe 2 reasons why a pre-trip plan (PLAN YOUR TRIP) can help to mitigate human factors that can challenge decisions and terrain choices.
2. How do you get around the potentially awkward issue of discussing compatible goals and risk tolerance with your backcountry travel partners?
3. Describe why a 3-person group can theoretically make better decisions than a 2-person group?
4. How can wind speeds of over 25 kph (15 mph) increase the hazard during a heavy snowfall?
5. The avalanche advisory highlights a principle concern or avalanche problem each day. It is up to you to anticipate the day's risk and make a plan that avoids the day's problem. After you read through the advisory, what are four questions that you should ask yourself to ensure that you grasp the advisory's key messages?
6. Why listen to a dissenting voice in the group who keeps challenging some of your statements and assumptions?
7. Why plan observation and check-in locations along the route?
8. If you are questioning whether the group can pull off the day's plan, what do you do? How can you effectively make your point?

See Page 98 for answers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Chapter 3:
Ride Safely

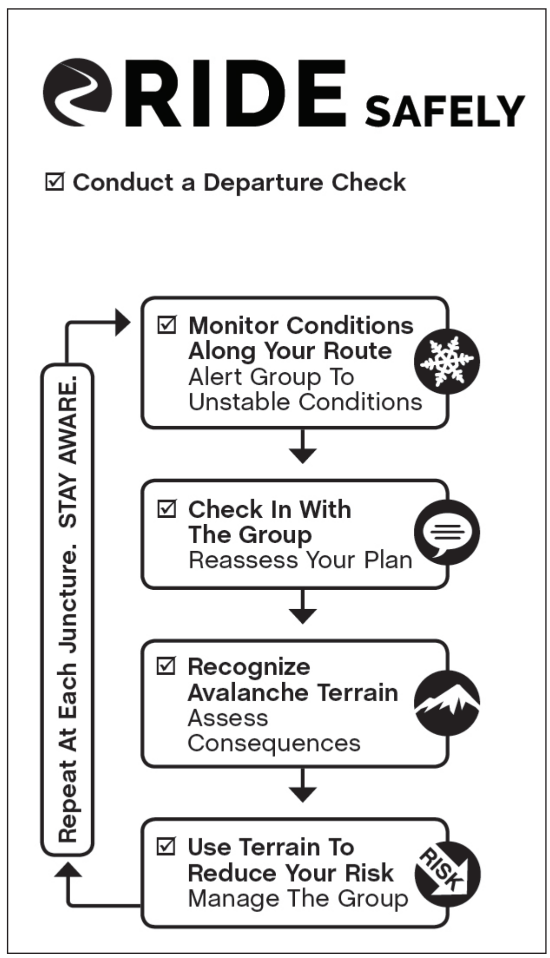
RIDE SAFELY

- ☑ Conduct A Departure Check
- ☑ Monitor Conditions Along Your Route
- ☑ Check In With The Group & Reassess Your Plan
- ☑ Recognize Avalanche Terrain
- ☑ Use Terrain To Reduce Your Risk

RIDING SAFELY in the backcountry is the reason your group has PREAPRED, PLANNED, and taken the time to engage with *The AIARE Framework*. But even good planning does not make a trip run by itself. Engaging with the team to maintain situational awareness and choose terrain is accomplished by using the RIDE SAFELY checklist. The outline of the RIDE SAFELY checklist is illustrated in the grey box to the left. Below is a more detailed flow chart that shows how the checklist items are put into action. Throughout this chapter, you'll see graphics with the detailed checklist points for each of the four key icons shown below. The complete checklist is shown on page 5 of *The AIARE Fieldbook.*

Once you ***Conduct a Departure Check***, the RIDE SAFELY checklist will help the group maintain situational awareness and make good decisions. You'll go through the checklist not just once but many times, repeating again and again during designated stops you decided on during PLAN YOUR TRIP or at junctures that come up along the way.

Similar to the planning process, TEAMWORK is the key element to making this checklist an effective risk management tool. Every team member needs to be engaged in *Monitoring Conditions* so that they can contribute to discussion when they *Check In With The Group*. Since each member has agreed to travel together and make decisions together, each person is responsible for ensuring this process repeats at each juncture and is used throughout the day. At any time, one person's veto on terrain must be respected by the whole group.



CONDUCT A DEPARTURE CHECK

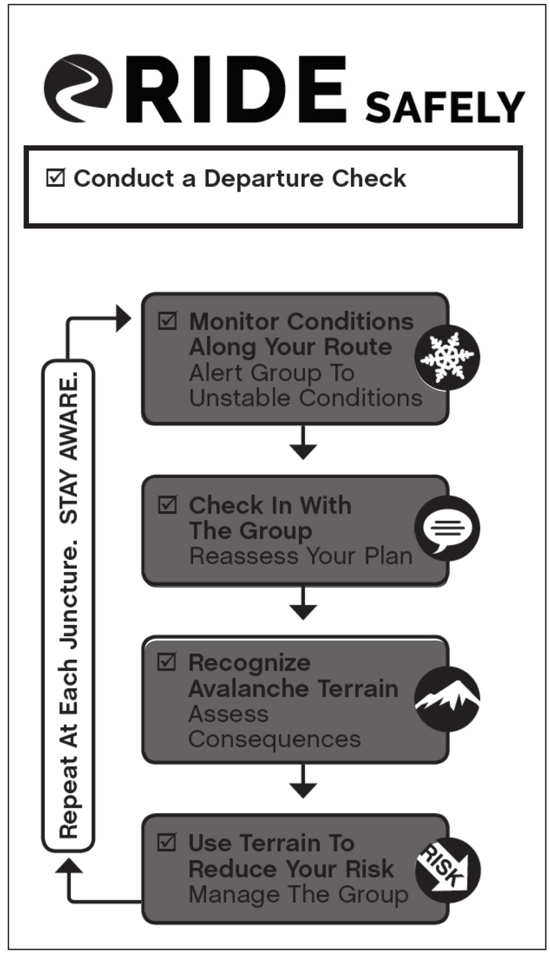
Every trip begins with a *Departure Check*. It is the global standard that at the trailhead or boundary gate, everyone in the group participates in a departure check.

The check works most efficiently if the group designates one person to lead the check. This person starts by confirming that the group has a repair kit, first kit, rescue sled, communication device(s), and navigation tools. The leader should also ask each individual to double check they have their personal rescue equipment—a transceiver, shovel, and probe.

This quick trailhead check will reveal if anyone has forgotten a critical item or if someone's equipment is damaged. More than once a team has discovered that a probe is broken or that the repair kit didn't make it to on the trip. The team faces may face a logistical dilemma at that point, but it's much better to be faced with that situation at the trailhead than to be ill-equipped during an emergency.

Check transceivers every time you leave the trailhead or backcountry gate. In addition to checking the functionality of the transceiver itself, a transceiver function check verifies each group member knows how to turn it on, is wearing it properly, has an appropriate battery level, and knows how to go into search mode. A team member that has a new transceiver or is unfamiliar with it is a reason for pause.

The individual designated as the transceiver check-leader should conduct the transceiver function check once away from vehicles or ski lifts.



TRANSCEIVER FUNCTION CHECK [11]

- Find a place away from conflicting transmitting devices. Stand in a half circle an arm's length or more apart with the transceiver check-leader a few meters away in the middle of the group.
- Turn transceivers on. As they power on, each individual checks that the transceiver runs a self-check and the display is ok. Note battery strength and report it aloud to the group.
- Switch all transceivers to Search mode. Silence indicates that everyone is ready and ensures that no transmitting units are on dogs, sleds, or in packs.
- The check-leader then switches to Transmit/Send and checks that each group member can receive a signal by walking toward each group member one by one while the group member reads their display out loud.
- Turn all units to Transmit. The check-leader witnesses that each group member stows their unit for the day, secured under an outside layer, and 30 cm from cell phone or radio.
- The check-leader returns to Search mode and confirms all group members are transmitting. The check-leader then switches to Transmit mode and confirms to at least one group member, who also verifies that the check-leader's device is stored under an outside later and 30cm from a cell phone or radio for the day.

11 To get a visual sense of how this works, check out the AMGA's Beacon Check video - https://amga.com/beacon-check/.

After checking the team's transceivers, reconfirm the group's communication and check-in strategies. Each member should commit to visual or verbal contact with a partner at all times during the tour. The group should know regroup locations and recommit to traveling and deciding together, and the fact that each member has a veto and is part of any decisions. Include a radio function check or confirm whether or not cell reception is available.

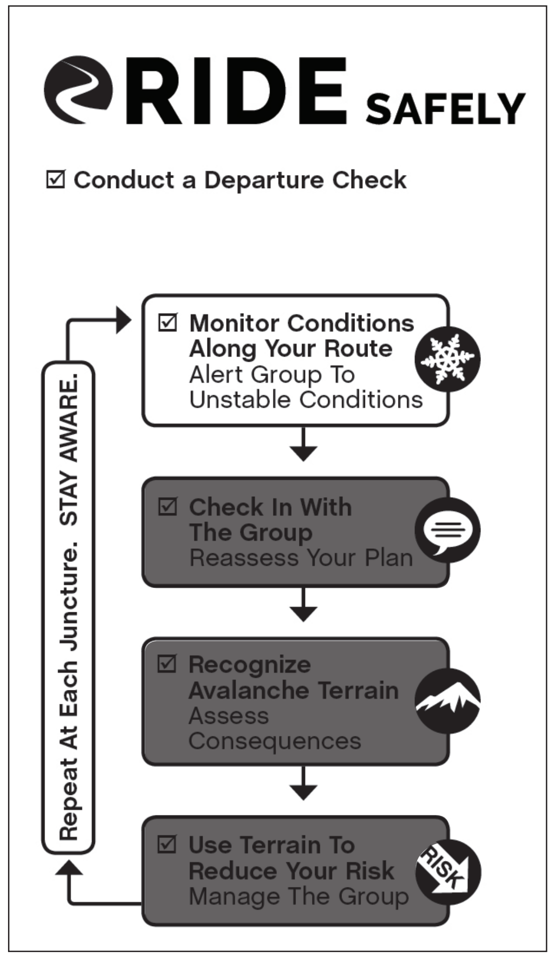
The best decision makers are flexible. They maintain situational awareness and modify plans as conditions change. These conditions include not only weather and snowpack, but how the group interacts and travels through the back-country. The ultimate objective is to have fun and live to ride another day.

MONITOR CONDITIONS ALONG YOUR ROUTE

The first of four steps your group will iterate through in the RIDE SAFELY checklist is to *Monitor Conditions Along Your Route*.

Monitoring conditions means both making regular observations while traveling along your route and stopping to make relevant observations. These observations may have been planned for during PLAN YOUR TRIP or conditions warranted a closer examination. Monitoring conditions ranges from looking for avalanche activity, to noting changes in the weather, to closely examining the snowpack by digging a snow profile.

In *The Fieldbook*, record what you see in the space to the right of the RIDE SAFELY checklist and/or use the test profile pages beginning on page 44 of *The Fieldbook.* Communicate your observations to the group at a designated location, via radio, or within the group as you move through the terrain. If you note rapidly changing conditions or signs of unstable snow, it's imperative to alert the group, share observations, and discuss what to do. Don't assume your teammates also noticed the same things you saw, speak up if you notice any-thing.



SIGNS OF UNSTABLE CONDITIONS

The most important observations are those that indicate unstable conditions. Whenever you observe these, be sure to alert the group in order to make a decision as a team about what to do. The prompts on page 5 of *The Fieldbook* explain how different signs in the weather and snowpack can indicate unstable conditions. Note that these guidelines were introduced in PLAN YOUR TRIP and represent the same weather and snowpack criteria.

Step 1: Monitor Conditions Along Your Route.

⚠ **Alert Group To Unstable Conditions.**

WEATHER

- **Heavy snowfall**: 30cm (12”) in the past 2 days (even less with wind). Watch out for rapid accumulation (>2cm or 1”/hr.)
- **Recent drifting snow** means windslabs can form downwind of ridge lines.
- **Rapid warming** from sunshine or rain can make unstable snow. Extra caution with warming right after a storm.

SNOWPACK

- **Signs of avalanche activity** from today or yesterday.
- **Whumph!** This sound is a warning that weak layers are collapsing in the snowpack.
- **Cracks** in the snow surface that shoot out from skis or track.
- Overhanging or drooping cornices.
- A **slab above a weak layer** (reported or observed in tests).

Prompts for Monitor Conditions Along Your Route of the Ride Safely Checklist from page 5 of The AIARE Fieldbook.

Heavy Snowfall

Colin Zacharias

Snowfall accumulation can be measured or estimated from visual clues or foot penetration.

Significant new snow or rapidly accumulating snow can increase the avalanche hazard. Heavy snowfall of 30 cm (12 in) in the past two days should be noted. Measure the new snow with your pole, ruler, or probe. If there is wind, even less snow is required to be of concern. Regardless of the overall amount of snow, whenever there is rapidly accumulating snow (greater than 2 cm or 1 in per hour) is a sign of unstable conditions.

Recent Drifting Snow

Recent drifting snow indicates that windslabs may be forming downwind of ridgelines or other terrain features. Figure 10 shows how wind moves snow from the windward slope and deposits on the leeward side, creating snow loading that can potentially avalanche. Figure 11 shows how the wind blowing across mid-slope features can have the same effect.

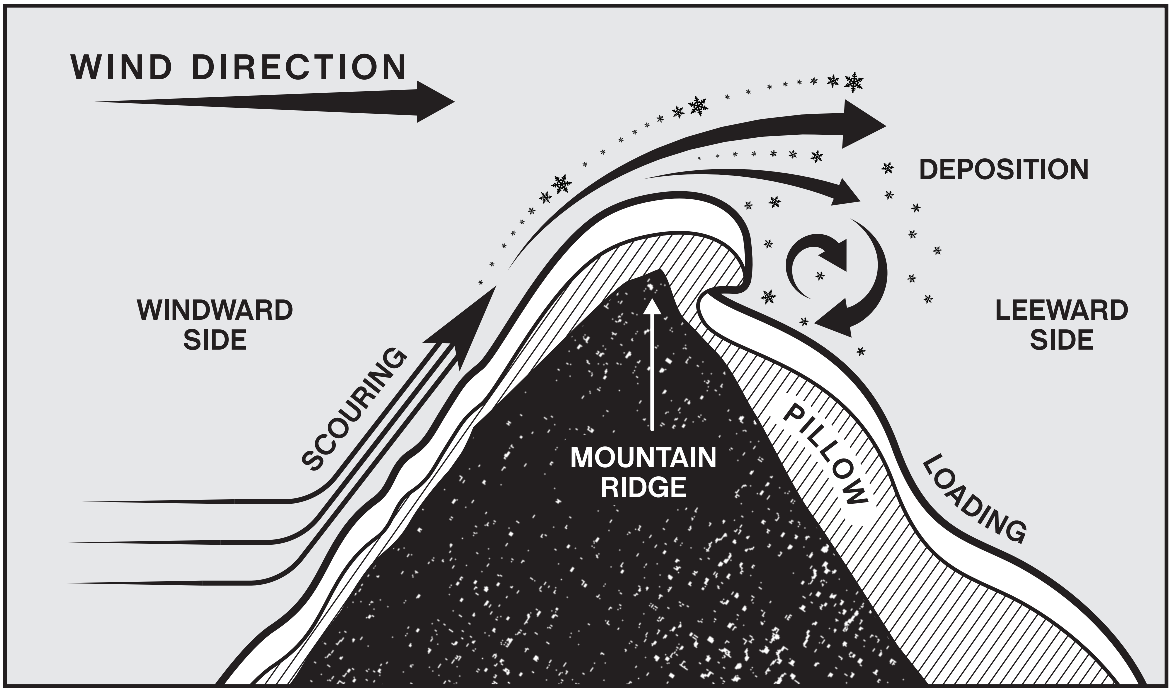


FIGURE 10. WIND MOVING AND DEPOSITING SNOW OVER A RIDGE

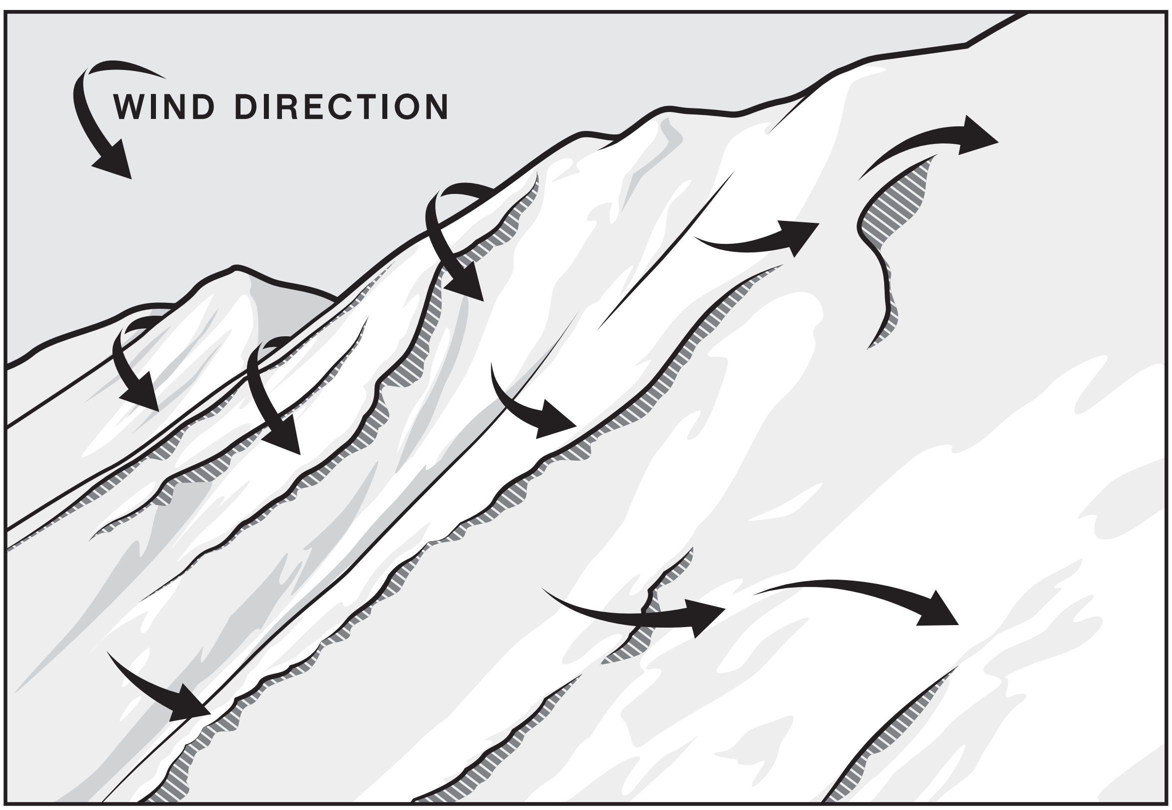


FIGURE 11. WIND MOVING SNOW AND LOADING CROSS SLOPE FEATURES

Recent Warming or Rain

Alison Mehravari

Rapid warming from sunshine or rain can make unstable snow. Signs of recent warming from heat, radiation, or rain can include "roller balls" on steep slopes, which indicate increased avalanche hazard. Exercise extra caution with warming right after a storm.

Signs of Avalanche Activity

Recent avalanches are the most obvious indication of unstable snow. Signs of a recent avalanche and the terminology associated with the parts of an avalanche are shown in Figure 11. When you share avalanche observations with your team, include the following critical details:

- Release type (loose or slab avalanches)
- Location (elevation, and aspect relative to wind and sun)
- Terrain shape (slope incline, bowl or gulley, presence of rocks or cliffs, steep glade in the trees, etc.)

When and how the avalanche happened may be unknown, but if the avalanche was actually watched in motion, include those details too.

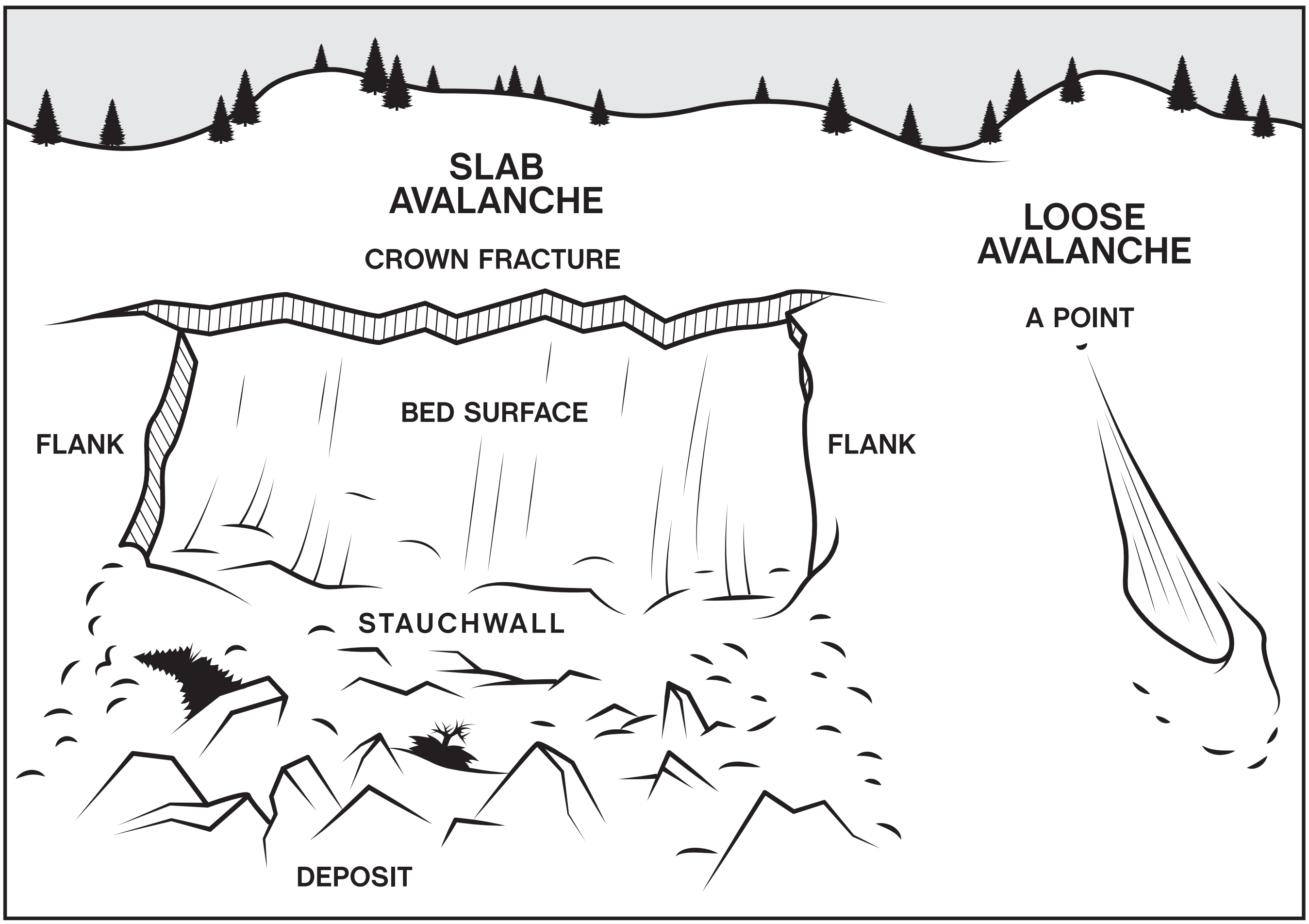


FIGURE 12: PARTS OF AN AVALANCHE

In addition, when sharing information about observed avalanches, the advisory or an expert might describe the size of an avalanche as small, large, and very large. Professionals also use a numeric D1-D5 scale to describe an avalanche's destructive size and another scale, R1-R5, to describe an avalanche's size relative to its potential size based on the avalanche path.

Whumphing

Whumphing is the term used when you feel or hear weak layers collapsing under a rider's weight. The whumph may be barely audible or it can be loud and rumbling, enough so that tree branches will shake. Shooting cracks, cracks that initiate at the tip of the ski, sled, or snowshoe and quickly grow or shoot away from the traveler often appear on the snow surface when whumphing occurs.. Either of these signs clearly indicates unstable snow, and steeper terrain should be avoided. Figure 13 shows the cracks on the snow surface as a result of a whump or collapse within the weak layer. In Figure 14, a profile shows the weak layer of large crystals collapsed with cracks on the surface. *The large crystals of the weak layer are still standing up on the right side of the picture and have collapsed on the left causing the crack above the layer.*

Bruce Jamieson

FIGURE 13: CRACKS IN THE SNOW SURFACE DUE TO THE COLLAPSE OF A WEAK LAYER

ASARC, University of Calgary

FIGURE 14: CROSS SECTION OF A COLLAPSED WEAK LAYER

Cornices

Cornices form when wind blows over a ridgeline. These dense, wave-like formations of snow overhang the ridge (as shown in Figure 15) and present a hazard for three reasons. First, they break unexpectedly from the ridgetop, often further back from the edge than expected, creating a serious fall hazard for riders and climbers. Second, a cornice collapse can send tons of destructive, dense snow blocks down the lee slope and trigger a cornice avalanche. Last, a relatively small chunk of cornice can weigh hundreds of pounds and act as a relatively large trigger, starting a destructive slab avalanche on the slope below.

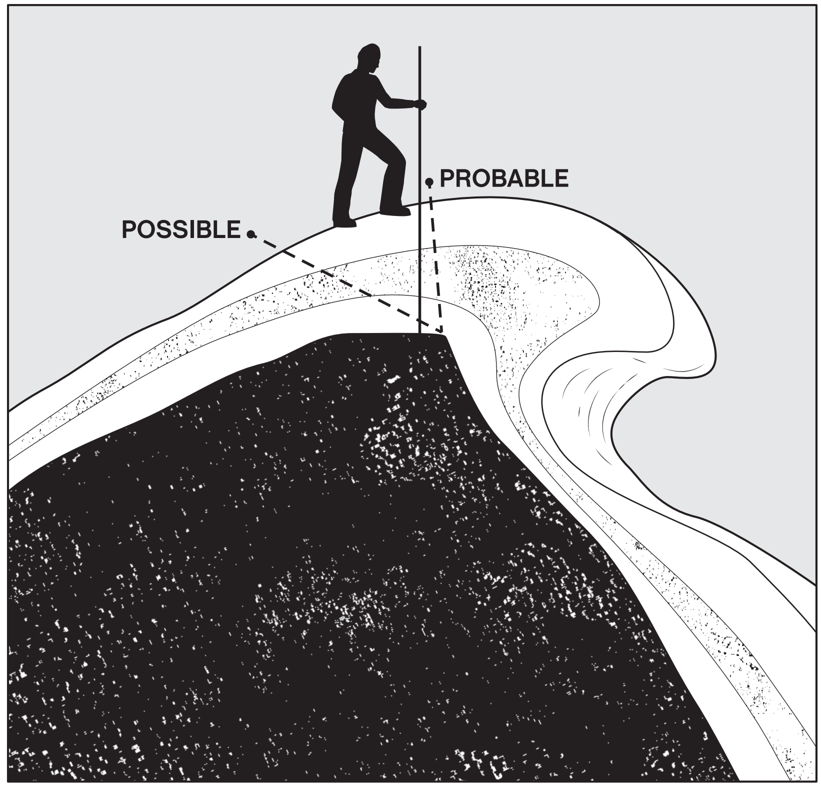


FIGURE 15. CORNICES CAN BREAK OFF SIGNIFICANTLY FURTHER BACK FROM THE RIDGE THAN EXPECTED.

A Slab Overlying a Weak Layer

The final sign of unstable conditions is the observation (in snowpack tests) or a report of a slab overlying a weak layer. This condition is often reported in an avalanche center advisory or by field observers conducting snow profiles and snowpack tests.

There are a variety of ways to identify the presence of a slab over a weak layer, from quick tests done by hand to digging a snow profile. Based on information given by the advisory or advice from an expert, the group may decide to conduct one of these tests before traveling in certain terrain or riding a particular slope. While Monitoring Conditions Along the Route, the team may also observe weather or other conditions they weren't expecting, which usually warrants gathering more information while out in the backcountry. Recent avalanche activity, new snow fall, and high winds are examples that would prompt a group to gather more information.

THE AVALANCHES AND OBSERVATIONS REFERENCE

AVALANCHES & OBSERVATIONS

CAUSE: Hazard from new snow and/or wind			
PROBLEM	SIGNS OF UNSTABLE CONDITIONS	OBSERVATIONS AND TESTS	CONSIDERATIONS
Dry Loose Avalanche 	• Recent point releases observed in steep terrain. • Forms a fan-shaped avalanche with fine, even sized debris.	• Boot deep penetration into loose surface snow. • Ski tests on small slopes result in accelerating sluffs.	• Can be naturally triggered in steep terrain by falling snow, cornice fall, rock fall, increased wind or sun. • Rider triggered sluffs on steep continuous slopes can accelerate fast and run far. • Small slides dangerous when rider is carried into terrain traps or over cliffs. • Sluffs can trigger slabs in certain conditions.

The Avalanches and Observations Reference, on pages 56-58 of *The Fieldbook* and printed in a larger format in Appendix B of this manual, gives additional signs of unstable snow and what type of avalanche problem is associated with each sign. Use this reference while PLANNING YOUR TRIP and refer to it in the field while *Monitoring Conditions*. Not only will this help you understand the correlation between the observations you see for yourself with the specific avalanche problems that an advisory has listed as concerns for that day. It can also help your group take an advisory and forecast made for a regional scale and apply it at a local scale by matching your group's observations to the type of avalanche problem.

MAKING SNOWPACK OBSERVATIONS


AIARE Files

Different storms bring different types of snow throughout the season. Some storms might bring heavy, wet snow while others might bring light, dry powder. Each unique storm forms a layer or multiple layers of the snowpack. In addition, weather events, such as cold temperatures, rain, and time cause those layers to continue to change, either bonding together or becoming more distinct. Sometimes, the right combination of snow and weather events creates a solid, stable snowpack. Other times, the layers don't fuse together, and we are left with a snowpack that is more likely to avalanche if triggered on steep terrain.

Understand the Layers

Different storms bring different types of snow throughout the season. Some storms might bring heavy, wet snow while others might bring light, dry powder. Each unique storm forms a layer or multiple layers of the snowpack. In addition, weather events, such as cold temperatures, rain, and time cause those layers to continue to change, either bonding together or becoming more distinct. Sometimes, the right combination of snow and weather events creates a solid, stable snowpack. Other times, the layers don't fuse together, and we are left with a snowpack that is more likely to avalanche if triggered on steep terrain.

As you conduct your observations, take note of obvious differences between layers, such as the size and shape of the snow crystals in the layers or the hardness of the layers. What is the thickness of the layers? Are there strong layers on top of weak layers?

Observe the Layered Snowpack as You Travel

Chris Meder

You can use quick tests to observe layers closer to the surface. Probe with ski poles to track layers, use your hands to isolate and then pull on a column of snow to see if it cleanly fractures away, or test small rolls over unsupported snow mushrooms or boulders. As you travel through avalanche terrain, these quick tests can supplement what you read in the advisory or learned in a more formal observation.

Dig in the Layered Snowpack

The conditions that form avalanches can result from a storm event (new snow accumulation and/or wind transporting and depositing snow onto steep slopes) or a warming event (sun/heat or rain warming the snow surface layers to 0°C/32°F). However, in cooler mountain regions (Intermountain and Continental climates) unstable conditions frequently linger beyond the initial storm cycle or weather event. It is during these conditions that experts and the avalanche advisories warn about Persistent Slab and Deep Slab avalanche problem types.

Colin Zacharias

Conducting a snowpack test to identify and assess a slab overlying a weak layer.

INTERPRETING SNOWPACK OBSERVATIONS

Snowpack observations can identify signs of unstable snow and help verify expert-identified avalanche problems. *The Avalanches and Observations Reference* (Figure 16 shows a sample of the reference) draws an important connection between the avalanche problem and signs of unstable conditions recognizable in the field. The reference also matches avalanche problem types to recognizable conditions that can be observed using simple tests. The right-most column of the reference provides important terrain considerations that help the observer manage risk.

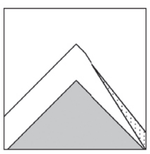
CAUSE: Hazard from new snow and/or wind			
PROBLEM	SIGNS OF UNSTABLE CONDITIONS	OBSERVATIONS AND TESTS	CONSIDERATIONS
Dry Loose Avalanche 	• Recent point releases observed in steep terrain. • Forms a fan-shaped avalanche with fine, even sized debris.	• Boot deep penetration into loose surface snow. • Ski tests on small slopes result in accelerating sluffs.	• Can be naturally triggered in steep terrain by falling snow, cornice fall, rock fall, increased wind or sun. • Rider triggered sluffs on steep continuous slopes can accelerate fast and run far. • Small slides dangerous when rider is carried into terrain traps or over cliffs. • Sluffs can trigger slabs in certain conditions.

FIGURE 16. SAMPLE OF THE AIARE AVALANCHE AND OBSERVATIONS REFERENCE

Observation of avalanche activity provides direct evidence of unstable snow.

Observing current avalanche activity provides direct evidence of both unstable snow on a slope as well as the potential for an avalanche to release. Signs of unstable snow can be straightforward to observe. Shooting cracks, whumpfing, and snow layers fracturing and displacing on small terrain features provides localized evidence of unstable snow – meaning this evidence tells you a lot about the snow that you are standing on at the moment. However, relating these compelling clues to actual avalanche release on adjacent and distant avalanche paths takes experience with interpreting and applying the information. Beyond identifying signs of unstable snow and verifying the avalanche problem, interpreting snowpack observations is challenging, requiring more experience interpreting data from multiple locations.

Grant Gunderson

The absence of signs of unstable snow does not mean that the snow is stable.

While these described conditions provide obvious signs of unstable conditions, it is very difficult to determine when the snow is stable and strong. Backcountry travelers with basic knowledge should follow the advice given in the advisory even when they don't see the signs of instability themselves.[12]

Snowpack layering may vary significantly from one area of terrain to the next and often without any noticeable difference on the surface. The snow layers near the trailhead will generally be very different from the layers found near ridgetop. The layers in the trees will differ from open areas. North-facing slopes will have a completely different snow-pack from south-facing slopes. The profile you dig within the sheltered tree line likely won't represent the snowpack on the open, rideable terrain above you. As mentioned before, evidence is required from multiple targeted locations chosen for their potential to provide evidence about the nature of the snowpack.

Even on a smaller scale, tests done in separate profiles within several yards of each other can yield different results. The main point is, don't let a couple of snowpack observations in one or two specific areas give you a false confidence in your understanding of the snowpack in the surrounding terrain.

Digging in the snow is not a decision-making tool.

Digging in the snow is not a decision-making tool, only a means for gathering a piece information that feeds into the decision-making process. Digging is only recommended for very experienced backcountry travelers under specific conditions. In most cases digging is not required. Nevertheless, snow cover observations performed and interpreted correctly can contribute to informed decision making avalanche terrain, especially if little or nothing is known about the snowpack conditions and stable conditions cannot be assumed.[13]


Ruby Mt. Heli

The best way to interpret snowpack observations is to put them in the context of the avalanche advisory and the morning plan. The group should ask:

- "Do our field observations relate to the avalanche problem and danger as described in the bulletin?"
- "Did we find what we were looking for, or are we still uncertain?"

Occasional snowpack tests performed by backcountry travelers can identify problems and inform caution. But a few tests a few times a week is not enough information to prove the snowpack is strong and will not avalanche. Experts use a detailed spectrum of information to determine avalanche probability including:

- Seasonal snowpack development
- Knowledge of snowpack distribution over terrain
- Seasonal and historic avalanche history for specific slopes
- A variety of different types of tests over different aspects and elevations
- A proven process informed by the nearest observations by a professional

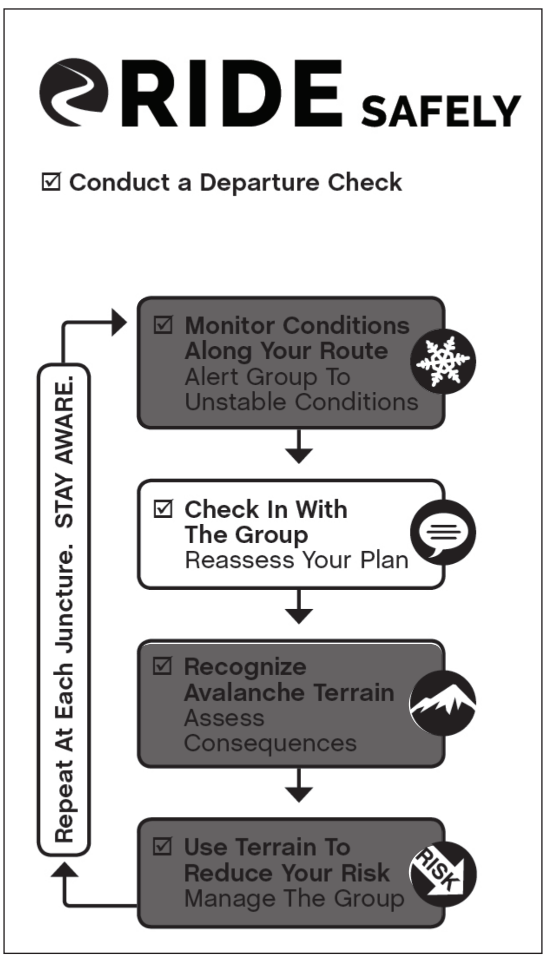
In short, backcountry travelers don't bet a big decision on one or two snowpack tests. However, snowpack tests can add information—specifically identifying problem layers and layer distribution over terrain to encourage caution, reduce uncertainty, and minimize risk.

12 Bellaire, S., Jamieson, B., and Schweizer J. "When to dig? Thoughts on estimating slope stability." Montana State University Library, ISSW (2010): 424-430. Squaw Valley, CA.

13 Bellaire, S., Jamieson, B., and Schweizer J. "When to dig? Thoughts on estimating slope stability." Montana State University Library, ISSW (2010): 429. Squaw Valley, CA.

CHECK IN WITH THE GROUP

D. Jackson



In the backcountry, the group is tasked with monitoring both the changing conditions **and each other**. Anytime the group gathers, whether it's at a designated check-in spot or if signs of unstable conditions have warranted a regrouping—it is important to *Check in with the Group* and *Reassess Your Plan*. Take the time to share information and assess how each person is feeling and if they have observed anything worth noting. If any of the group members have changed their perspective on the day, it's important they share it with the team.

Step 2: Check In With The Group.

Reassess Your Plan.

- See anything **unexpected**?
- Hungry? Healthy? Happy?
- Gear issues?
- **Will anything affect decisions or travel**?

When *Checking in With the Group*, use the prompts from the RIDE SAFELY Checklist on page 5 of *The AIARE Fieldbook.*

Include everyone and ask:

- Who saw what?
- *What do your observations mean?*
- *Are the conditions what you expected?*
- *Did you see anything unexpected or unusual?*

Keep in mind fatigued and stressed individuals can have difficulty making decisions, as well as maintaining situational awareness. Environmental conditions can also short circuit a person's mental faculties or general level of enthusiasm. Keep an eye on your teammates and they'll do the same for you. Ensure everyone is well fed, warm, and hydrated at each step of the trip. Make sure everyone's gear is working and recognize when someone isn't enjoying the experience but doesn't want to be the first one to complain. Identify anything within the group that impacts its ability to travel and make decisions together.

Make sure everyone participates in the day's decisions. When people have a part in decision making, they're more invested in the outcome. If someone's not participating, ask why:

- *Do they feel heard and respected?*
- *Are they worried?*
- *Or are they simply confident and comfortable with the day and how it's progressing?*

To achieve real consensus, you need to ask for everyone's opinion regardless of the individual's experience or expertise. Likewise, if you're out with a team more experienced than you, don't feel like your observations and concerns are less important than those of other group members. Everyone has a voice and is expected to challenge assumptions. Less experienced group members are often better equipped to notice and question if the group is doing something out of habit or by choice. Engaged members are more likely to express veto.

It is important to reassess the plan at each juncture (during a water break, change in the terrain, or as new observations are made). As the group comes together and discusses pertinent observations and the team's condition, reassess the plan you outlined.

Ask yourselves:

- *Are we on track?*
- *Do we need to reevaluate our time plan and/or trip plan?*

The options to manage unfamiliarity and uncertainty are always the same:

- *Shorten the trip*
- *Abort the trip*
- *Choose simpler, less exposed terrain*

RECOGNIZE AVALANCHE TERRAIN

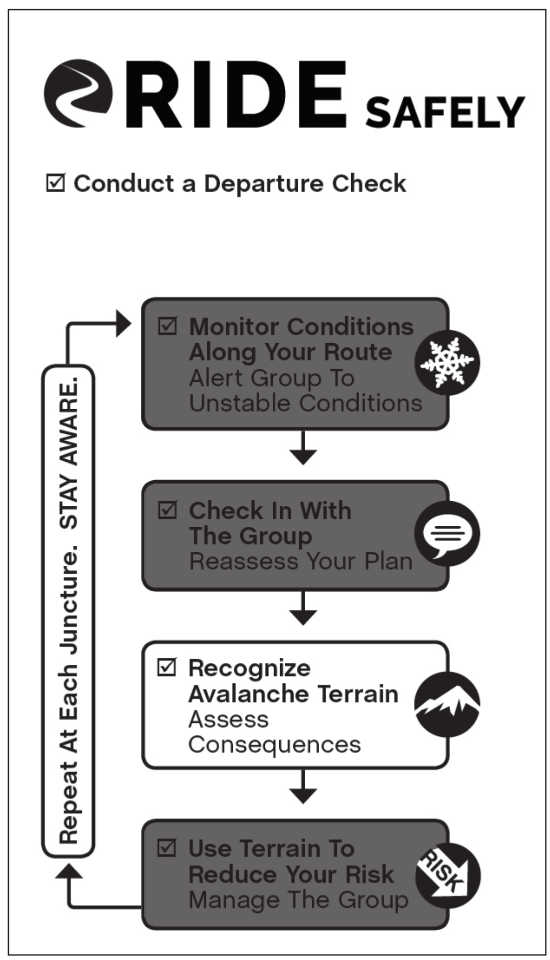
Grant Gunderson

After the group has checked in, shared observations, and if necessary, reassessed the plan, the group should assess the terrain on the next leg of the trip. When creating a trip plan, the group planned to limit exposure to avalanches through a careful examination of terrain in maps and photos. Now in the field, the group should ground-truth their assessment by reevaluating all slopes the group will travel on or near for their avalanche potential.

When assessing consequences, ask yourself:

- *Does this slope have the potential to avalanche?*
- *If so, how big and destructive could the avalanche be?*

Realistic terrain evaluation—and a respectful fear of an avalanche's consequence—are the two most valuable assets when deciding **where you go** and **how you go**.



Consider the following prompts outlined in the expanded RIDE SAFELY Checklist on page 5 of *The AIARE Fieldbook* when reassessing terrain in the field:

Step 3: Recognize Avalanche Terrain.

⚠ **Assess Consequences.**

- Slope has the same aspect/elevation as **today's avalanche problem**?
- **Steepest part of the slope** inclined near or > 35 degrees?
- **Dangerous slope above** or **terrain trap** below?
- A known or obvious avalanche path (**open path, flag trees, broken trees**)?
- **Steep convex roll overs** & other hard to avoid trigger points?
- Committing slope? Once there, can we opt for a less consequential slope?

Does this Slope Fall Under the Day's Forecasted Avalanche Problem?

An avalanche center's advisory describes conditions at region scale, not for specific slopes. Depending on the direction of the incoming storms, parts of the range have more or less snow, more or less wind, and differing elevations. Because of these variations, avalanche activity—or unstable conditions—may pertain to a specific part of the range. It is up to the traveler to take the advisory's region scale information and apply it at slope scale. Review the key message and summary to identify the location of primary concern, then review submitted observations of *where avalanches have recently occurred*. That is your most important clue in how a regional advisory applies to the specific slope your group is looking at, helping your group determine the terrain to avoid.

Does this Slope have the Same Elevation as the Day's Forecasted Avalanche Problem?

The forecasted avalanche problem may be elevation specific. Air cools as it rises and as rain or snow falls, and as a result, higher elevations receive more total precipitation and more snow. During warmer periods, meteorologists will forecast the elevation where rain turns to snow—called the freezing level. This is a critical elevation threshold where you should expect different avalanche concerns.

<u>Does this Slope have the Same Aspect as the Day's Forecasted Avalanche Problem?</u>

Most storms combine precipitation and wind. Wind can cause scouring by blowing away snow and making windward slopes shallower. Wind transports moving snow along the ground, depositing it onto lee or wind-sheltered slopes, making those deeper. The photo in Figure 17 is an extreme illustration of this effect.

FIGURE 17. AN EXTREME EXAMPLE OF WIND TRANSPORTING SNOW: *Moving snow from slopes on the left side of the ridges and depositing it on the slopes on the right side of the ridges.*

During a storm, drifting snow can load a slope at 3-to-5 times the rate that snow will accumulate in sheltered areas. The small-grained, wind-deposited snow settles and bonds quickly into a slab. These wind slabs are layered with stronger (smaller-grained) layers, overlying weaker (larger-grained) layers.

Snow that is visibly blowing off ridges, as shown in Figure 18, clue you into available snow drifting from windward slopes onto lee slopes. Other visual clues that wind loading has occurred or is occurring include recent cornice growth, and snow drifts or pillows on or below ridge lines.

While not as dramatic an influence as precipitation or wind, a slope's aspect to the sun and solar radiation has a profound impact on the near-surface snow layers. Always be cautious if you observe short term change and discuss it with your team. Earlier in the season, southeast, south, and southwest slopes get more sun. Later in the year, the sun can affect even northwest aspects in the afternoon. Steeper slopes are subject to more radiation as they are oriented more perpendicularly to the sun.

FIGURE 18. PLUMES OF SNOW BLOWING OFF A RIDGE.

Is the Slope Steep Enough to Avalanche?

When considering slope angle, assess not just the slope that you are or intend to get in, but also the slopes above you. Most slopes enjoyable to ride are steep enough to avalanche. Destructive, slab avalanches generally occur on slopes from 30-45 degrees. Exercise greater caution when estimating (versus measuring) slope angle.

Lower-angle terrain that's attached to steeper terrain can be overrun by an avalanche. You can also trigger an avalanche that starts above you (sometimes hundreds or thousands of feet above) from lower-angle terrain.
If measuring from a safe distance, you're also only averaging the slope angle—don't miss a small feature mid-slope that could surprise you.

Figure 21 shows an example where the slope's average incline is 30 degrees, but the steepest section of the slope is 38 degrees.

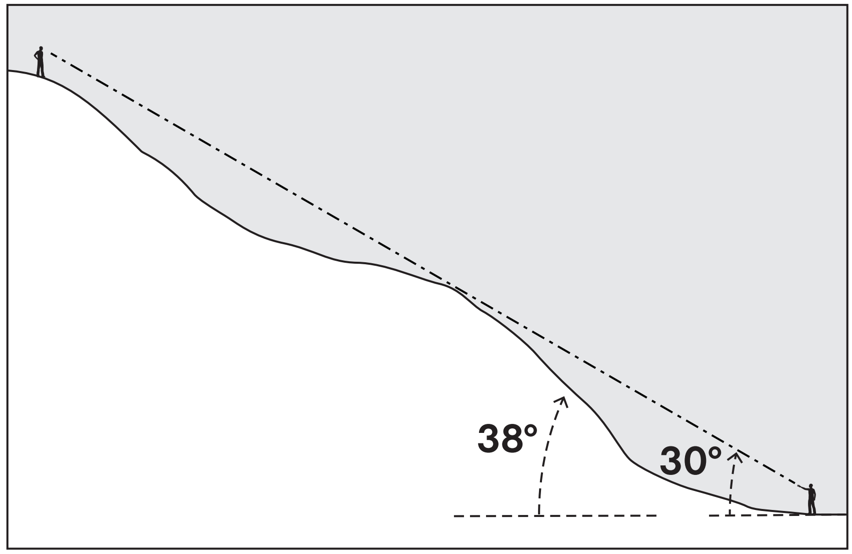


FIGURE 19: MEASURING A SLOPE ANGLE OVER A WHOLE SLOPE MAY MISS SMALL SECTIONS THAT ARE LOCALLY STEEPER.

Is there a Dangerous Slope Above and/or Terrain Trap Below?

When assessing exposure and consequence, it is critical to assess whether the terrain surrounding the slope will increase the consequences if an avalanche occurs there. Any terrain features (rocks, trees, crevasses, or flat areas) that increase the consequences of an avalanche are known as a terrain trap. If there are multiple avalanche start zones above you and an avalanche could hit your group and sweep you into a terrain trap, the additional destructive forces and entrained snow will almost certainly be lethal.

Flat benches, roads, and depressions all can result in avalanches piling up in a confined space, burying victims under meters of snow. Creek beds, canyons, and terminal moraines below even small avalanche paths can be fatal due to huge debris piles and deeply buried victims. If victims wash over cliffs or into trees, the chance of death from injury greatly increases even if their backcountry partners can extract them quickly.

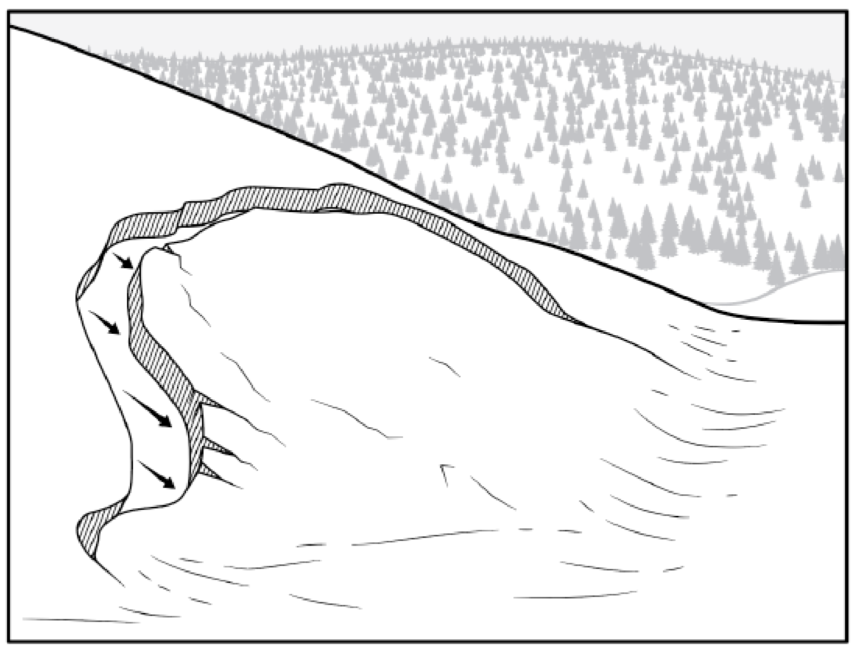


FIGURE 20: A SHORT STEEP MORAINE OR GULLEY WALL WITH A BENCH OR DEPRESSION BELOW CAN FORM A DEADLY TERRAIN TRAP.

Even small avalanches can quickly accelerate to speeds of 30mph. Imagine jumping out of a vehicle at that speed and striking a solid object. That is what it feels like to be caught in an avalanche.

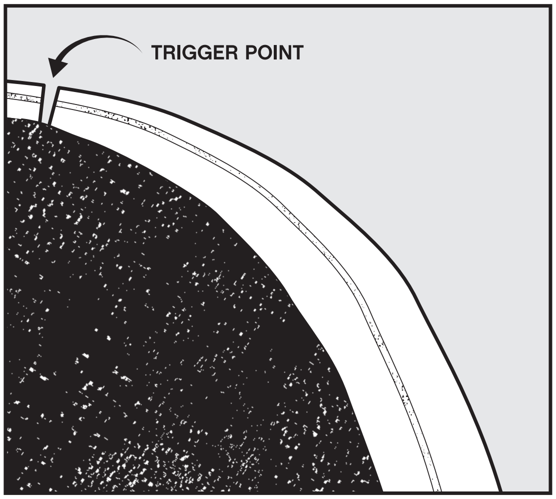


FIGURE 21: TRIGGER ZONES INCLUDE STEEP CONVEX UPPER OR MID SLOPE ROLL OVERS.

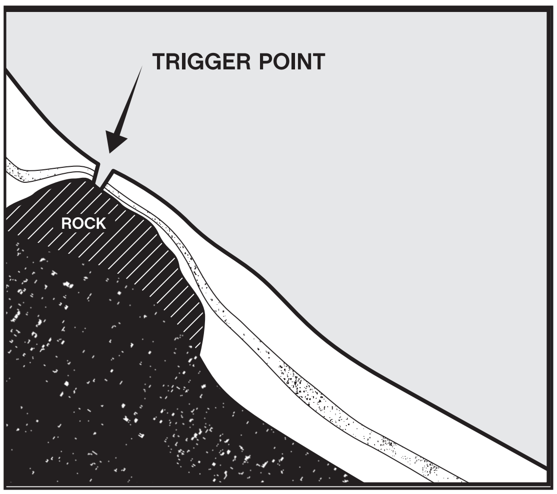


FIGURE 22: TRIGGER ZONES IN ROCKY OR VEGETATED SHALLOW SNOW AREAS.

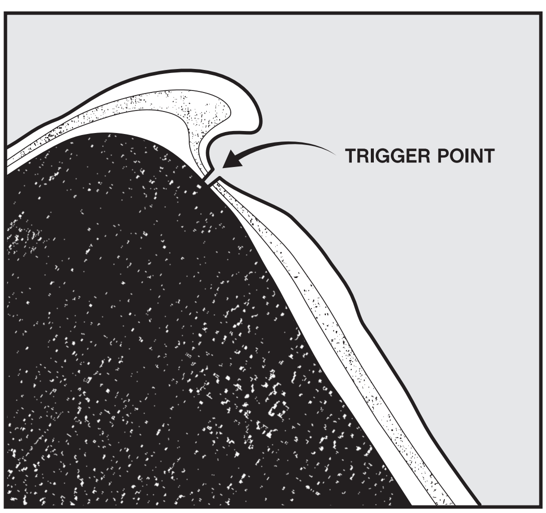


FIGURE 23: TRIGGER ZONES BELOW CORNICES OR CLIFFS.

Does the Slope have Steep Convex Roll Overs and Other Hard to Avoid Trigger Zones?

Avalanches are frequently triggered from specific features. These include upper or mid-slope roll overs (convexities), shallow rocky areas, and in areas near vegetation and below cornices or cliffs. As a rule, avoid these terrain features unless conditions are very stable, which is usually (but not always) in the spring. Avalanches are frequently triggered from specific features. These include upper or mid-slope roll overs (convexities, as shown in Figure 21), shallow rocky areas (see Figure 22), near vegetation, and below cornices or cliffs (see Figure 23). As a rule, avoid these terrain features unless conditions are very stable, which is usually (but not always) in the spring.

Is the Slope a Known or Obvious Avalanche Path?

Avalanche survivors often admit that they weren't aware that their group was in avalanche terrain. What may seem obvious in a classroom setting or to experienced backcountry travelers is often misleading. Seek out important clues:

Local knowledge. Talk to those with experience about which slopes have slid during storms or periods of unstable conditions. These are places to avoid. Recognize what terrain experts actively avoid when they have any unfamiliarity or uncertainty and do the same. Remember features by name and communicate your own knowledge to your group members.

Vegetation provides clues. Often in poor weather you can't see start zones, but you can recognize avalanche trim lines (where open slopes end in trees) and the run-out zones where the forest has been cleared by occasional avalanches. Notice trees with stripped or damaged bark or branches on the uphill side. Flagged trees are easily recognizable because avalanches have stripped off branches on all sides except for the downhill-facing side. Debris piles from old avalanches may also still be visible on the uphill side of well-spaced trees. Small trees may be pushed downhill at an angle.

Is the Slope Committing? Is there an Easy Escape Option?

It is much more difficult to make a fair risk evaluation when you are at the top of a tempting slope and about to drop in. Your assessment of potential avalanche terrain must consider your perspective from below and from the side in addition to what you can see when you are up close and personal with the terrain.

Ensure the terrain has an easy out—a lower-angle, less exposed, or less consequential option to one side. This will present a different scenario than when the terrain provides only a one shot, go-or-no-go decision.

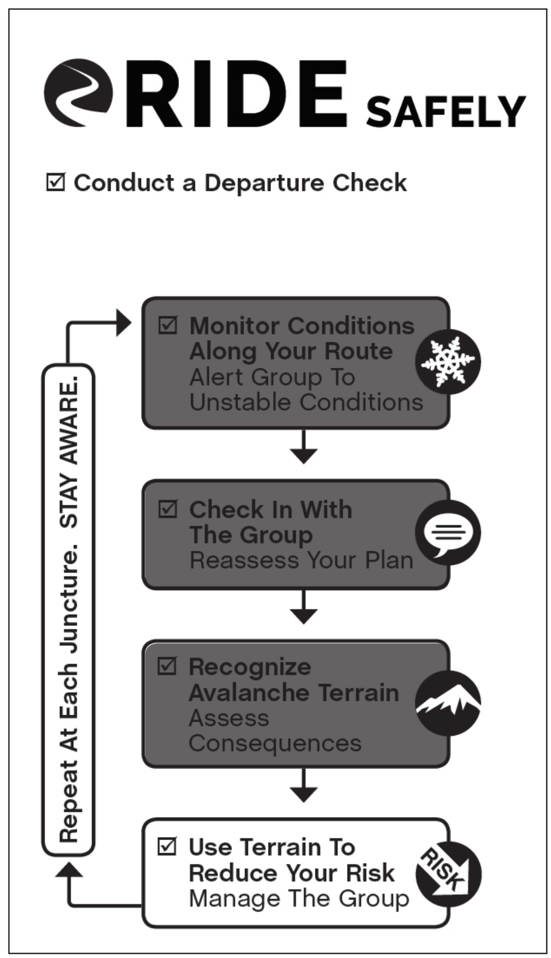
Keep the decision easy. By identifying simpler options (or options to minimize exposure) from a comfortable observation point, you will more accurately assess the consequences of an avalanche in the moment.

USE TERRAIN TO REDUCE YOUR RISK

Colin Zacharias

After monitoring conditions, discussing he potential for avalanches with your group, and understanding the potential for avalanche in your surrounding terrain, it's time to get even more specific about reducing your risk. How will your team travel in the terrain, limit its exposure, minimize the consequences of an avalanche, keep everyone together, maintain communication, and still have a good time?

You are no longer looking at a dot on the map or GPS; you are looking at the exact line along which you will travel on the slope before you. This is when you determine **where you go** and **how you go**.



The detailed checklist on page 5 of *The AIARE Fieldbook* lists techniques to consider:

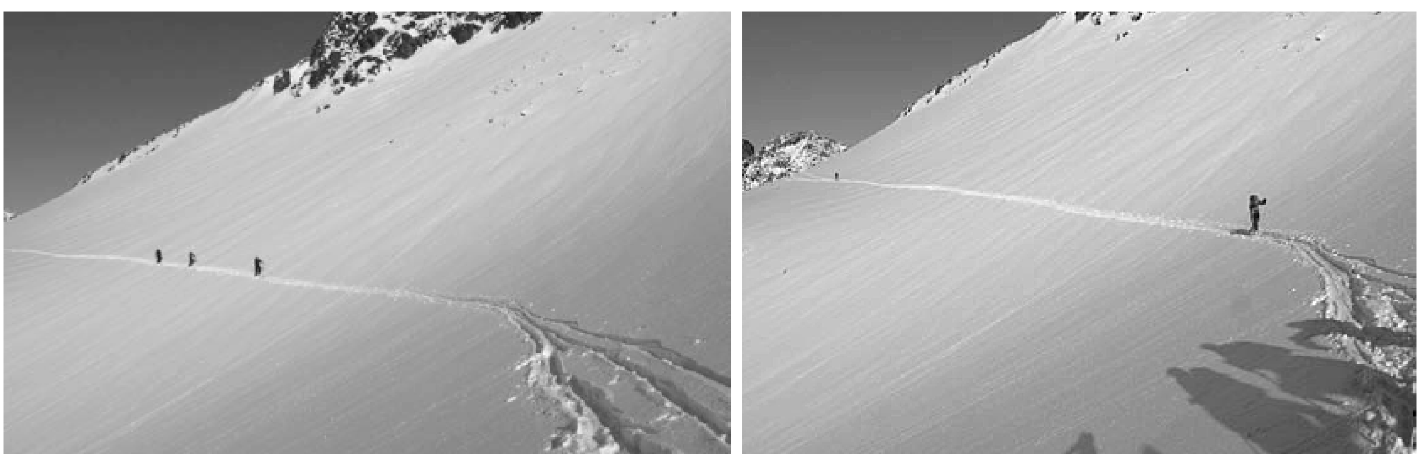
Step 4: Use Terrain To Reduce Your Risk.

Manage The Group.

- Choose a smaller slope.
- **One at a time**: minimize # exposed.
- **Watch each other. Regroup away from the avalanche hazard.**
- If your buddy is stuck on the avalanche slope let them dig themselves out.
- Avoid travel above or below other groups.
- **Choose high ground out of the flow** of the avalanche.

When in doubt, **choose a smaller, open slope**. If you have any uncertainties about conditions or feel the likelihood of triggering an avalanche is too great, consider reducing consequence and exposure by choosing a smaller slope with an open runout (free of trees, rocks, or other terrain traps) that transitions gradually to flatter ground. Smaller slopes mean smaller avalanches and an open, smooth transition means any avalanche is less likely to bury you.

Expose only one group member to the potential hazard. Try to limit exposure to one person at a time on the slope. Consider using radios to help maintain verbal contact in bigger terrain where spacing increases.



Colin Zacharias

FIGURE 24: TWO GROUPS MANAGE THE SAME TERRAIN.
The group on the left exposes three group members to the slope at one time, while the group on the right maintains enough distance to expose only one.

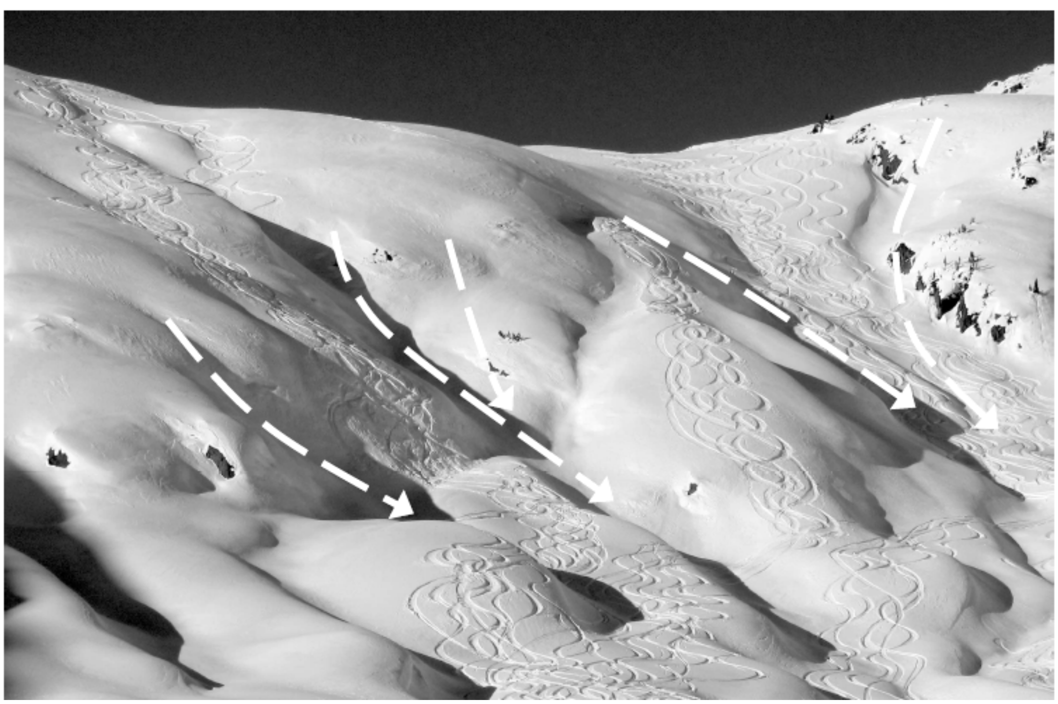
Make sure the group or an appointed member can see most or all of the slope. Ensure you have visual and/or verbal contact with each other. Agree to regroup in a truly safe spot, away from the avalanche hazard. Make sure everyone knows clearly where this is before people take off down the slope.

If a backcountry partner falls and loses a ski or their sled becomes stuck, let them dig themselves out. You might want to help them, but having more people on the slope at one time exposes more of the team to avalanche danger at once. It's good to talk this over with your teammates ahead of time so they understand and know to do the same for you.

Colin Zacharias

Avoid travel above or below other groups. You and your crew might accurately assess the hazard and manage your risk, but if another backcountry party isn't as thorough in their own travel plan, you don't want to suffer from their mistake. When possible, identify where other parties plan to travel and communicate the same to them. Ensure that slopes above and below your route are clear prior to crossing or entering.[14]

When possible, stay on high ground and out of the flow of avalanches. Many riders have escaped harm by identifying true safe zones and regrouping on higher ground. Notice the ski tracks in the photo below. The white arrows indicate where avalanche debris might flow.



Colin Zacharias

FIGURE 25: STAY ON HIGH GROUND.

The white arrows indicate where avalanche debris might flow. Notice the ski tracks on the high ground away from potential debris flow.

14 For a fascinating case history, read about the Rescue at Cherry Bowl: http://www.avalanche.ca/cherry-bowl.

REPEAT THE RIDE SAFELY CHECKLIST THROUGHOUT THE DAY


Alison Mehravari

As the group moves through the terrain, the cycle of the RIDE SAFELY checklists repeat. Members continue to *Monitor Conditions Along the Route*. They stop and alert the group when they see signs of unstable conditions. At designated junctures or when conditions or the terrain warrant, members *Check In with the Group* and *Reassess the Plan*. After matching observation to the expected conditions, and taking stock of the condition of the group, group members *Recognize Avalanche Terrain* along the next leg of their trip and then once again *Use Terrain to Reduce Risk*.

Chapter 3: Summary

RIDE SAFELY

- ☑ Conduct A Departure Check
- ☑ Monitor Conditions Along Your Route
- ☑ Check In With The Group & Reassess Your Plan
- ☑ Recognize Avalanche Terrain
- ☑ Use Terrain To Reduce Your Risk

The Ride Safely Checklist is a cyclical step-by-step process to use when traveling in the backcountry. The checklist ensures each individual monitors weather and avalanche conditions, uses a consensus-based process to assess the plan based on conditions, recognizes avalanche terrain and then uses terrain to reduce the group's risk.

CHAPTER 3 QUESTIONS

1. Describe the key steps in a transceiver function check (from memory).
2. When recording field observations, which is the most important sign of unstable conditions?
3. What are four questions that a group can ask each other at the top of a slope that may provide some insight about the slope's potential to avalanche?
4. List four general observations your group can make when assessing a slope that can better help the group estimate the consequences of triggering a slide.
5. Avalanche professionals utilize a concept known as a "margin of safety" in their decision-making process. A margin of safety builds in a buffer that provides an extra level of security in a dynamic, and sometimes uncertain environment. What specific components of terrain use add a margin of safety in response to uncertainty?

See Page 100 for answers

Chapter 4: Debrief the Day

Tom Murphy

The final step in *The AIARE Framework* is to DEBRIEF THE DAY. Debriefing[15] is a way to intentionally cultivate expertise rather than haphazardly gain experience. Debriefing is not simply identifying what went wrong and creating a plan to fix it the next time. Perhaps more importantly, it is also noting what went right and then working to identify why it went well in order to repeat those actions and behaviors the next time. When debriefing, the group reflects on what it did and didn't get right in order to continue growth and learning .

Recall the Predict > Observe > Compare outline of the learning process engaged when using *The AIARE Framework.* During PLAN, the group used information from experts to *Anticipate the Hazard* and make predictions about the conditions it expected to encounter in the field. During RIDE, the group *Monitored Conditions* and looked for signs of avalanche activity and unstable snow while keeping tabs on the group dynamic. Now during DEBRIEF, the group will compare what was experienced to what was predicted in order to understand if there was something the group correctly anticipated or missed. The DEBRIEF is the key to learning from experience without having to be involved with an avalanche.

15 Sundheim, Doug. "Debriefing: A Simple Tool to Help Your Team Tackle Tough Problems." Harvard Business Review, 2 July 2015.

❓DEBRIEF

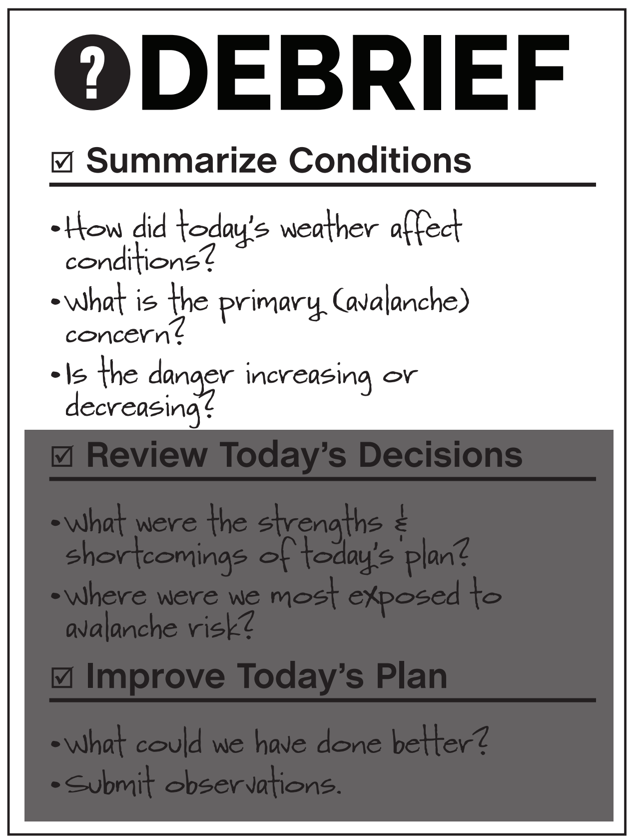
Debriefing accelerates the learning process by making individuals more adaptable to new scenarios and less likely to repeat the same mistakes twice. The DEBRIEF focuses the team's collective wisdom to highlight successes and mistakes that can be translated into concrete improvements for future outings.

DEBRIEF THE DAY consists of three parts:

- *Summarize Conditions* based on observations from the field
- *Review the Day's Decisions* receiving feedback from each participant
- *Improve the Day's Plan* in order to utilize lessons learned on the next outing

Debriefing is an essential part of the risk management process. Without feedback from both the environment and the team, you are more likely to repeat errors that you got away with last time, perhaps with less forgiving consequences.

SUMMARIZE CONDITIONS



Summarizing Conditions from the day helps the team internalize how field observations relate to anticipated hazards named during PLAN YOUR TRIP.

Discussion prompts for *Summarizing Conditions* are listed on page 4 of *The AIARE Fieldbook.* It is helpful to record notes on the page of your current trip for future reference or reflection.

How did the Day's Weather Affect Conditions?

Start with Trip Plan for the day. Specifically, look at your notes under *Anticipate the Hazard* and ask yourself:

- How did the day's weather affect that hazard?
- Was there more wind and snow?
- Warming? Mild temperatures and calm?

Discuss if and how the weather you observed (and noted in your *Fieldbook*) changed the hazard.

What is the Primary (Avalanche) Concern? Is the Danger Increasing or Decreasing?

Next, review the primary avalanche concern identified by the group using the advisory and through conversation with experts. Based on what the group saw in weather and snowpack observations, is there a secondary concern or a different primary concern? Is the danger increasing or decreasing? Your field observations and group conversations should inform this assessment.

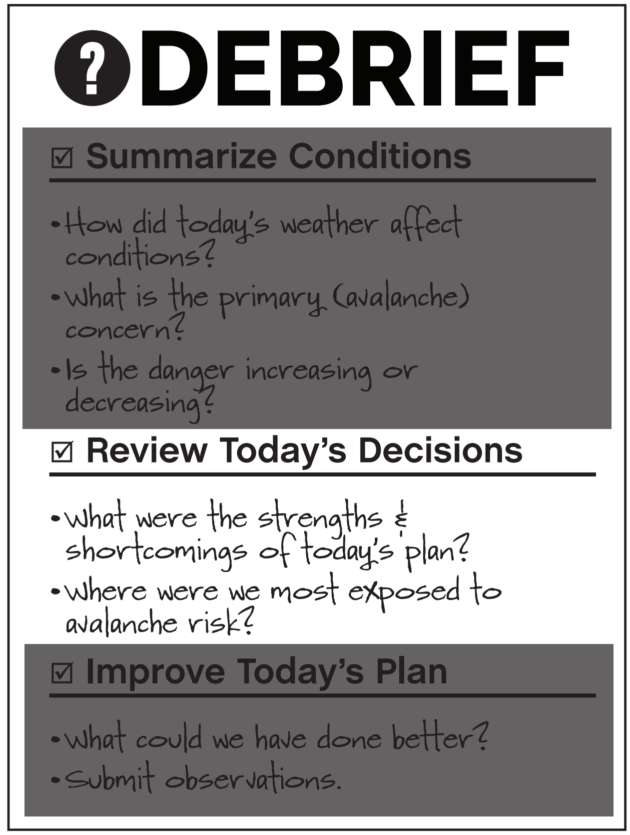
As different travelers make different observations, it is critical to accurately document everyone's observations. For the sake of future trips, take notes on conditions, the group's observations, how consensus was reached, etc.

REVIEW TODAY'S DECISIONS

After compiling and discussing conditions, the team will examine both their plan and their execution of the plan. The objective of this review is not to assign blame, but to identify strengths and reinforce good decisions while acknowledging that there is always room to grow.

The review should focus on two main points:

- What were the strengths and shortcomings of today's plan?
- Where and when were we most at risk?



Every group member should use their voice during DEBRIEF THE DAY. The same group dynamics that went into building and executing the travel plan should play an important role in the DEBRIEF as well. Respect everyone's opinion. It is okay to disagree with your teammates but you should manage your different opinions respectfully, hear everyone out, and incorporate any insights or uncertainties into future trips.

A crucial piece of information comes out when comparing group member perspectives, especially regarding the question of when and where the group was exposed to the most risk. Often people perceive risk differently, and this may be the most critical question of the whole debrief.

DEBRIEF

IMPROVE TODAY'S PLAN

Now answer a simple question with your teammates: given the current discussion, if the team returned tomorrow in the same conditions with the same group on the same trip—*what would you do differently?*

This act of retrospection allows you to benefit from your errors, however minor, by creating solutions from observations and additional information.

Answering this question yields more than just hindsight. You know more than you did this morning. The DEBRIEF facilitates learning and develops skills. It forces both you and your team to continuously improve and hold each other to higher standards as backcountry travel partners. Incorporate the insights from this conversation into future trips.

After Summarizing Conditions, Reviewing the Day's Decisions, and Improving on the Plan, the group's final step is to share information by submitting observations to the local avalanche center. This will help forecasters monitor conditions and inform the forecast moving forward. Other travelers can see your observations and get a better sense of the conditions and problems in the specific area you traveled.

DEBRIEF

☑ Summarize Conditions

- How did today's weather affect conditions?
- What is the primary (avalanche) concern?
- Is the danger increasing or decreasing?

☑ Review Today's Decisions

- What were the strengths & shortcomings of today's plan?
- Where were we most exposed to avalanche risk?

☑ Improve Today's Plan

- What could we have done better?
- Submit observations.

Chapter 4: Summary

? DEBRIEF THE DAY

- ☑ Summarize Conditions
- ☑ Review Today's Decisions
- ☑ Improve Today's Plan

DEBRIEF THE DAY is the final and essential step of The AIARE Framework. Debriefing enables you to gain experience faster by making you more adaptable to new situations and less likely to repeat the same mistakes twice.

A DEBRIEF is able to highlight successes and mistakes and then translate that into improvements for the next outing through three tasks:

- **Summarize Conditions** based on observations from the field
- **Review the Day's Decisions** receiving feedback from each participant
- **Improve the Day's Plan** in order to utilize lessons learned on the next outing.

CHAPTER 4 QUESTIONS

1. How do you confirm the accuracy of your field observations prior to documenting or submitting to the local avalanche center?
2. What's the best way to review the day and identify the strengths and weakness of your plan without insulting those who participated in the planning stages?
3. How often have you formally debriefed your backcountry trip outside the course environment? Can you see the value in this exercise? How often do you expect professional avalanche workers do this?

See Page 101 for answers

RESOURCES

Appendix A:
Avalanche Problem Types

This reference is a print version of the definitions found in the Avalanche Encyclopedia found on avalanche.org[16] and is based on the definitions outlined in the *Conceptual Model of Avalanche Hazard.*[17]

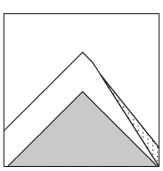
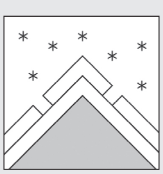
The avalanche danger scale is a broad brushstroke of daily conditions. Avalanche Problems are an extension of the danger scale and use four factors to give a more nuanced description of the day's avalanche conditions:

- **The type of potential avalanche**
- **The location of that avalanche in the terrain**
- **The likelihood of triggering an avalanche**
- **The potential size of the avalanche**

Avalanches have a wide variety of personalities. Avalanche specialists in the United States use nine distinct "avalanche problems types" or "characters" to better describe and communicate the avalanche conditions.

Understanding the following definitions is an imperative part using and understanding your local avalanche forecast.

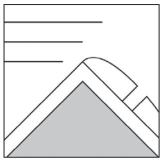
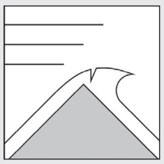
HAZARD FROM NEW SNOW AND/OR WIND:

Dry Loose Avalanche 	**Dry Loose** avalanches are the release of dry unconsolidated snow and typically occur within layers of soft snow near the surface of the snowpack. These avalanches start at a point and entrain snow as they move downhill, forming a fan-shaped avalanche. Other names for loose dry avalanches include point-release avalanches or sluffs.
Storm Slab Avalanche 	**Storm Slab** avalanches are the release of a cohesive layer (a slab) of new snow that breaks within new snow or on the old snow surface. Storm-slabs typically last between a few hours and few days (following snowfall). Storm-slabs that form over a persistent weak layer (surface hoar, depth hoar, or near-surface facets) may be termed Persistent Slabs or may develop into Persistent Slabs.

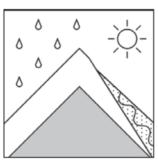
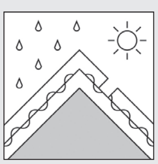
16 See the entries for "Avalanche Problem" and "Avalanche Character (aka Avalanche Problem Type)" in the Avalanche Encyclopedia at https://avalanche.org/avalanche-education/ - avy-encyclopedia. The Avalanche Problem entry also has a five-minute video that provides a useful primer on avalanche problems.

17 Statham, Grant, Pascal Haegeli, Ethan Greene, Karl Birkeland, Clair Israelson, Bruce Tremper, Chris Stethem, Bruce Mcmahon, Brad White, and John Kelly. "A Conceptual Model of Avalanche Hazard." Natural Hazards 90, no. 2 (November 02, 2017): 663-91. doi:10.1007/s11069-017-3070-5.

HAZARD FROM NEW SNOW AND/OR WIND (CONT'D):

Wind Slab Avalanche 	**Wind Slab** avalanches are the release of a cohesive layer of snow (a slab) formed by the wind. Wind typically transports snow from the upwind sides of terrain features and deposits snow on the downwind side. Wind slabs are often smooth and rounded and sometimes sound hollow, and can range from soft to hard. Wind slabs that form over a persistent weak layer (surface hoar, depth hoar, or near-surface facets) may be termed Persistent Slabs or may develop into Persistent Slabs.
Cornice Avalanche 	**Cornice Fall** is the release of an overhanging mass of snow that forms as the wind moves snow over a sharp terrain feature, such as a ridge, and deposits snow on the downwind (leeward) side. Cornices range in size from small wind drifts of soft snow to large overhangs of hard snow that are 30 feet (10 meters) or taller. They can break off the terrain suddenly and pull back onto the ridge top and catch people by surprise even on the flat ground above the slope. Even small cornices can have enough mass to be destructive and deadly. Cornice Fall can entrain loose surface snow or trigger slab avalanches.

HAZARD FROM RAPID WARMING OR RAIN:

Wet Loose Avalanche 	**Wet Loose** avalanches are the release of wet unconsolidated snow or slush. These avalanches typically occur within layers of wet snow near the surface of the snowpack, but they may quickly gouge into lower snowpack layers. Like Dry Loose Avalanches, they start at a point and entrain snow as they move downhill, forming a fan-shaped avalanche. Other names for wet loose avalanches include point-release avalanches or sluffs. Wet Loose avalanches can trigger slab avalanches that break into deeper snow layers.
Wet Slab Avalanche 	**Wet Slab** avalanches are the release of a cohesive layer of snow (a slab) that is generally moist or wet when the flow of liquid water weakens the bond between the slab and the surface below (snow or ground). They often occur during prolonged warming events and/or rain-on-snow events. Wet Slabs can be very unpredictable and destructive.

HAZARD PERSISTING WITHIN OLD SNOW LAYERS:

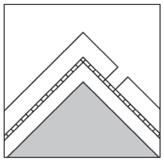
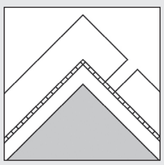
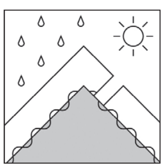
Persistent Slab Avalanche 	**Persistent Slab** avalanches are the release of a cohesive layer of snow (a slab) in the middle to upper snowpack, when the bond to an underlying persistent weak layer breaks. Persistent layers include: surface hoar, depth hoar, near-surface facets, or faceted snow. Persistent weak layers can continue to produce avalanches for days, weeks or even months, making them especially dangerous and tricky. As additional snow and wind events build a thicker slab on top of the persistent weak layer, this avalanche problem may develop into a Deep Persistent Slab.
Deep Slab Avalanche 	**Deep Persistent Slab** avalanches are the release of a thick cohesive layer of hard snow (a slab), when the bond breaks between the slab and an underlying persistent weak layer deep in the snowpack. The most common persistent weak layers involved in deep, persistent slabs are depth hoar or facets surrounding a deeply buried crust. Deep Persistent Slabs are typically hard to trigger, are very destructive and dangerous due to the large mass of snow involved, and can persist for months once developed. They are often triggered from areas where the snow is shallow and weak, and are particularly difficult to forecast for and manage.
Glide Avalanche 	**Glide Avalanches** are the release of the entire snow cover as a result of gliding over the ground. Glide avalanches can be composed of wet, moist, or almost entirely dry snow. They typically occur in very specific paths, where the slope is steep enough and the ground surface is relatively smooth. They are often proceeded by full depth cracks (glide cracks), though the time between the appearance of a crack and an avalanche can vary between seconds and months. Glide avalanches are unlikely to be triggered by a person, are nearly impossible to forecast, and thus pose a hazard that is extremely difficult to manage.

Table 4 Types of avalanche problems

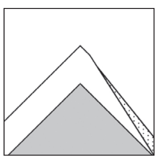
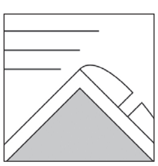
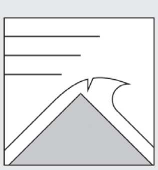
Name	Description[1]	Formation	Persistence	Typical Physical Characteristics					Typical Risk Mitigation
				Weak Layer Type[2]	Weak Layer Location	Slab Hardness[3]	Propagation Potential	Relative Size Potential[4]	
Dry Loose Avalanche Problem	Cohesionless dry snow starting from a point. Also called a sluff or point release.	Surface layers of new snow crystals that lack cohesion, or surface layers of faceted snow grains that lose cohesion.	Generally lasts hours to days when associated with new snow, and longer when associated with facets.	~	~	~	Downslope entrainment	R1-2	Avoid terrain traps where avalanche debris can concentrate, exposure above cliffs where small avalanches have consequence, and steep terrain overhead where sluffs can start.
Wet Loose Avalanche Problem	Cohesionless wet snow starting from a point. Also called a sluff or point release.	Snow becomes wet and cohesionless from melting or liquid precipitation.	Persistence correlates with warm air temperatures, wet snow or rain, and/or solar radiation.	~	~	~	Downslope entrainment	R1-3	Avoid gullies or other confined terrain features when water from melting or precipitation is moving through the snowpack.
Storm Slab Avalanche Problem	Cohesive slab of soft new snow. Also called a direct-action avalanche.	Cohesive slab of new snow creates short-term instability within the storm snow or at the old snow interface.	Peaks during periods of intense precipitation and tends to stabilize within hours or days following.	DF, PP	In new snow or at new/old snow interface	Very soft to medium (F-1F)	Path	R1-5	Avoid avalanche terrain during periods of intense precipitation, and for the first 24-36 hours following. Assess for crack propagation potential in all avalanche terrain during and in the days following a storm.
Wind Slab Avalanche Problem	Cohesive slab of locally deep, wind-deposited snow.	Wind transport of falling snow or soft surface snow. Wind action breaks snow crystals into smaller particles and packs them into a cohesive slab overlying a non-persistent weak layer.	Peaks during periods of intense wind loading, and tends to stabilize within several days following. Cold air temperatures can extend the persistence.	DF, PP	Upper snowpack	Soft to very hard (4F-K)	Terrain feature to path	R1-4	Identify wind-drifted snow by observing sudden changes in snow surface texture and hardness. Wind erodes snow on the upwind side of an obstacle, and deposits it on the downwind side. They are most common on the lee side of ridge tops or gullies and are most unstable when they first form and shortly after.
Persistent Slab Avalanche Problem	Cohesive slab of old and/or new snow that is poorly bonded to a persistent weak layer and does not strengthen, or strengthens slowly over time. Structure is conducive to failure initiation and crack propagation.	Weak layer forms on the snow surface and is buried by new snow. The overlying slab builds incrementally over several storm cycles until reaching critical threshold for release.	Often builds slowly and then activates within a short period of time. Can persist for weeks or months but generally disappears within six weeks.	SH, FC, FC/CR combo	Mid to upper snowpack	Soft to hard (4F-P)	Path to adjacent paths	R2-4	Complex problem that is difficult to assess, predict and manage. Typically located on specific aspects or elevation bands but sometimes widespread. Identification and tracking of weak layer distribution and crack propagation propensity is key, along with a wide margin for error and conservative terrain choices.
Deep Persistent Slab Avalanche Problem	Thick, hard cohesive slab of old snow overlying an early-season persistent weak layer located in the lower snowpack or near the ground. Structure is conducive to failure initiation and crack propagation. Typically characterized by low likelihood and large destructive size.	Weak layer metamorphoses within the snowpack forming facets adjacent to an early-season ice crust, depth hoar at the base of the snowpack, or facets at the snow-glacier ice interface. The overlying slab builds incrementally over many storm cycles until reaching critical threshold for release.	Develops early in the winter and is characterized by periods of activity followed by periods of dormancy, then activity again. This on/off pattern can persist for the entire season until the snowpack has melted.	DH, FC, FC/CR combo	Basal or near-basal	Medium to very hard (1F-K)	Path to adjacent paths	R3-5	The most difficult avalanche problem to assess, predict and manage due to a high degree of uncertainty. Low probability/high consequence avalanches. Triggering is common from shallow, weak snowpack areas, with long crack propagations and remote triggering typical. Weak layer tracking and wide margins for error are essential, with seasonal avoidance of specific avalanche terrain often necessary.
Wet Slab Avalanche Problem	Cohesive slab of moist to wet snow that results in dense debris with no powder cloud.	Slab or weak layer is affected by liquid water which decreases cohesion. Crack propagation occurs before a total loss of cohesion produces a Wet Loose Avalanche Problem.	Peaks during periods of rainfall or extended warm air temperatures. Persists until either the snowpack refreezes or turns to slush.	Various but often FC or DH	Any level	Soft to hard wet grains (4F-P)	Path	R2-5	Rainfall, strong solar radiation, and/or extended periods of above-freezing air temperatures can melt and destabilize the snowpack immediately. Timing is key regarding slope aspect and elevation, and overnight re-freezing of the snow surface can stabilize the snowpack.
Glide Slab Avalanche Problem	Entire snowpack glides downslope then cracks, then continues to glide downslope until it releases a full-depth avalanche.	Entire snowpack glides along smooth ground such as grass or rock slab. Glide crack opens, slab deforms slowly downslope until avalanche release results from a failure at the lower boundary of the slab.	Can appear at any time in the winter and persists for the remainder of the winter. Avalanche activity is almost impossible to predict.	WG, FC	Ground	Medium to very hard (1F-K)	Path	R3-5	Usually localized, visible and easy to recognize, the presence of a glide crack does not indicate imminent release. Predicting a glide slab is almost impossible, so avoid slopes with glide cracks and overhead exposure to glide slabs.
Cornice Avalanche Problem	Overhanging mass of dense, wind-deposited snow jutting out over a drop-off in the terrain.	Wind transport of falling snow or soft surface snow develops a horizontal, overhanging build out of dense snow on the leeward side of sharp terrain breaks.	Persists all winter on ridge crests, and tends to collapse spontaneously during periods of warming, or following intense wind loading events.	~	~	~	Path	R1-5	Avoid overhead exposure to cornices whenever possible, particularly during storms or periods of warmth and/or rain. Cornices are heavy and can trigger slabs on the slopes below. Use great care on ridge crests to stay on solid ground, well away from the root of the cornice.

[1]Haegeli et al. 2010; [2]Fierz et al. 2009 (p 4); [3]Fierz et al. 2009 (p 6); [4]AAA 2016 (p 54)

Appendix B:
Avalanche Observations & References

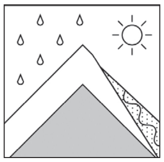
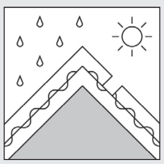
The *AIARE Avalanche and Observation Reference* helps you understand signs of unstable conditions and relevant observations that match the avalanche problem types of concern. Knowing the type of avalanche problem, *The Avalanches and Observation Reference* lists signs of unstable conditions in the first column, relevant observations and tests in the second column, and special considerations specific to each problem in the third column. In order to have this reference in the field, this table is on pages 56-58 of *The AIARE Fieldbook*. A larger print format is included here for reference.

CAUSE: Hazard from new snow and/or wind

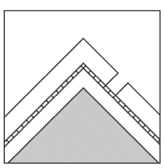
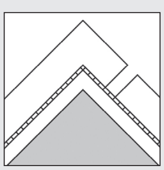
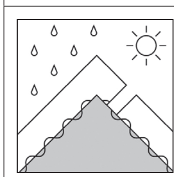
PROBLEM	SIGNS OF UNSTABLE CONDITIONS	OBSERVATIONS AND TESTS	CONSIDERATIONS
Dry Loose Avalanche 	• Recent point releases observed in steep terrain. • Forms a fan-shaped avalanche with fine, even sized debris.	• Boot deep penetration into loose surface snow. • Ski tests on small slopes result in accelerating sluffs.	• Can be naturally triggered in steep terrain by falling snow, cornice fall, rock fall, increased wind or sun. • Rider triggered sluffs on steep continuous slopes can accelerate fast and run far. • Small slides dangerous when rider is carried into terrain traps or over cliffs. • Sluffs can trigger slabs in certain conditions.
Storm Slab Avalanche 	• Recent slab avalanches during or just after storm observed in steep sheltered terrain.	• Hand hardness in profiles shows denser storm slab has formed over less dense weak layer. • Decreased ski/foot penetration, snow cones illustrate recent snow settlement. • Snowpack tests show slab is not bonding to underlying weak layer.	• Triggers on convexities or steepest section of start zone. • Waiting several days after storm may reduce likelihood of triggering. • When storm slabs exist in sheltered terrain wind slabs may be also present in exposed terrain. • As with all slab avalanches, the deeper the weak layer and larger the slope the more destructive the avalanche.
Wind Slab Avalanche 	• Recent slab avalanches observed below ridge top, cornices, and cross-loaded features. • Observe snow drifting near ridge lines onto steep slopes.	• Evidence of wind-transported snow (drifts, plumes, cornice growth.) • Snow surface rippled and crusty or smooth and firm. • Once snow covered trees are now blown clean. • Moderate or strong mountain wind speeds reported at weather stations.	• Deposition zones may accumulate 3-5x more snow than snowfall accumulation in sheltered areas. • Strong winds may result in deposition lower on slopes or in less typical locations. • Riders commonly trigger slopes from thinner areas on either side or toe of wind slab. • The wind drifting of dry, loose surface snow and subsequent avalanching can occur days after the last snowfall. • New snow can bury and hide signs of prior wind event.
Cornice Avalanche 	• Recent cornice fall. • Cornice fall releases slab avalanches on slopes below.	• Cornice growth after heavy snowfall or drifting snow. • Cornice droop from sun. • Watch for wind slab problem on slope below new cornice formation.	• Cornices often break further back onto ridge top than expected. • Observers may underestimate sun's effect on the back of cornice when traveling on cool, shaded aspects. • Cornice fall chunks may not look large but have significant mass and can be destructive or trigger slope below.

AVALANCHES & OBSERVATIONS

CAUSE: Hazard from warming or rain

PROBLEM	SIGNS OF UNSTABLE CONDITIONS	OBSERVATIONS AND TESTS	CONSIDERATIONS
Wet Loose Avalanche 	• Fan shaped avalanches with lumpy and chunky debris. • Rain on snow, especially on dry snow. • Pinwheels or roller balls.	• Wet snow surface from sun, heat or rain. • Air temperature at or above 0°C (32F.) • Timing is critical: danger can increase quickly (minutes to hours.)	• No freeze for multiple nights worsens condition. However, nighttime freeze can stabilize. • Avalanches may start from rocks or vegetation. • Can occur on all aspects on cloudy days/nights. • Conditions may also include increased hazard from cornice fall, rockfall or icefall. • Difficult to escape from loose wet or wet slab avalanches. Avoid terrain when wet conditions begin to penetrate into the snowpack.
Wet slab avalanche 	• Observe recent wet slab avalanches with debris that has channels/ridges, high water content. May entrain rocks and vegetation. • Prolonged warming trend or rain, especially the first melt cycle on dry snow.	• Avalanches may have rocks or dirt in debris. • Deep foot penetration through wet surface snow. • Snow profiles show slab is at 0°C (32F) and/or weak layer below is wetted.	• Loose wet conditions may lead to wet slabs. • Shallow snow areas become unstable first and may slide to ground. • Nearby glide cracks may be widening during rapid warming or rain event. • Consequences of an avalanche in steep, confined or cliffy terrain increase as surface wetness penetrates deeper into the snowpack.

CAUSE: Hazard persists with old snow layers

PROBLEM	SIGNS OF UNSTABLE CONDITIONS	OBSERVATIONS AND TESTS	CONSIDERATIONS
Persistent Slab Avalanche 	• Advisories warn of persistent weak layer. • Collapsing/whumping or shooting cracks from rider's weight. • Warning: active avalanching may not be observed.	• Profiles reveal a soft coarse grained weak layer just above or just below a firmer fine-grained layer. • Advisories describe the weak layer as surface hoar, depth hoar or facets. • The weak layer fractures cleanly across the column in snowpack tests.	• Persistent weak layers can continue to produce avalanches for days or weeks making them especially dangerous and tricky to forecast. • Despite no natural avalanches in observed area, persistent slabs may be triggered by the weight of a rider—particularly soft slabs (4F to 1F) that are <1m thick. • Weak layer may have formed in select terrain or may be widespread. Multiple tests and expertise is required to identify extent and degree of hazard.
Deep Slab Avalanche 	• Advisories warn of deep persistent slab problem. • Recent but isolated large slab avalanche may indicate a sleeping problem is becoming active. • No result from rider tracks but cornice fall triggers deep slab.	• Consider persistent slab conditions. • Snow profiles show increased depth of persistent layer. • Despite a recognizable weak layer in snow profiles column tests may not be conclusive.	• A "stubborn" or sleeping deep weak layer may reactivate after new snow, drifting snow or warming. • Deep slabs are difficult to forecast and manage. Large and/or historic avalanches may result. Avoid slopes with a known deeply buried & unstable layer. • Deep slabs have been remotely triggered from shallower weak snowpack areas, from low on the slope, or from adjacent slopes. • Observing and testing a weak layer deeper than 1m may be time consuming and strenuous.
Glide Avalanche 	• Observed slab release of the entire snow cover to the ground or to a near ground layer. • Glide slabs often proceeded by widening of full depth "glide cracks" visible on surface.	• When a glide slab releases other glide cracks nearby may also release. • Continued snowfall loading event and/or a significant warming and/or rain event may release glide slabs.	• Unlikely to be human triggered and nearly impossible to forecast. Large destructive avalanches result. • Often reoccur annually on the same, specific slope. This is the best clue. Avoid these slopes!

Appendix C: Answers to Chapter Summary Questions

CHAPTER 1: PREPARE

CONTINUE YOUR AVALANCHE EDUCATION

1. How will you continue your avalanche education? List two steps you will take to continue to learn and gain experience after this course.

AIARE course participants can continue their avalanche education through a combination of several pathways. First, they can complete the 7-day *Decision Making in Avalanche Terrain* program. This stream of education teaches participants how to recognize risk in avalanche terrain (AIARE 1), manage uncertainty in avalanche terrain (AIARE 2) and includes an intensive 1-day rescue course (Avalanche Rescue). Second, course participants can seek out mentors or hire avalanche professionals to practice and refine the tools and techniques they learned on their AIARE courses. Third, they can stay up to date on current best practices, industry trends, and research by either attending a regional snow and avalanche workshop and/or subscribing to *The Avalanche Review* published by The American Avalanche Association.

Specific examples could include:

Complete an AIARE 2 course after one year of implementing the tools and skills learned in an AIARE 1 and an Avalanche Rescue course. This would include filling out the AIARE Fieldbook each morning prior to heading into the backcountry, recording observations in the field and debriefing each evening.

Hire a Ski Guide with a group of friends to do a custom avalanche refresher course. The guide observes your group's decision making process, terrain selection, and travel strategies. The guide then can provide meaningful feedback so your group can develop as backcountry travelers and decision-makers.

Become a member of The American Avalanche Association, which includes a subscription to *The Avalanche Review.*

2. What are three qualities, in addition to avalanche expertise, that make a good backcountry mentor?

An ideal mentor is an experienced backcountry traveler with years of applying field observations to conservative terrain decisions. This individual has spent time tracking the layered snowpack across the local terrain for many seasons. Additionally, a good backcountry mentor coaches the mentee through the complete decision-making process and provides timely, specific, and helpful feedback. Most importantly, a mentor is somebody who wants to continue to learn alongside you, and is interested in your development as an informed backcountry traveler.

PRACTICE AVALANCHE RESCUE

3. Why is it so important to practice avalanche rescue several times each winter?

Organizing an effective and efficient rescue takes practice. Pre-event rehearsal is a proven strategy to reduce stress and focus on actions during critical, life-saving situations. Practicing realistic rescue several times each winter is critical to ensure that your rescue skills stay "tuned up" throughout the season. How you practice is how you will respond in an emergency. And remember, skills that are not used tend to expire.

4. If you have multiple rescuers and burials, should your team rescue the closest, shallowest burial first? Or should you divide your searchers and excavate two sites at once?

Excavate the closest shallowest burial first!

TRACK THE SEASON'S CONDITIONS

5. When we monitor the season's conditions, what should we watch for and why?

Monitor weather and snowfall events, avalanche events, and danger trends throughout the season. In particular, use the advisory (where it's available) to help make the connection between what weather events cause the avalanche danger to spike. Paying attention to avalanche patterns across your local terrain is another critical part of monitoring the season's conditions. This can be done on a slope scale, a drainage scale, or a range scale. Lastly, make a note of when the advisory, or local professionals, warn of persistent weak layers in the snowpack and adjust terrain choices accordingly.

INVESTIGATE TRIP OPTIONS

6. It is helpful to have a catalog of trip options to reference and add to throughout the season when planning trips. What factors should you consider when choosing a trip from this list?

Avalanche conditions will drive terrain choices on most days. However, other factors include: timing, length of trip, weather and travel conditions, partners' abilities, and goals for the day. Choosing the right trip is the first step in reducing the likelihood of a problem or accident. Ensure that your catalog has enjoyable options for ALL conditions.

CHAPTER 2: PLAN YOUR TRIP

1. Describe two reasons why a pre-trip plan can help to mitigate human factors that can challenge decisions and terrain choices.

The first part of the PLAN YOUR TRIP checklist is to check in with the group. A systematic Group Check In helps identify potential problems and human factors in the group before the group heads out into the field. It is worth pointing out that The Group Check In can also bring out group strengths.

The complete process of using the Plan Your Trip checklist creates a collaborative environment for a group to discuss goals, hazards, terrain and emergency plans. This process mitigates human factors since groups decide through consensus what terrain they want to explore and what terrain they want to avoid before they head out into the field.

2. How do you get around the potentially awkward issue of discussing compatible goals and risk tolerance with your backcountry travel partners?

Group decisions in and around avalanche terrain should be consensus-based. Use the concept of consensus to tackle potentially awkward questions during the pre-trip planning process. Framing specific questions that address goals and risk tolerance in a non-judgmental way is a great place to start off the process of building consensus. This sets the tone that each team member's opinion is valued and will be incorporated into the day's decisions.

3. Describe why a three-person group can theoretically make better decisions than a two-person group?

A two-person group may not benefit from as much collective experience and wisdom as a three-person group. A slightly larger group introduces more opinions and alternative perspective. Research (Bolognesi, 2000) and experience show that the ideal group size is between 3 and 5 people.

4. How can wind speeds of over 25 kph (15 mph) increase the hazard during a heavy snowfall?

Wind speeds greater than 15 mph are strong enough to drift snow—either falling from the sky or on the ground and available for transport—into slabs. Fresh deposits of wind-drifted snow are called wind slabs; they commonly form on the lee sides of ridges and terrain features.

5. The avalanche advisory highlights a principle concern or avalanche problem each day. It is up to you to anticipate the day's risk and make a plan that avoids the day's problem. After you read through the advisory, what are four questions that you should ask yourself to ensure that you grasp the advisory's key messages?

1. What is the primary problem type? (Ex. Wind Slabs)
2. How destructive is this problem? (Size)
3. Where is the problem located? (Aspect, elevation, terrain features)
4. Is the danger improving or getting worse? (Danger Trend & Timing)

6. Why listen to a dissenting voice in the group who keeps challenging some of your statements and assumptions?

If all team members can't agree on a safe and fun route it may indicate unfamiliarity or uncertainty with the conditions or the terrain. This could be a sign that the group could be in over its head. Listening to other opinions and challenging assumptions are critical steps in the process of reaching a consensus-based decision. Remember that consensus means that everybody, not just the majority, agrees to a decision.

7. Why plan observation and check-in locations along the route?

Planning observation locations and group check-in provides the group ample opportunity to monitor the conditions throughout the day. These stops are chances where the group can preview terrain, discuss changes in the weather, and observe potential avalanche activity. Having pre-built check-ins also ensures that the group both travels together and decides together—the group can't have a real discussion if everyone is spread out while traveling.

8. If you have questions whether the group can pull off the day's plan, what do you do? How can you effectively make your point?

Highlighting uncertainty is an effective way to make the point out that the group may not be able to safely pull off the day's plan. Some signs of uncertainty include: not being able to answer questions prompted by the checklists, not being able to build consensus, not being sure about changing weather and avalanche conditions. A key tenet throughout the AIARE curriculum is that as uncertainty increases, defer to simpler terrain. During the trip planning phase the group can build and agree to alternative trip options that they can implement should the day not go according to plan or conditions change. This way, if the group has any question about their ability to complete the day's objective once they are in the field, they can switch gears to a simpler, less exposed option.

1. Describe the key steps in a transceiver function check (from memory).

1. Find an appropriate location away from conflicting signals and stand in a ½ circle at least an arm's length apart. The check leader stands a few meters away in the middle of the group.
2. Turn all transceivers on. Each individual checks that their transceiver's display is OK, checks that their transceiver runs a self-check, and then note battery strength.
3. Report battery strength aloud to group
4. Switch all transceivers to SEARCH mode
5. Check leader switches to TRANSMIT/SEND mode and checks that each group member can receive a signal.
6. Group switches over to TRANSMIT/SEND and stows transceivers for the day—under an outside layer and 30 cm from cell phones and radios.
7. Check leader returns to SEARCH mode and confirms all group members are transmitting.
8. Check leader switches to TRANSMIT/SEND and confirms this to group. Group verifies the transceiver is stored appropriately.

2. When recording field observations, which is the most important sign of unstable conditions?

Recent avalanches, specifically ones that are naturally occurring, are the most obvious indications of unstable snow.

3. What are four questions that a group can ask each other at the top of a slope that may provide some insight about the slope's potential to avalanche?

1. Is this slope a known or obvious avalanche path?
2. Is the slope steep enough to slide? (This is generally between 30 and 45 degrees.)
3. Does this slope have the same aspect/elevation as today's avalanche problem?
4. Does the slope contain steep convex roll overs and other hard to avoid trigger points?

4. List four general observations your group can make when assessing a slope that can better help the group estimate the consequences of triggering a slide.

1. The result of getting caught in an avalanche of any size would be dire.
2. The slope has dangerous terrain above or adjacent to it.
3. The slope has a terrain trap below it.
4. The slope is committing and does not have an easy escape option.

5. Avalanche professionals utilize a concept known as a "margin of safety" in their decision-making process. A margin of safety builds in a buffer that provides an extra level of security in a dynamic, and sometimes uncertain environment. What specific components of terrain add a margin of safety in response to uncertainty?

The simplest way to combat uncertainty and build in a margin of safety into decision-making is to defer to smaller, less consequential slopes. If a group does decide, by consensus, to ride in avalanche terrain they should be riding one at a time. Riding one at a time does not miraculously make an unsafe slope safe, but it does minimize the number of riders exposed and ensures that the rest of the group is watching/communicating with the rider. Other travel techniques that can add a buffer of security include staying on high ground, not traveling above or below other groups, and stopping/re-grouping away from the avalanche hazard.

1. How do you confirm the accuracy of your field observations prior to documenting or submitting them to the local avalanche center?

The group can summarize the observed conditions as part of the DEBRIEF at the end of the tour day. During this time, group members can share field observations, compare notes, and start the process of submitting an observation to the local avalanche center. This process ensures that each team member has a voice in describing conditions, but it also creates a finished product sourced from the group's collective base of knowledge and observations.

2. What's the best way to review the day and identify the strengths and weakness of your plan without insulting those who participated in the planning stages?

In a debrief it is important to note what went well and identify the reasons those aspects of the plan went well, in addition to identifying what went wrong. Framing the DEBRIEF as simply picking apart a plan and identifying what was wrong creates too narrow of a fame that makes group members reluctant to engage in a debrief. It is important to frame this exercise as a means to build intentional experience. The goal is not to assign blame; it is to develop as backcountry travelers and decision makers. As the group discusses strengths and weaknesses of the day's plan and when they felt they were most at risk, encourage each group member to use their voice and build off of the same group dynamics that went into the trip planning process.

3. How often have you formally debriefed your backcountry trip outside the course environment? Can you see the value in this exercise? How often do you expect professional avalanche workers do this?

Professional avalanche workers debrief at the end of each day. This is often times in the format of an Evening Hazard and Risk Assessment Form (PM Form) and/or PM meeting. The PM form touches on many of the same questions that the DEBRIEF process does. Typical questions a PM form might ask include:

"Were the conditions similar to what we expected?"
"Where did the team encounter the greatest risk?"
"Based on the information we now have, what would we have done differently?"

Professional avalanche workers are constantly reflecting on their decisions so that they can incorporate that insight into future trips. Sound familiar?

Appendix D:
Potential Human Factor Traps

Humans have evolved complex cognitive ways to take in and process the large and constant stream of information we receive from the world around us. Additionally, humans are social beings. How we interact with others and our need at some level to "fit in" is a powerful (and generally unconscious) driver of our behavior. We call these cognitive and social aspects that influence our behavior and ultimately our decision making human factors. These cognitive and social aspects that influence our behavior and ultimately our decision making are known as human factors.

There are many ways to identify, group, and combat human factors. This is also a constantly evolving conversation as the field of behavioral economics and the study of how our brain works grows. While this list is not exhaustive, we have grouped major human factor traps relevant to backcountry travel and decision making in five categories:

1. Social Pressure
2. Overconfidence and/or Low Self Confidence
3. Closed Mindedness
4. Shortcuts
5. Impaired Objectivity

Even experienced backcountry travelers succumb to these human factor traps. Regardless of avalanche knowledge or experience, watchful team members help each other identify these traps at work during the PLAN and RIDE components of The AIARE Framework. These deliberate actions can help prevent biases from driving a poor decision.

SOCIAL PRESSURE

The drive to be or remain a part of a group and how we behave and define ourselves around others is powerful and usually unconscious. Peer pressure, a desire for acceptance, social proof, feelings of scarcity or a need to express individualism can drive us to make poor decisions or not see all the information for what it is.

- **Peer Pressure:** People are susceptible to peer pressure. It can be difficult to be the lone dissenter. Professionals such as ski patrollers and guides have additional status within the group and potential to affect decisions.
- **Scarcity:** Also identified as a common trap by Ian McCammon, Scarcity is a trap related to the pressures of a window of opportunity or a diminishing resource.[18] The most common example of this is "powder fever" which is usually seen in popular backcountry areas with limited terrain. The desire to capitalize on a special, limited opportunity can cause people to make poor terrain choices.
- **Social Proof / Risky Shift:** Social Proof is the idea that an action is correct because other people are doing it (seeing skiers on a slope of concern).[19] The Risky Shift is a phenomenon identified where a group may accept a higher level of risk than each individual might choose alone.[20] These two traps relate to what has been called the "herding instinct" - the illusion of safety in numbers. Avalanches are commonly triggered by the 3rd, 4th or 5th person rather than the first one down.

18 Ian McCammon, "Heuristic Traps in Recreational Avalanche Accidents," International Snow and Science Workshop, (2002): 275-280.

19 ibid

20 James A. Stoner, "A comparison of individual and group decisions involving risk" (Unpublished master's thesis, Massachusetts Institute of Technology, Cambridge, 1961).

- **Acceptance:** McCammon calls this the tendency to engage in activities that we think will get us noticed or accepted by our peers, or by people whose respect we seek.[21] Alain de Botton refers similarly to "Status Anxiety," or the desire for status in modern society and the anxiety resulting from a focus on how one is perceived by others.[22] It is easy to see how this pressure can become a trap that influences people to make poor backcountry decisions.
- **Individualism:** People sometimes have a compulsion to feel uniquely individual. (Skiing alone is one example). Those who do not embrace a team mentality often show an inability to communicate effectively, a lack of empathy for other group members, and an unwillingness to listen to the group. This leads to a lack of cohesion in the team and can provoke tension and poor choices.

OVERCONFIDENCE AND LOW SELF CONFIDENCE

We can be quite poor at judging our own abilities (see the Dunning-Kruger effect) and as novices may not have the experience to differentiate between real and perceived risk. We can both overestimate or underestimate the risk, which causes us to build a plan for the wrong hazard. Technology, education, and skill as a rider can give us confidence to falsely transfer our skills in one realm to another or cause overconfidence. Conversely, low self-confidence can make us distrust our instincts and cause us to go along with the group and agree with a decision we instinctively feel is wrong.

According to one study by Dale Atkins, overconfidence was the leading human factor attributed to fatal avalanche accidents by people with some level of formal avalanche training.[23] Overconfidence is a dangerous trap as it generally results in more risky behavior.

- **Overconfidence Effect:** This effect is a well-established bias in which one's subjective confidence in their judgments is greater than their objective accuracy. Numerous studies demonstrate that this bias can adversely affect backcountry decisions.
- **Actual vs. Perceived Risk:** There is a gap between perception and reality. Since decisions can only be based on perceptions, this trap can lead to miscalculation of risk and poor terrain choices.
- **Technology:** In the modern world, technology has made possible the inconceivable. People sometimes demand more from their avalanche safety equipment, electronics, and snow study tools than that technology is actually able to provide. This can lead to a misperception of risk.
- **Education:** "A large percentage of people caught in avalanches had formal avalanche training."[24] A little knowledge can offer just enough confidence to overreach on decisions. It takes a lot of experience on top of training to make consistently good decisions, and what experts come to realize is that it is rare to be very confident when it comes to forecasting avalanches.
- **Abilities Outperforming Experience:** Skiers and snowboarders can become expert riders as teenagers in the boundaries of a ski resort. Sometimes, it is hard for them to imagine that they might only be beginners at backcountry decision making, even though they are capable of great feats of mountain athleticism. Confidence in physical abilities has a tendency to transcend to overconfidence in terrain decisions.
- **Low Self-confidence:** Low self-confidence can lead people to distrust their instincts and allow them to agree with a decision that they intuitively feel is wrong. In some cases, people with little formal training or group members with less experience than the leader may observe or become aware of significant data that is crucial to the decision being made. These people are often unwilling to challenge or question the "experienced" leader in the group or the status quo even when they have information or knowledge that others do not.

21 Ian McCammon, "Heuristic Traps in Recreational Avalanche Accidents," International Snow and Science Workshop, (2002): 275-280.

22 Alain De Button, Status Anxiety, (New York: Random House, 2004).

23 Dale Atkins, "Human Factors in Avalanche Accidents," International Snow Science Workshop, (2000).

24 Ian McCammon, "The Role of Training in Recreational Avalanche Accidents in the United States," International Snow Science Workshop (2000).

CLOSED MINDEDNESS

These are cognitive biases that stem out of brain's strategy to not be pulled around by every new piece of information that enters it. This means entrenched (even if incorrect) beliefs take time to change, even in light of new information. We tend to place more importance on information that we've acquired recently, hear more frequently, or that is more readily available. The key is that these biases are unconscious. Simply knowing about them doesn't mean we will change them. Using processes such as *The AIARE Framework* helps slow down group decision making and allows for recognition of when these biases are at work.

The filters listed below affect the ability to observe, process, and respond to information, resulting in a deceptively incomplete picture. (These excerpts come from *The Avalanche Handbook*)[25]

- **Conservatism**: "Failure to change (or changing slowly) one's own mind in the light of new information or evidence."[26] It takes time or a great effort to make decisions based on what we now know versus what we used to know, even we have new knowledge at our disposal.
- **Recency:** In one's mind, recent events dominate those in the past, which may be downgraded or ignored. This trap can allow more recent information to override more relevant information from the past. For example, a rider might base terrain choices on recent habits, rather than modifying the approach to match a successful strategy used in similar snowpack conditions not seen for 3 years.
- **Frequency:** Again, in one's mind, more frequent events dominate those that are less frequent. This is a trap because smaller storm events tend to be more frequent than larger ones, but larger ones can present higher danger.
- **Availability:** This trap involves making decisions based on past events easily recalled by memory to the exclusion of other relevant information. The availability of memories to be recalled may cause unusual or exceptional events to be treated as more common and may bias the decision maker to disregard other important data.
- **Prior Experience:** People tend to see problems in terms of their own background or experience. For example, one can imagine that a snowboarder with experience gained riding a resort terrain park might have a different approach to terrain use than an experienced backcountry snowmobiler.

SHORTCUTS

The human brain has efficiently processed the constant incoming stream of information and stimulus. Most of the time, the brain's methods are an effective way to keep from being overwhelmed with information and the effort involved in consciously making millions of decisions each day. These decision-making shortcuts are called heuristics. These heuristics can get us into trouble when we mistakenly apply a shortcut developed for one situation to what is actually a completely different situation.

- **Stress and Logistics Pressure:** Feelings of stress and pressure can complicate decision making. Uncorrected errors often result in increased stress, as do unanticipated conditions or scenarios. Time applies pressure. When stressed or under pressure the tendency is to take shortcuts to change the immediate scenario.
- **"Rules of Thumb" or Habits:** Habits tend to shortcut thoughtful evaluation. Independent rules of thumb may be functional at times, but they often oversimplify the problem. Good terrain selection is a complex process that demands unique assessment for each situation. Dependence on rules will lead to a decrease in accuracy, and errors can be fatal.
- **Decisions from Few Observations:** Observations take time and energy to gather. Consider if the quality/ quantity of observations represents reality, or simply convenient support for the group's desire to not find instability. For example, "I don't see any avalanches; it must be good to go!"
- **Back to the Barn:** The urge to simply "get it over with" and return to safety, food, and shelter is powerful. Commonly, people make poor decisions late in the day, when people are tired and nearly home.
- **Expert Halo:** People with more experience or knowledge tend to be perceived as experts. Group members often shortcut their own cognitive processes and allow someone they perceive as more competent to dominate the decision making.

25 David McClung, and Peter A. Schaerer, The Avalanche Handbook, (Seattle: Mountaineer Books, 2006).

26 ibid

IMPAIRED OBJECTIVITY

We all live in our own subjective realities. We can never be truly objective, but recognizing that our subjective reality colors our perception helps us to be more open to the idea that we may actually be missing evidence and more open to the input of others in our group. The occurrence of avalanches can provide a pretty low feedback environment. We may only see the evidence to support our desires (the snow looks really good) or may interpret non-events as evidence of our good decision making. The key is that we can't make ourselves more objective simply by recognizing that subjectivity happens. We need team members to provide a mirror and point our blind spots to contradictory evidence.

- **Search for Supportive Evidence:** Bruce Tremper says that people often say, "I'll believe it when I see it," when actually it is the other way around.[27] People tend to see what they already believe to be true. People tend to gather facts that lead to certain conclusions and disregard facts that threaten them.
- **Blue Sky / Euphoria:** Avalanche accidents tend to occur during blue sky days following storms.[28] Experiencing a day with great snow conditions can cloud judgement because of the hormones released during the throes of euphoria.
- **Familiarity / Non-event Feedback Loop:** McCammon pointed out that many accidents happen in familiar terrain.[29] People often feel comfortable in familiar areas. They let their guard down or base their current decisions on past experience. The trap here relates to the "Non-event Feedback Loop" in decision making. When backcountry decisions result in no avalanche, people may believe that they made the best choice. The traveler may have been simply "lucky." It may be only a matter of time before acquired habits that seem adequate result in an accident.
- **Optimism:** This is a bias also known as "wishful thinking," and has been referred to as "Commitment" by McCammon.[30] The more someone prefers an action, the more likely they are to decide to do it. Being optimistic in the face of facts we don't want to acknowledge would be like rearranging the deck chairs on the Titanic as it goes down.

27 Bruce Tremper, Staying Alive in Avalanche Terrain, (Seattle: Mountaineers Books, 2001).

28 ibid

29 Ian McCammon, "Heuristic Traps in Recreational Avalanche Accidents," International Snow Science Workshop, (2002): 275-280.

30 ibid

Appendix E: The Changing Mountain Snowpack

MOUNTAIN WEATHER RESOURCES

Mountain weather and terrain combine to form the layered mountain snowpack. To forecast where and when avalanches are likely to occur, the backcountry traveler must have basic understanding of mountain weather—and experience with how the weather interacts with the local terrain. For avalanche forecasters, reading and interpreting current weather data and weather forecasts and projecting how the weather interacts with the local mountains becomes a daily routine. The following are some additional resources to supplement those you use regularly in addition to those introduced on your course to help you Continue Your Education about mountain weather.

ONLINE WEATHER RESOURCES

Each of these sites has a vast number of specific products. To explore these sites thoroughly will take a long time. It is helpful to choose a few weather products, stick with them and watch them daily to learn to recognize trends. The list below represents a few of many websites available.

- National Weather Service: http://www.weather.gov/
- Colorado Avalanche Info Center weather model forecasts (Western US domain): https://avalanche.state.co.us/pub_model_wx.php
- Unisys Weather: http://weather.unisys.com/
- San Francisco State University: http://squall.sfsu.edu/
- University of Washington: http://www.atmos.washington.edu/weather.html
- Colorado State University GOES satellite imagery: http://rammb.cira.colostate.edu/ramsdis/online/goes-west_goes-east.asp
- National Center for Atmospheric Research real-time weather data: http://weather.rap.ucar.edu/
- Snotel Data from NRCS: http://www.wcc.nrcs.usda.gov/partnerships/links_wsfs.html
- Mesowest Wx Stations: http://mesowest.utah.edu/index.html
- MetEd Comet Mountain Weather Distance Learning Course (estimate learning time 9-12 hrs)
- http://www.meted.ucar.edu/dl_courses/mtnwx/index.htm

RECOMMENDED READING

The Avalanche Handbook, 3rd ed. by David McClung and Peter Schaerer (Seattle, WA: Mountaineers Books, 2006).

Selections from Chapter 2:

- Mountain Weather and Snow-Climate Types & Mountain Wind and Precipitation, p.21-26
- Convergence: Upward Motion around a Low-Pressure Area; Frontal Lifting; Orographic Lifting & Convection, p.26-28

THE LAYERED SNOWPACK

This reference compliments both the classroom and field snowpack lessons. It begins with the formation of snow in the atmosphere and introduces changes that begin to affect the shape of the snow grain and the surface layers. The mechanisms of heat exchange are covered, which lays the framework for discussing the processes that are responsible for snowpack metamorphism, including the creation of weak layers.

The knowledge of how snow crystals form and change in the atmosphere is an important building block toward understanding the effects that crystal form can ultimately have on new snow instability and how well new snow will bond to the old snow surface.

THE FORMATION OF NEW SNOW

When the environment is right, snow crystals form in the atmosphere. These crystals are created when water vapor condenses (deposits) as ice on a crystalline nucleus (or dust molecule). Depending on the temperature and humidity in the regions where snow is forming, new snow crystals take a variety of shapes and fall to earth in a variety of sizes.

The classic six-sided "Dendrite or Stellar" crystal is what most people visualize when we talk about a new snow crystal. In reality, atmospheric (new) snow comes in a variety of shapes and sizes. We recognize a number of sub-classes that reflect the main types of new snow. Large irregular snow grains including plates, needles, or columns may form weak layers if covered by storm snow.

Each of the sub-classes in turn has numerous variations. More than one sub-class and/or variation can form in a single storm as the temperature and humidity regimes change. It is not uncommon to see several different types of new snow during a single storm, sometimes changing back and forth over relatively short periods of time (a few minutes or hours).

When a new snow crystal gains enough mass to overcome gravity and escape any updrafts that might exist in the air mass, the crystal falls from the atmosphere and eventually lands on the ground. The build-up of snow crystals on the ground from successive snowfalls creates what we refer to as the snowpack, which is really just the total accumulation of snow that has fallen to the ground to date in a given winter.

RECORDING NEW SNOW

In avalanche work, we refer to most atmospheric snow simply as new snow (also precipitation particles) and often use one symbol (+) as the basic grain classification for all types when making field notes. Notable exceptions include plates, needles, or graupel. Advanced practitioners often identify sub-classes when they are able to clearly identify the grain type and when a sub-class is significant in terms of stability.

Observers are interested in observing and recording precipitation type, rate, and intensity. Even when the snowpack is stable avalanches can result when precipitation rates exceed 2cm/hr and deposit 30cm or more on the mountain slope. Varying types of snow falling during a storm cycle can result in a buried weak layer (example: large, well-shaped dendrites forming a thin layer under 30cm of small, more densely packed precipitation particles).

Additional specialized symbols for new snow sub-classes are in the SWAG[31] , Table 2.3, and pg. 30.

31 A3. Snow Weather and Avalanches: Observation Guidelines for Avalanche Programs in the United States (3rd ed). (Victor, ID: American Avalanche Association, 2016).

RIMING, GRAUPEL, AND HAIL

Under some conditions, tiny water droplets form in the atmosphere and remain in a liquid state at temperatures below 0o C due to a lack of a freezing nucleus. These water droplets are described as super-cooled. When a super-cooled water droplet comes into contact with any surface or object, it immediately adheres to the surface or object and freezes, forming a small spherical piece of ice. This process is called riming. The tiny ice spheres are referred to as rime.

The most visible form of rime is when super-cooled water is driven against a surface by wind. Under these conditions, rime accretes on the windward side of the surface and creates a kind of icy stalactite formation that grows larger as additional rime is added. These rime formations are often seen on rocks, trees, communication towers, etc., in wind-exposed areas, especially in maritime climates.

If a snow crystal comes into contact with super-cooled water droplets, riming occurs and the rime accretes on the crystal. When this happens, we refer to the new snow crystal as being rimed. When only a few of these ice spheres exist, they are almost invisible to the naked eye; however, they can usually be observed using a simple hand lens magnifier. As the amount of riming increases, rime becomes visible to the naked eye.

Under heavy riming, new snow crystals can accumulate so much rime that their original form becomes completely obscured, eventually forming a roughly spherical (seldom a perfect ball) pellet. Sometimes referred to as "pellet snow," this is what we call graupel. Graupel particles that ride atmospheric updrafts and accrete multiple layers of rime can eventually form hail.

Riming may occur to individual snow crystals, or it can be deposited directly onto the snowpack if conditions are right. For example, if super-cooled water is present and the wind blows directly onto a slope where rime can be deposited and accumulate, a rime crust may form on the surface of the snowpack. While not a new snow crystal, rime added to the snowpack in this way becomes a layer that is part of the snowpack. Rime crusts are generally white and opaque, rough, and feel crunchy underfoot or to the touch.

CONCLUSION

This section presents a simplified discussion of how new snow forms and riming takes place. The actual processes are complex meteorological subjects. The previous paragraphs have limited the discussion to observable characteristics relevant to snowpack stability.

Since different sub-classes and variations of new snow often fall during a storm and since each of these may have significantly different characteristics, it is not unusual to see a number of layers form in the snow that accumulates during a storm (the storm snow).

Even if the storm snow is homogeneous, in most cases it differs from the surface of the snowpack it falls onto. This often forms the first of what may be many layers in the mountain snowpack, with the interface between the storm snow and the old snowpack surface being the boundary. In addition, riming may occur to individual snow crystals or on the snowpack itself.

The snow climate has an influence on the type of snow that forms, weather conditions under which it is deposited, and the likelihood that surface hoar will form.

Due to all these factors, it is unusual to see a snowpack composed of a single homogeneous layer with consistent characteristics throughout its height. Successive storm snow deposits, the weather conditions present during and between storms, riming, surface hoar deposits, and the snow climate combine to create a succession of layers in the snowpack as it develops over the winter. These layers are often significantly different from one another. Even if they are initially similar, they may become different over time due to snow metamorphism processes. Since there are layers in the snowpack, and if they are different from one another, the layers may not bond to each other. It is this layering that is the basis for the formation and release of avalanches.

It is important to have this foundation prior to understanding the processes that drive snow metamorphism over time. Observers of the mountain snowpack require a solid grasp of the metamorphic processes. This knowledge provides essential clues to know where and what to look for when making field observations, recording findings, and eventually analyzing and forecasting snow stability.

RECOMMENDED READING

The Avalanche Handbook, 3rd ed. by David McClung and Peter Schaerer (Seattle, WA: Mountaineers Books, 2006).
Selections from Chapters 2 & 3:

- Mountain Weather and Snow Climate Types, p.21
- Snow Formation and Growth in the Atmosphere & Classification of Newly Fallen Snow Crystals, p.43-50

Snow Weather and Avalanches: Observation Guidelines for Avalanche Programs in the United States (3rd ed). (Victor, ID: American Avalanche Association, 2016).
Selections from Chapter 2

SNOWPACK STRUCTURE

To understand how snow deposited from the atmosphere changes over time, it is helpful to begin with a mental framework of the physical structure of the snowpack and forces acting upon it.

THE ICE LATTICE

The snowpack is a structure comprised of two basic components, the grains and the pore space. These parts may be apparent even to the casual observer. It is important to understand the physical nature of each component and its respective role in the transfer of heat and the movement of vapor.

The snow grains are ice particles comprised mostly of solid water and a smaller proportion of water vapor. The mass contained in these particles is not constant, and neither is their shape. Instead, the surface of these solid particles actually gives off water vapor to the air immediately surrounding the grains within the snowpack, also known as the pore space. Additionally, water vapor in the pore space migrates back onto the surface of the snow grains. The interplay of this movement of water vapor will determine the shapes that these snow grains will take in the near future. We call this process metamorphism. The actual process of snow metamorphism will be discussed more in section 1.2.4.

To the observer, it is important to understand that in low-density snow, where the grains are widely spaced, water vapor can move more readily. In contrast, with high-density snow, water vapor movement through the pore space is inhibited.

The transfer of heat is also determined by the structure of the snow grains and pore space. Solid ice conducts heat better than air, so dense snow or ice layers will transmit heat better than less dense snow. This concept will come into play in the upcoming section on heat exchange.

LAYERS AND INTERFACES

Each time snow falls from the sky, the snowpack gains a new layer. In some cases, where the nature of the storm changes, a single storm may produce multiple layers. As snow changes over time, multiple adjacent snowpack layers may become quite similar in their grain size and form. In practice these layers may be considered a single layer. Other times a single buried layer may be exposed to different conditions at various heights within that layer, becoming multiple layers over time. In short, avalanche practitioners consider a snowpack layer to be a band of snow grains with similar characteristics.

The boundary between two adjacent layers is referred to as the interface. This distinction between layers and interfaces will play an important role for the snowpack observer.

SETTLEMENT, CREEP, AND GLIDE

Over time, individual snow grains will move under the influence of gravity. This movement can be categorized in three basic categories—settlement, creep, and glide (see The Avalanche Handbook[32] p. 75 & 78). Ultimately, the impact of these processes causes snow grains to move both down slope and to settle into place closer to the ground. All of these processes tend to happen more quickly and play a more significant role in analyzing snowpack instability at warmer temperatures—particularly in relation to a dry snowpack.

Settlement involves the snow grains fitting together tighter like pieces of a puzzle. This process results from snow grains rearranging as they change shape over time and settling under the weight of overlying layers. Settlement tends to happen on the order of hours to days and can play a role in both weak layers stabilizing as well as slabs forming.

Snowpack creep is settlement occurring on a slope, where gravity acts to pull snow grains slowly downhill. On an incline the grains in the snowpack rearrange and move down slope at a faster rate near the snow surface than near the ground.

Snow gliding involves the entire snowpack slipping down slope. When the snowpack is dry, glide is small or negligible. Glide in late spring can occur on certain slopes at a fast enough rate to produce a full-depth avalanche, called a glide avalanche. In this case the snowpack glides along a warm, (0°C), smooth, lubricated surface such as a smooth grassy slope, a smooth rock slab, or occasionally an ice layer. Glide cracks in the snowpack are often visible.

Snowpack creep is a continuous process and glide features can often be observed over multiple days.

CONCLUSION

A basic understanding of the physical structure of the snowpack is essential to understanding snowpack processes. In general terms, the snow grains interconnect to form a solid lattice of ice. In a dry snow layer, every pore space not filled with ice is filled with varying amounts of water vapor. The mountain snowpack is not a complete solid but a porous material that changes structure, deforms, and very slowly creeps downhill under the influence of gravity. The knowledge of how layers form, how grains change shape, and how the snowpack deforms as it lies over terrain is the foundation for anticipating and observing where and why avalanches occur.

RECOMMENDED READING

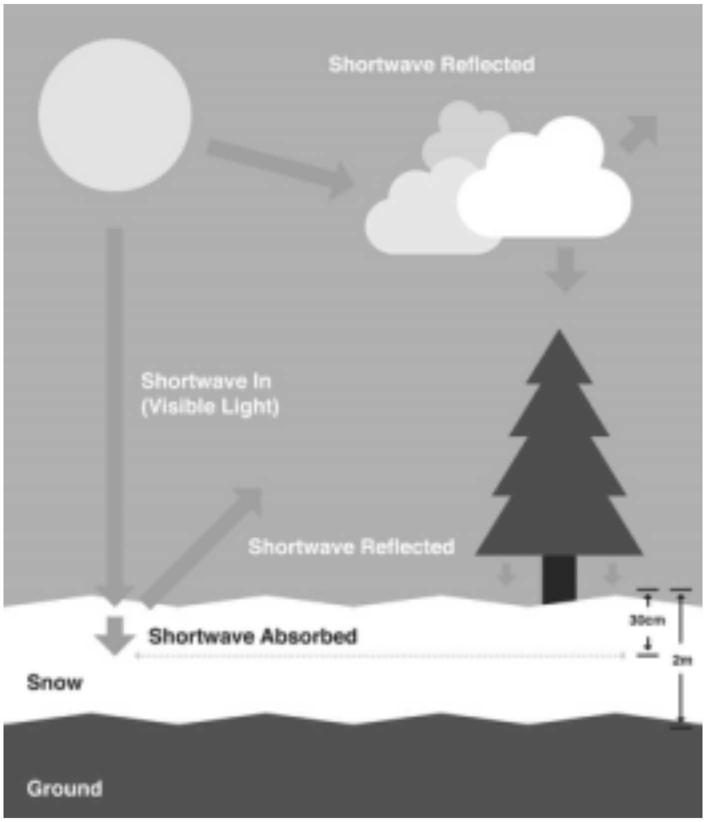
The Avalanche Handbook, 3rd ed. by David McClung and Peter Schaerer (Seattle, WA: Mountaineers Books, 2006).

Selections from Chapter 4:

- Snowpack Creep & Snow Gliding, p.75-79

32 McClung, D. and Schaerer, P. The Avalanche Handbook, 3rd ed. (Seattle, WA: Mountaineers Books, 2006).

SNOWPACK INTERACTION WITH THE ENVIRONMENT



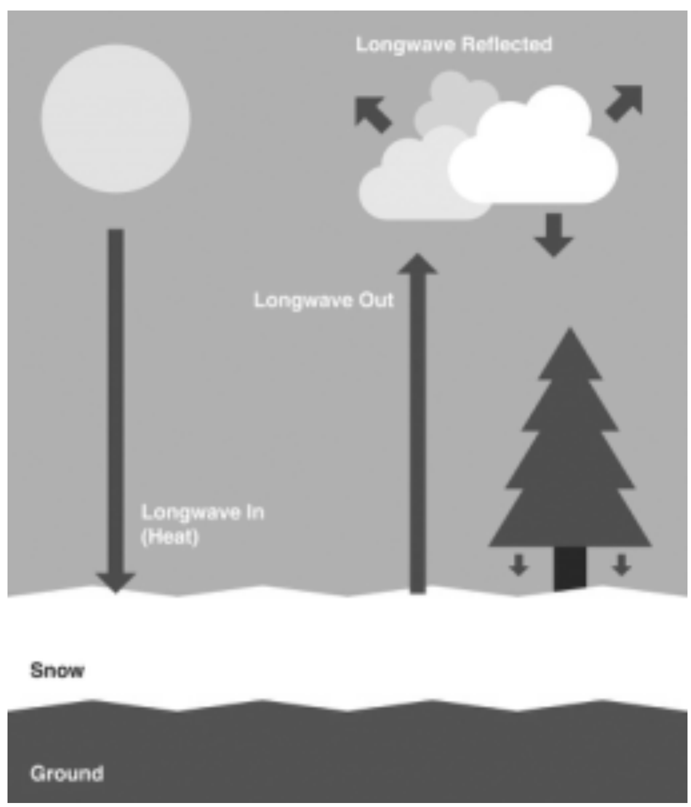
Now that snow crystal and snowpack formation have been introduced, and the basic conceptual model of snowpack structure has been reviewed, the next step is to review how the snowpack interacts with the environment. This lesson introduces how energy (heat) is transferred to, from, and within the snowpack. It addresses the mechanisms for heat transfer, the importance of energy exchanges at the snow surface, and how air temperatures and precipitation can influence these heat exchanges to, from, and within the snowpack. This lesson illustrates the importance and usefulness of quality weather and snowpack observations in assessing how the snowpack changes over time.

Solar Components: Short-wave Radiation, Penetration Into Alpine Snow, Reflecting, Warming of the Snow Surface

Energy (heat) exchanges at the snow surface play a major role in determining many properties of snow on the ground, including: snowpack stratigraphy, temperature, grain size and type, and snow density and depth. By examining energy exchanges at the snow surface, we can interpret and estimate metamorphism, and thereby make our weather observations more useful. This section describes how short-wave (sunlight) radiation factors into this overall energy balance at and near the surface.

Terrestrial Components: Radiation into Space, From Clouds, Heat Flux Through Snow Cover, Conduction Grain-to-Grain

Long-wave radiation (heat) exiting or entering the snowpack is a primary component in estimating the overall energy balance at the snow surface and within the snowpack. This section describes how heat exchanges between the snowpack and the overlying atmosphere, between the snowpack and the ground, and within the snowpack factor into metamorphic processes.



Near-Surface Temperature Inversions

Temperature inversions are common occurrences in the mountains. Inversions can result in wind patterns that may transport snow and can influence spatial variability in temperature gradients and surface hoar formation. In addition, inversions affect the heat exchange between the snowpack and the overlying atmosphere.

Precipitation, Melting, and Freezing

Sensible heat (the heat you can feel) is exchanged if new precipitation is a different temperature than the temperature of the snow surface on which it falls. Rain contains more heat energy than snowfall. The warmer the rain, the more heat energy it has, and vice versa. If rain percolates into the snowpack and freezes, latent heat (heat released or absorbed from water changing phases) is released. Similarly, latent heat is also exchanged through melting, refreezing, sublimation, and condensation of snow grains. Latent heat exchange is a process that can warm or cool certain areas of the snowpack and alter temperature gradients. This can have an effect on metamorphic processes

There is heat exchange between the three distinct layers of the atmosphere (air), the snowpack, and the ground. Heat is also transferred within the snowpack itself. The ground releases stored heat into the atmosphere, and the snowpack acts like an insulating layer that "slows down" the transfer of heat from the ground to the overlying atmosphere. It may be easiest to think of the snowpack as insulating the ground from cold winter air like a down jacket. Conditions at the ground-snow interface remain fairly constant, while conditions at the snow-atmosphere interface can vary considerably throughout the course of the day.

Heat exchanges are responsible for many of the changes snow goes through, from the time it crystallizes in the atmosphere, to how it changes while exposed to atmospheric weather conditions, to how it changes once within the snowpack and, ultimately, to how and when snow melts.

By examining heat exchange at the surface and within the snowpack, the observer can interpret and estimate metamorphism, and thereby make weather observations more relevant.

This is a simplified discussion of energy (heat) exchange at and near the snow surface and within the snowpack. Energy exchange drives the metamorphic processes we consider relevant to avalanche analysis (covered in section 1.2.4). The actual processes are complex physical processes beyond the scope of this course.

RECOMMENDED READING

The Avalanche Handbook, 3rd ed. by David McClung and Peter Schaerer (Seattle, WA: Mountaineers Books, 2006).

Selections from Chapter 2:

- Heat Exchange at the Snow Surface; Penetration of Heat into Alpine Snow; Interaction of Radiation with the Snow Cover & Temperature Inversions, p.36-41

METAMORPHISM: ROUNDING, FACETING, & SINTERING

This section discusses the processes that drive snowpack metamorphism. It begins with a review of snow grain decomposition and fragmentation. It covers how heat exchange drives metamorphic processes and the importance of the relationship between temperature and vapor pressure. The concepts of temperature gradients and regimes, conditions that promote rounding and faceting, and snow grain sintering are covered. The topics covered in this lesson further emphasize how quality field observations are instrumental in assessing how the snowpack changes over time.

DECOMPOSITION AND FRAGMENTATION

Snow crystals are constantly trying to achieve a state of equilibrium and are undergoing constant change through vapor transport within the snowpack. In addition, as wind redistributes the snow, it mechanically changes the crystals; they tend to break up into smaller fragments and pack together more tightly. This forms a harder, denser layer (a wind slab or wind crust) on the surface of the snowpack. Snow grains that have been broken into small pieces and packed by wind are properly referred to as "broken" grains, but field practitioners tend to refer to them simply as wind-affected, wind crust, or wind slab depending on the extent of the effect.

Changing wind speeds and/or duration of wind transport of snow from the "fetch," or windward, slope to the lee slope results in stiffer and less stiff layers being formed on the leeward (deposition) slope. Strong layers (slabs) over weak layers on steep lee slopes may be conducive to avalanching. Temperature and humidity play a role in drifting snow and slab formation. Drier, colder snow favors more drifting and redistribution. Higher humidity favors bonding and sintering that may inhibit wind redistribution, but may favor slab formation.

OBSERVING TEMPERATURE GRADIENTS IN THE SNOWPACK

In this context, a temperature gradient is simply a change in snowpack temperature over height. Temperature gradients and vapor pressure gradients are related in a predictable way, and vapor pressure gradients drive the movement of water vapor in the snowpack.

Water vapor pressure is not practical to measure for most field practitioners and backcountry travelers, so we estimate vapor pressure by measuring snow temperatures. Because relative humidity in the snowpack pore space is always near 100%, as temperature increases in the pore space, so does vapor pressure. This is because warm air can "hold" more water vapor than cold air, so warmer pore spaces in the snowpack will have higher vapor pressures than similarly sized cooler pore spaces. This relationship between temperature and vapor pressure is non-linear, implying that a small change in temperature can cause a large change in vapor pressure.

Heat transfers from warmer areas of the snowpack to cooler areas by conduction of heat through the ice skeleton (or through liquid water if present) and convection of water vapor across the pore space. The rate of the vapor movement across the pore spaces dictates what type of metamorphic process likely will dominate. By measuring or estimating snowpack temperature gradients, it is possible to estimate where, and at what rate, vapor is diffusing through the pore spaces. The observer can therefore infer from careful field observations how the snowpack is changing (for example, estimating the dominant metamorphic process that is changing the grain shape).

CONDITIONS THAT PROMOTE ROUNDING AND FACETING

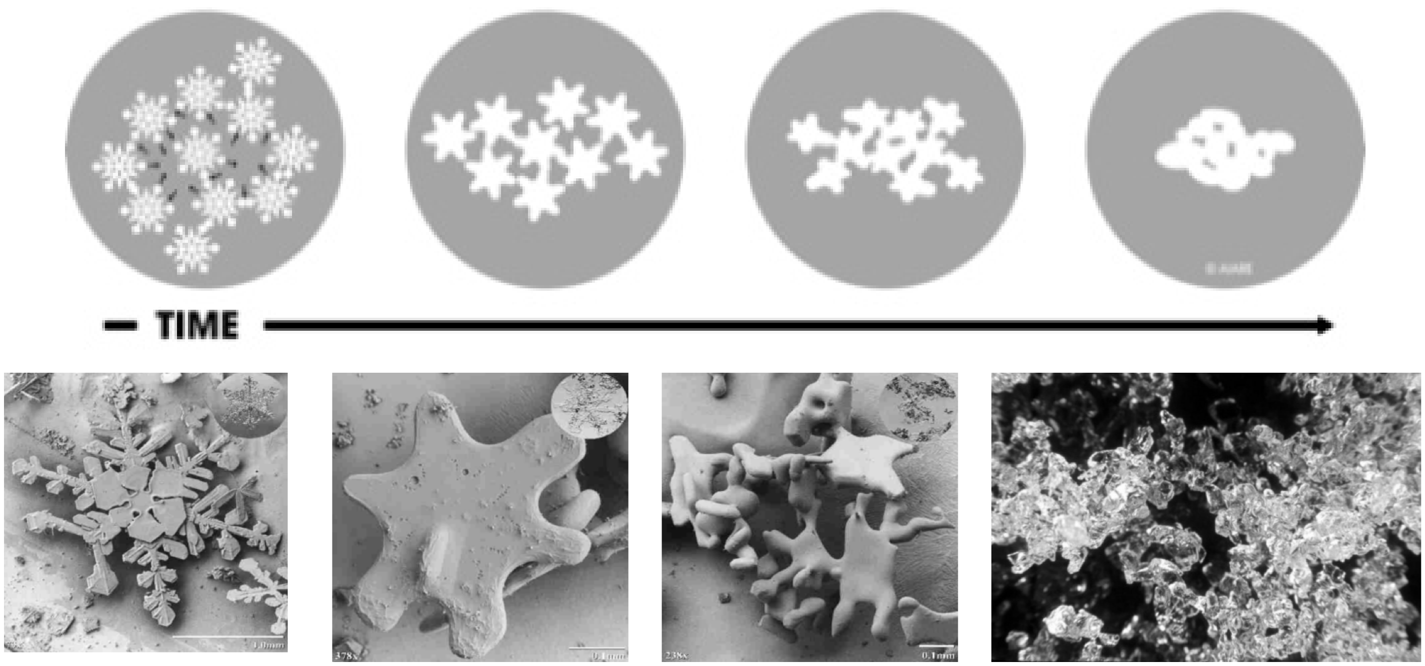
In avalanche work, temperature gradients are measured in degrees centigrade per 10 centimeters. This can be done for the layers of concern or for the entire depth of the snowpack. Taking temperatures throughout the entire depth of the snowpack is, of course, a time consuming and tedious process and often not practical. It may be worthwhile, however, to have a general idea of what the gradient is; this allows us to infer what metamorphic processes might be occurring in the snowpack so we can assess what the effect of those processes might be. Then we can decide whether it might be worthwhile for us to take a closer look at certain places to make a more detailed assessment.

Temperature gradients are described in this avalanche course as being either “low” or “high.” A low temperature gradient is less than a 10C changing over 10cm of snowpack height, and promotes rounding in the snowpack. Rounding is also promoted by high-density snow and warm temperature regimes. A high gradient is more than a 10C change over 10cm of snowpack height, and promotes faceting in the snowpack. Faceting is further promoted by low-density snow and warm temperature regimes. Note that warm temperature regimes promote enhanced rates of metamorphism for both rounding and faceting.

The characterizations of general snowpack temperatures are often referred to as temperature regimes. Simply put, “things happen” more quickly when the snowpack temperature is closer to 0°C (i.e., at -20° given a “high” gradient and a cold snowpack temperature regime, faceting would occur more slowly than at -5°C given a high gradient and warm temperature regime).

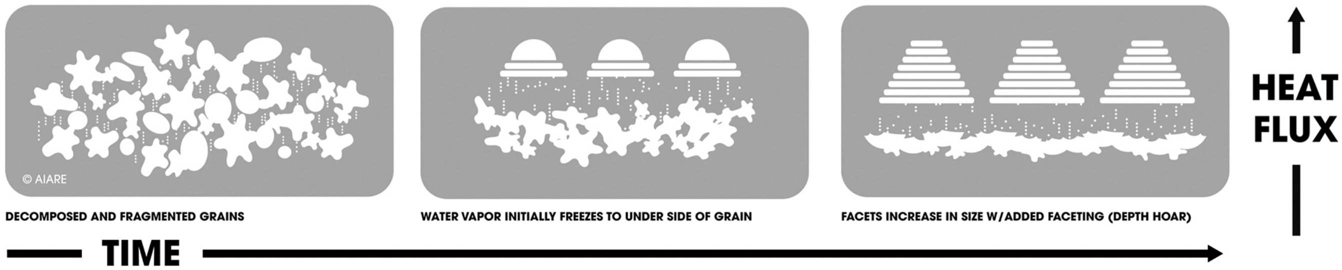
Rounding

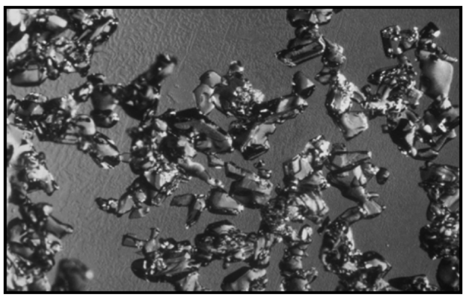
The figure and photos below shows rounding process under a low temperature gradient.

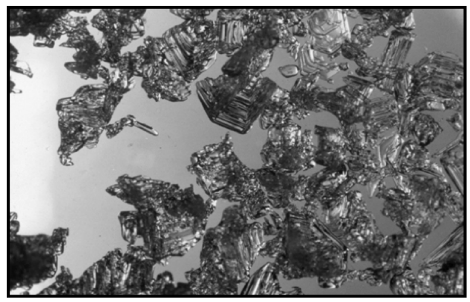


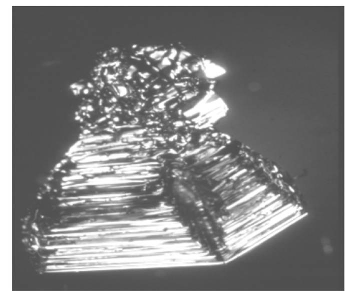
Faceting

The figure and photos below shows the faceting process under a high temperature gradient.





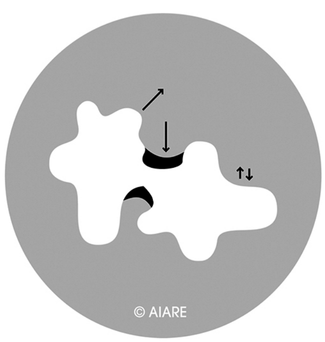


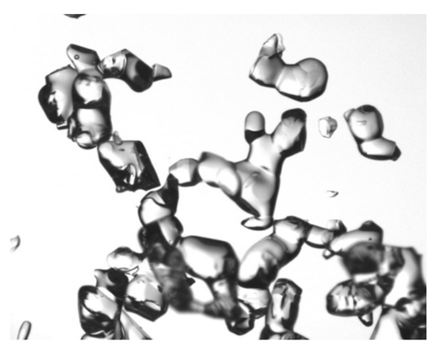


Sintering

Ultimately, it is the degree to which snow grains bond to one another that determines the strength of any given layer in the snowpack, and how well each layer bonds to the layers above and below it. The strength of bonds within and between layers plays a critical role in assessing overall snowpack stability. Understanding conditions that promote sintering/bonding in the snowpack, and being able to recognize these factors with quality field observations, is a key element in developing stability evaluations.

Figure and photo below shows sintering process and sintered grains



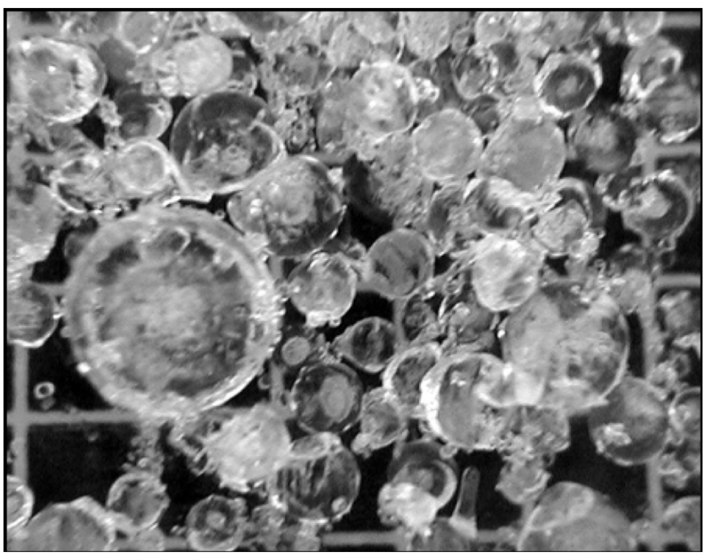


MELT-FREEZE METAMORPHISM

The effect of melt-freeze metamorphism is obvious and relatively easy to assess, as it is due to weather effects (primarily sun and warm temperatures) and occurs at or near the surface. It creates very strong snow in the frozen phase. When melted, the snow is very weak. One needs little in the way of experience, skills, or tools to assess the effects of melt-freeze metamorphism.

Despite the ease of observing melt-freeze, it's important to recognize melting and refreezing can happen in different parts of the snowpack due to differences in slope aspect and angle, vegetative cover, elevation, snowpack characteristics, and spatial differences in air temperature and cloud cover. Melting does not only occur in the spring, and occurs in mid-winter to varying degrees in different climates. The surface may melt and refreeze as crust and then become buried by snowfall. Alternatively, the surface may melt, become buried as a wet layer, and then slowly refreeze into a buried crust. Either of these successive events can create a melt-freeze crust that is a distinct layer in the snowpack. The presence of crusts within the snowpack has implications for snow metamorphism and snowpack stability.

There are various degrees to which melting can occur, which is observable by the liquid water content of the snowpack. Melting may be confined to near the surface layers, or the entire snowpack may be experiencing some degree of melt. Similarly, the entire snowpack may refreeze if melting has occurred throughout, or only a portion of the snowpack may refreeze. If temperatures at night do not become cold enough, or stay cold enough for long enough, or if cloud or vegetative cover cause long-wave radiation inputs to the snowpack, only the surface of the snowpack may refreeze. Observers may notice a wet snowpack with only a thin melt-freeze crust at surface. This frequently occurs in spring conditions. It is not an uncommon occurrence to ski out early in the morning on a spring day, and have the surface freeze provide support in most places. Once the surface warms, the melt-freeze softens and one begins to "punch through" the surface crust to the wet snow layer below.



The melting and refreezing usually occurs many times in a cycle driven by the diurnal temperature and radiation fluctuations. This is what avalanche practitioners refer to as the melt-freeze cycle.

CONCLUSION

Snow crystals constantly change as they grow, fragment, and metamorphose. The precipitation particles seen on the snow surface are recorded as a form identified "at the time of observation." Snow has already undergone substantial change before it hits the ground. When snow is on the ground, it continues to undergo change. This change is driven by heat exchanges, and the influence of atmospheric weather conditions such as air temperature, solar radiation, and wind. Once snow is buried, the changes are driven by heat exchange within the snowpack, pressure from overlying layers of snow, and/or the addition of liquid water through rain-on-snow events.

While a calculated temperature gradient may be useful (to determine the "direction" of faceting or rounding), determining what the temperature gradient might be and what processes are dominant quickly becomes intuitive and practical: if one is in a continental climate and it is early season, it's usually a no-brainer to figure out that the temperature gradient is probably high much of the time, and it's easy to tell that the snowpack is largely faceted when your skis are penetrating to the ground and the entire snowpack has a sugary texture. To the contrary, in maritime climates in the late winter where there are several meters of settled snow, you are skiing in a t-shirt, and ski penetrations are zero, you have a pretty good idea of what is going on in the metamorphic picture.

Despite this, it is valuable—one might say essential—to go through the exercise and a few examples to provide a thorough grounding in what temperature gradient is and how we measure it. Many people who have taken courses in the past will be stuck with the assumption that a high temperature gradient is "bad" because it creates "TG" snow. The instructors want to correct this "misperception." While facets are often associated with weak snow layers, and persistent grain types, old facets may be well sintered and relatively strong.

The important point is that snow metamorphism occurs as a result of vapor moving within the snowpack. How vapor moves around, and hence, what metamorphic process(es) is observable, can be estimated by considering several primary drivers:

- Snow temperatures
- Radiation balance near and at the surface
- Effects of precipitation and melting/refreezing
- The heat exchanges between the ground and snowpack, between the snowpack and the overlying atmosphere, and within the snowpack itself

In addition to these discussed drivers, physical preconditions such as grain size, type, and available pore space (or porosity of the grain lattice) affect the rounding and faceting process. Wind-blown snow has small equal-sized particles that settle close together, providing low porosity and high grain contact. In this case, rounding and sintering is often the dominant process even given a relatively high temperature gradient. Stiffer wind slabs may result from rapidly sintering grains. Loose new snow recently exposed to clearing skies can rapidly facet even in conditions where the snow surface is relatively warm and a high gradient isn't measurable (though radiation cooling can produce high gradients over a few millimeters or centimeters).

The discussion of rounding and faceting is not intended to delve into engineering or physics. The actual processes that cause rounding and faceting are complex and not fully understood. A good understanding of the factors that promote and influence the processes makes it easier to recognize which processes are likely dominating. The bottom line is: in stability analysis the observer needs to be able to recognize the difference between a rounded grain and a faceted grain and needs to know when rounding is likely occurring and when the factors favor faceting. A look at the bonds between the grains as well as the grains themselves is encouraged.

During faceting and rounding (or any other process), the resulting grains, and strong/strengthening or weak/weakening snow in and of themselves are not necessarily good or bad. Snow stability analysis requires us to take into account a much larger picture and look at not only individual factors but also combinations of factors. Yes, generally speaking, in the long term, weak or weakening snow is not desirable—but in certain combinations and over certain time spans, it may not be bad and, in fact, it may have a positive effect on stability (in the short term anyway). Conversely, strong/strengthening snow is usually preferred in the long run but it may not necessarily be good for stability in the short term. These concepts will be discussed further below.

RECOMMENDED READING

The Avalanche Handbook, 3rd ed. by David McClung and Peter Schaerer (Seattle, WA: Mountaineers Books, 2006). Selections from Chapters 2 & 3

- Snowpack Temperatures and Temperature Gradients, p.52
- Disappearance of Branches: Initial Changes in Dry, Newly Fallen Snow, p.53
- Dry Snow Metamorphism in the Seasonal Snow Cover & Crystal Forms in Dry, Seasonal Alpine Snow, p.55-63
- Growth of Crystals Around Crusts in Dry Snow & Bond Formation in Dry Alpine Snow, p.63-67
- Metamorphism of Wet Snow, p.68
- Snow with High Water Content & Snow with Low Water Content, p.68-70
- Bond Melting and Formation in Wet Snow, p.71

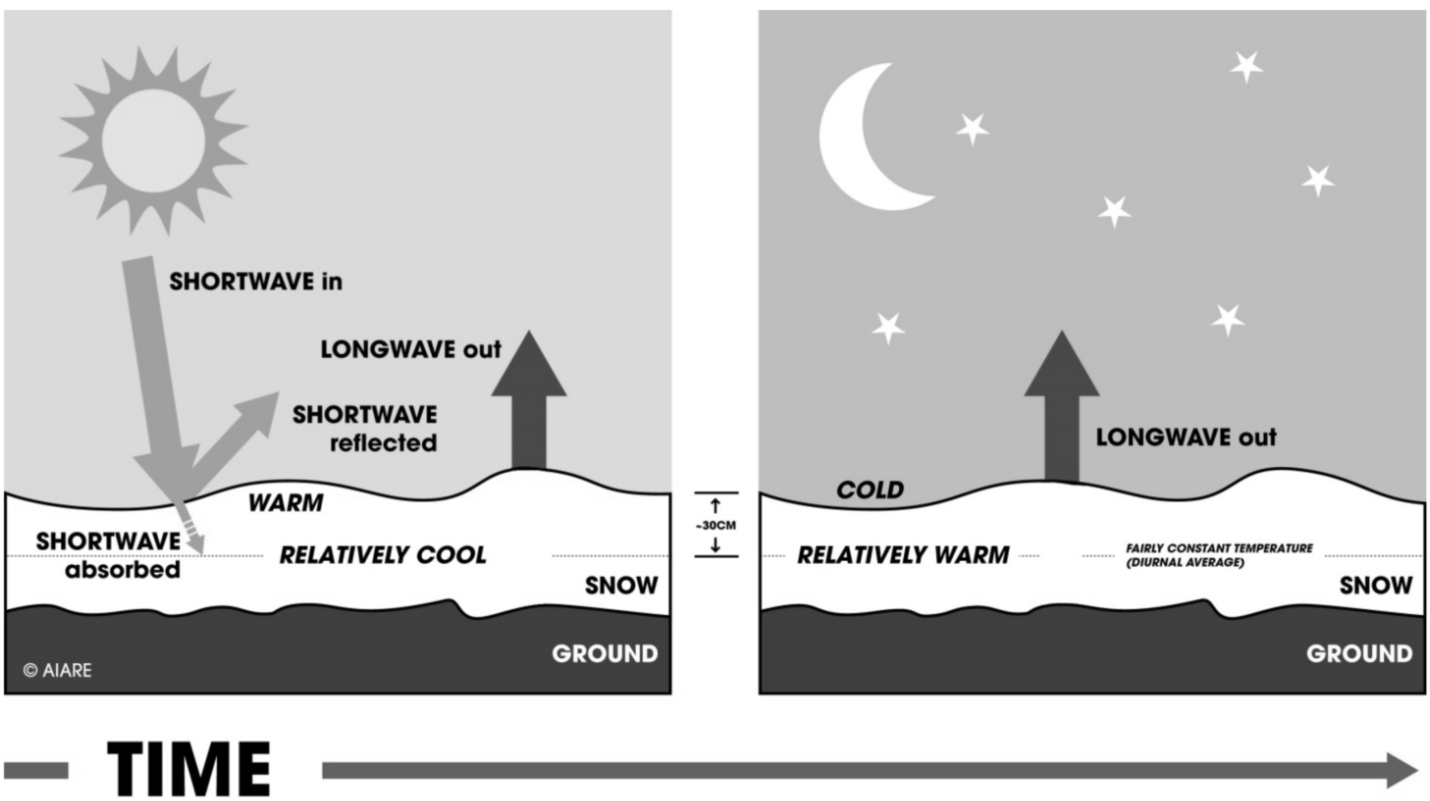
FACETS: NEAR-SURFACE FACETS, NEAR-CRUST FACETS AND DEPTH HOAR

We know that faceting can occur when there is a high temperature gradient observed in the layered snowpack. While it is common for facets to occur at or near the bottom of a shallow snowpack, especially early in the season, facets can and do develop in other parts of the snowpack—sometimes in very localized regions of the snowpack.

In this section we will discuss two specialized circumstances in which facets might occur where they may not be suspected: 1) on or near the surface of the snowpack, and 2) near buried crusts in the snowpack where the surrounding temperature gradients are observed to be low. The facetted crystals produced in these circumstances are examples of persistent weak layers (persistence discussed in section 1.2.7) that are responsible for a large percentage of avalanches. Being able to recognize the existence of the problematic weak layers, and the conditions in which they are likely to form, is very important in assessing overall snowpack stability.

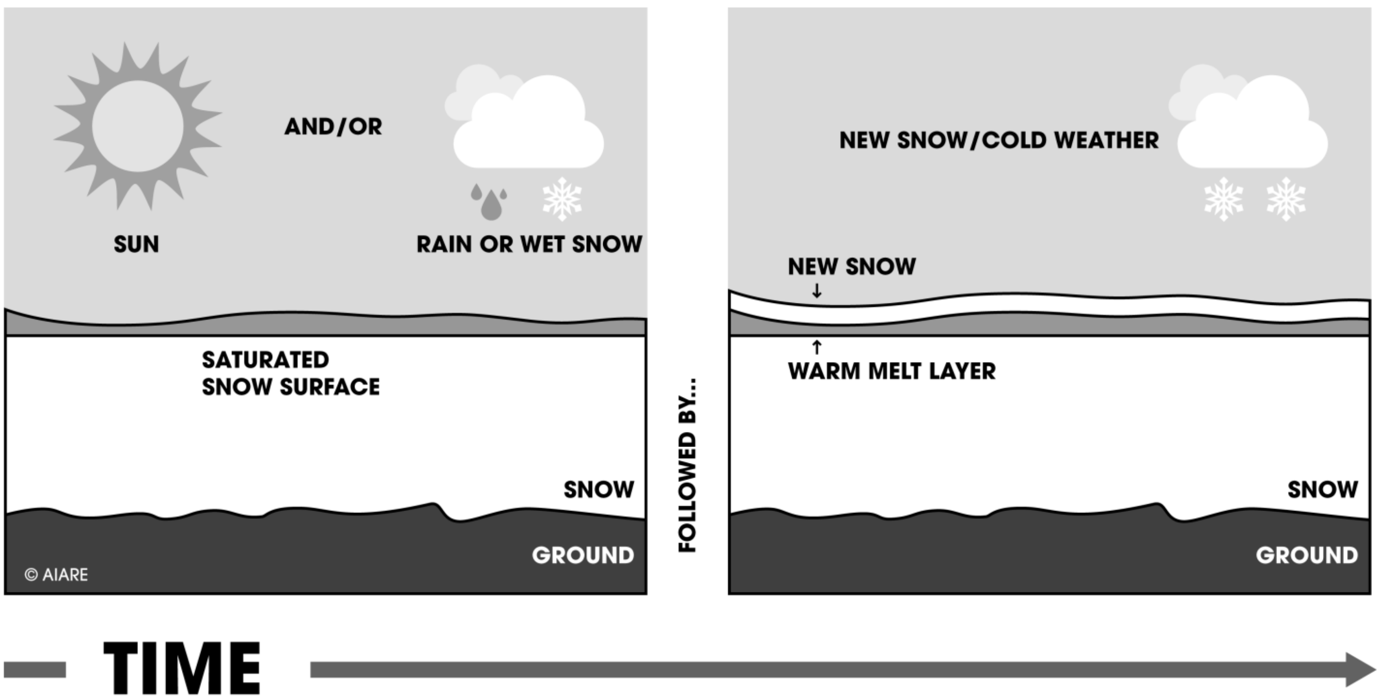
When surface or near-surface faceting is occurring, the surface of the snowpack will commonly change texture and appearance. Skiers often say the snow is "drying out" and skiing quality sometimes improves as moist or even wet snow which was sticky and well bonded loosens due to the breakdown in bonds with the development of faceted grains. Surface crusts and even soft slabs can soften or disappear altogether if surface faceting persists. Surface and near-surface facets often play a major role in skier-triggered avalanches. Understanding and recognizing when these layers are present, and when the conditions that promote the formation of these facets are present, is crucial in assessing stability.

The figure below illustrates the near-surface faceting process



Field practitioners have noted near-crust faceting for years. Yet, new theories and recent published research are cautioning practitioners to look more carefully at crusts. We are now better aware of how problems can develop over time regardless of the crust's initial characteristics, associated temperature gradients, and whether there was a bonding problem of some sort when the crust originally formed. Crust formation can also occur in conjunction with near-surface faceting. When dry snow over wet-layer faceting occurs, the wet layer that provides the heat and moisture source to drive the faceting process will end up refreezing as a crust, with the newly formed facets above (and likely below) it.

The figure below illustrates the dry-snow over wet-layer faceting process.



With more careful observations, near-crust faceting has been noted in a variety of scenarios. For example, in Crested Butte, Colorado, near-crust faceting was observed in a fracture line profile where the snowpack was completely faceted over its entire depth. An old, weak sun crust that was almost completely eroded had notably larger facets just above and below it. Another notable case occurred in conjunction with the famous "ice storm" of January 1998 that occurred in eastern Canada and New England. When the snowpack at Pinkham Notch in the White Mountains of New Hampshire was observed in March, the entire snowpack was moist or wet. Facets were observed on the bottom of a very strong, 10cm thick freezing rain crust. Near- crust faceting created a very persistent problem in the Columbia Mountains of Western Canada during the '96/97 season when facets that formed in conjunction with a November rain crust caused large avalanches for several months.

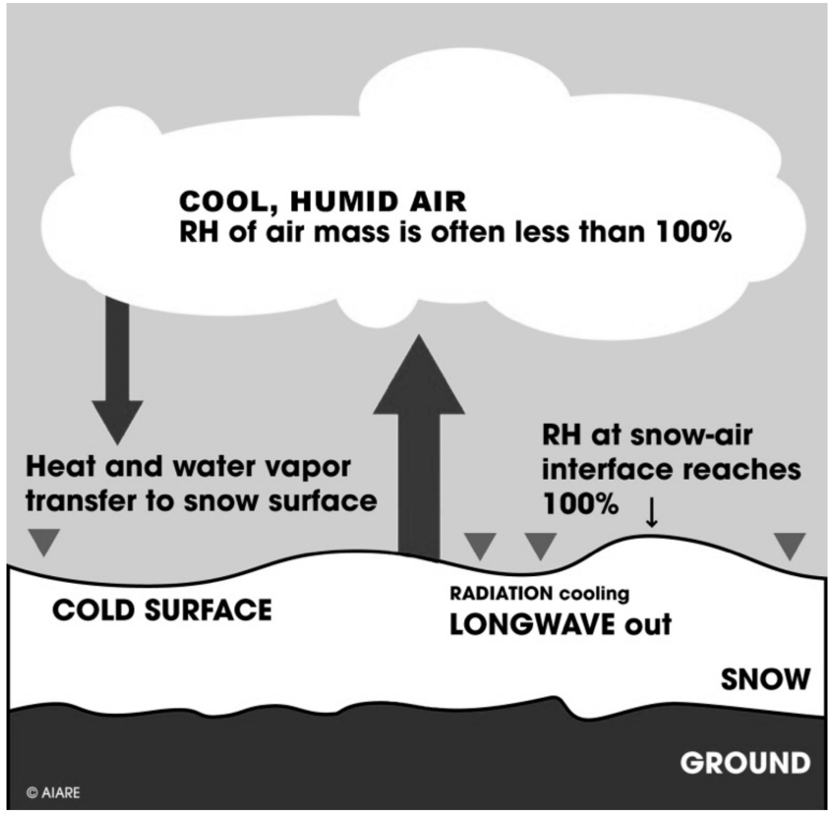
These examples, while extreme, indicate that near-crust faceting can be a significant factor in the metamorphism of the snowpack and that practitioners should be aware of its potential and know what to look for.

Both surface/near-surface and near-crust faceting are important processes to recognize, since they can create problematic and persistent weak layers relevant to snowpack stability. The good news is the conditions that promote these processes are easy to observe in the field. Conditions that promote surface/near-surface faceting can be ascertained by considering the radiation balance at the surface, the amplitude of diurnal temperature swings, and the presence of wet layers. Conditions that promote near-crust faceting can be ascertained by looking for crusts in the snowpack, and when dry snow is falling on a crust or wet snow surface.

RECOMMENDED READING

The Avalanche Handbook, 3rd ed. by David McClung and Peter Schaerer (Seattle, WA: Mountaineers Books, 2006).

SURFACE HOAR



Surface hoar is the winter equivalent of dew.

Under certain conditions, the surface of the snow cools a thin layer of air at the snow/air interface to the dew point. The surface hoar visible on the snowpack in winter comes from the air that was in contact with the snowpack. Surface hoar crystals grow when the moisture in the air condenses on the snow surface. This process is analogous to the moisture in the air condensing on a beer mug removed from the freezer. Surface hoar is not limited to forming on snow; it is often seen on trees, bushes, rocks, etc., and sometimes referred to as "hoar frost" in non-technical circles.

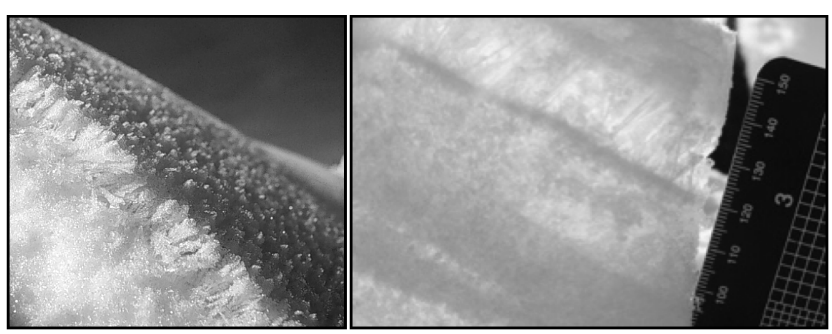
Surface hoar crystals have a characteristic "icy" looking "V" shape, but they can also form as needle, plate, and hollow six-sided cuplike varieties. Generally, striations are visible on the crystals. The number of ice crystals formed on the snow surface and the size and shape of the crystals depends primarily on how much water vapor was in the air, what the air temperatures were, and the temperature of snowpack surface while the surface hoar was forming.

Surface hoar is an example of a persistent weak layer that is a major factor in many avalanches, especially in inter-mountain and continental climates.

The figure above illustrates the process by which surface hoar forms

Surface hoar is quick to form (hours to overnight), hard to find once it is buried, and slow to decompose. Surface hoar can be easy to see when on the surface of the snow, but is often more difficult to find once it is buried. With an understanding of energy balance at the surface of the snow—and daily observations of radiation, cloud and vegetative cover, and wind patterns—inferring where and when surface hoar is likely to form becomes easier. For example, surface hoar is more likely to form in clearings and less likely to form in a dense forest because the tree cover interferes with radiation cooling. Additionally, surface hoar tends to form on clear nights, not on cloudy nights, again because clouds interfere with radiation cooling.

The photos to the right show surface hoar deposited on snow surface and buried surface hoar.



RECOMMENDED READING:

The Avalanche Handbook, 3rd ed. by David McClung and Peter Schaerer (Seattle, WA: Mountaineers Books, 2006).
Selection from Chapter 3:

- Surface Hoar: Formation and Growth Conditions, p.49-52
- Persistent and Non-persistent Weak-layer Forms, p.67

WEAK LAYER CHARACTERISTICS

For a slab avalanche to occur, a weak layer that prevents the slab from bonding to the bed surface is required. It is in this layer that shear (and perhaps compression) fractures occur and propagate. The Avalanche Handbook distinguishes between weak layers (the Avalanche Handbook refers to these as "non-persistent" weak layers) and persistent weak layers.

WEAK LAYERS

Non-persistent weak layers consist of snow grains that (while creating a weak layer after forming) strengthen quickly and bond to the slab and bed surface readily. These weak layers commonly consist of new snow grains, decomposing and fragmented grains, rounds, and perhaps wet grains. These types of grains metamorphose readily into stronger forms that bond well to each other and surrounding layers. Generally speaking, non-persistent weak layers will show observable strength gain and improvement in bonding in a matter of hours or days.

If a weak layer is related to new or recent snow (new snow or DF grains), note the depth of the fracture lines and watch the trend of avalanche activity. If avalanches are running in the layer of storm snow and activity tapers off in the first 24 - 36 hours after the storm ends, instability is almost certainly related to a non-persistent weak layer and stability will likely improve dramatically by the time 48 hours has elapsed.

If a weak layer is related to wet grains, watch (measure) air and snow temperatures above and below the wet layer. As air and snow temperatures fall to well below freezing, the problem will likely resolve itself quickly as the wet grains freeze. A wet layer may persist if temperatures are very warm and the grains do not freeze on an interface between grain types, as exemplified by density changes in storm snow.

PERSISTENT WEAK LAYERS

Persistent weak layers strengthen slowly (or continue to weaken) and do not bond readily to the bed surface or slab. Persistent weak layers usually consist of facets, either near-surface facets, depth hoar, or surface hoar. These grains do not metamorphose readily into stronger forms and do not bond well to each other or adjacent layers. Persistent weak layers may get weaker over time--even when strengthening persistent weak layers take many days, weeks, and sometimes months to show significant increases in strength or improvement in bonding. Persistent grain types forming above or below stiff layers and crusts can be durable and last for weeks, months, or even throughout the season in a mountain snowpack.

Persistent weak layers are often associated with mountain climates where extended periods of cold, dry weather are common, and where there are fewer precipitation events and accumulations are moderate or light.

Persistent weak layers are much harder to assess and forecast. Avalanches associated with these layers may occur sporadically when the layer first forms. Sometimes no avalanches occur until sometime after the layer has formed and some combination of seemingly minor events triggers failure. Persistent weak layers are difficult to assess as they may go through cycles where strength decreases, increases, and then decreases again. In conjunction with these strength fluctuations, persistent weak layers often go into extended dormant periods before becoming sensitive to triggering.

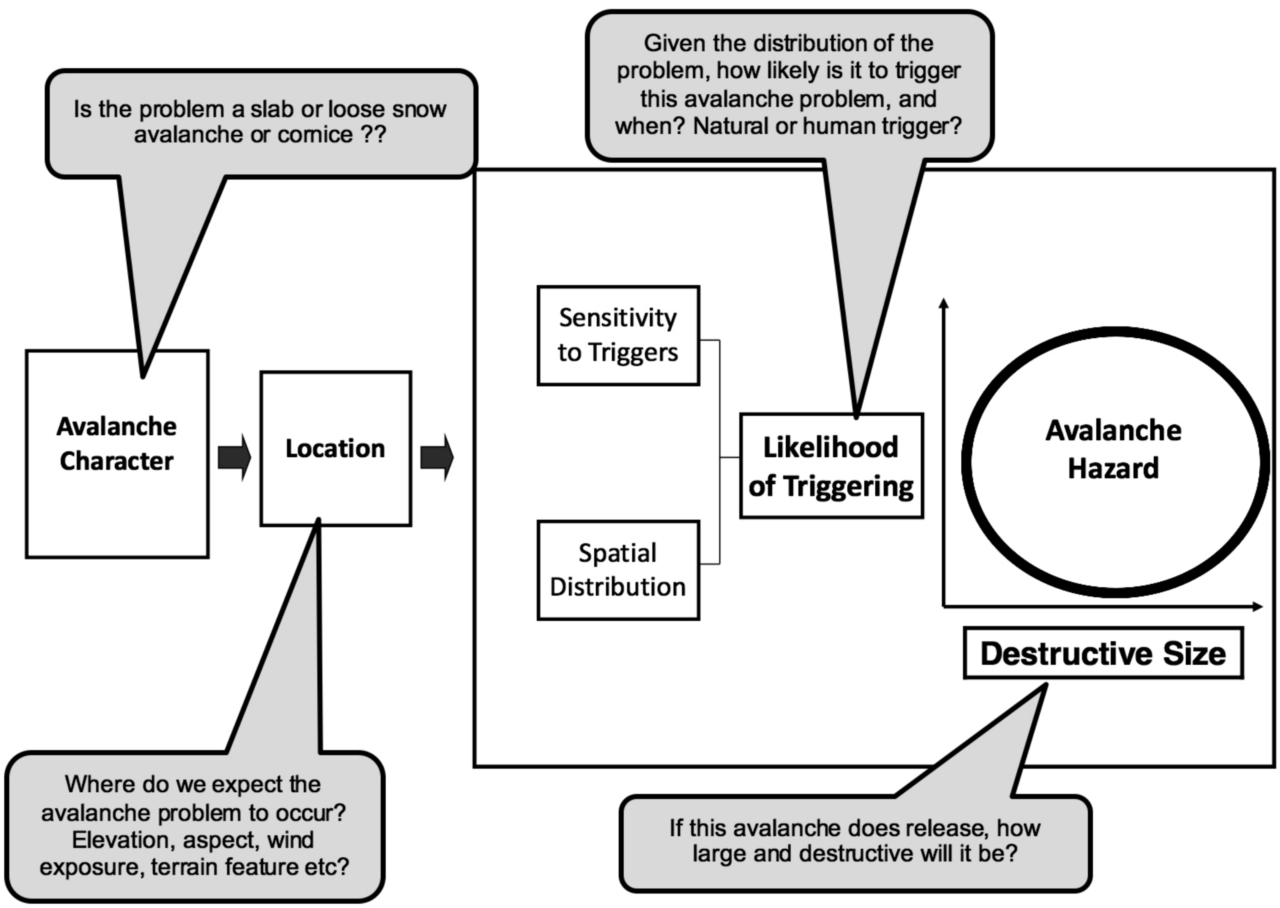
Persistent weak layers require ongoing, long-term monitoring using a variety of observation, testing, and recording methods to ensure one does not lose track of their locations and characteristics (observation and testing methods are discussed later when we talk about observing and recording instability factors). Typically, persistent weak layers also call for a more conservative approach to terrain selection and hazard forecasting.

Appendix F:
Avalanche Formation & Release

UNDERSTANDING "THE PROBLEM"

As an important component of evaluating avalanche risk, experts assess the avalanche hazard. The following diagram illustrates a commonly used approach when assessing avalanche hazard:

Chart from A Conceptual Model of Avalanche Hazard[33] . Comments, AIARE



33 Statham, Grant, Pascal Haegeli, Ethan Greene, Karl Birkeland, Clair Israelson, Bruce Tremper, Chris Stethem, Bruce Mcmahon, Brad White, and John Kelly. "A Conceptual Model of Avalanche Hazard."Natural Hazards 90, no. 2 (November 02, 2017): 670. doi:10.1007/s11069-017-3070-5.

Our ability to evaluate the avalanche hazard relies on our understanding of how the mountain snowpack develops over terrain. This includes understanding how snow layers become relatively strong or weak, and it includes relating snowpack instability to a loss of cohesion of near surface snow or to propagating cracks through weak layers. This is knowledge of how avalanches form and how avalanches release.

Understanding the mechanism of avalanche release improves our ability to:

- Determine where (distribution) and when (timing) avalanches could occur.
- Determine the probable extent and consequence resulting from avalanche release.
- Better understand which field observations and tests provide valuable clues that describe the avalanche problem.

Participants should follow along using the AIARE Avalanches and Observations Reference (Appendix B) while reading this section. The reference supplements information on "how avalanches release" by targeting the important field observations and tests specific to each avalanche type and characteristic.

LOOSE SNOW AVALANCHES

Loose new snow has low cohesion. Loose snow avalanches begin when a localized area of cohesion-less surface snow begins to move downhill; setting into motion additional subsurface loose snow (entrainment). The result is a fan-shaped avalanche initiating from a point in steep terrain (approximately ≥40 degrees) and widening as it proceeds downhill.[34]

Loose dry snow avalanches are also referred to as point release avalanches and sluffs. Larger avalanches of this type tend to entrain subsurface loose snow or gain mass and speed on longer, larger slopes. The loss of cohesion occurs in both loose new snow and loose faceted old snow on steep slopes.

Loose dry snow avalanches tend to be small (size 1-2) though destructive potential increases with slope size or the exposure of those at risk to cliffs or terrain traps. Loose dry snow avalanches can trigger larger destructive slab avalanches.

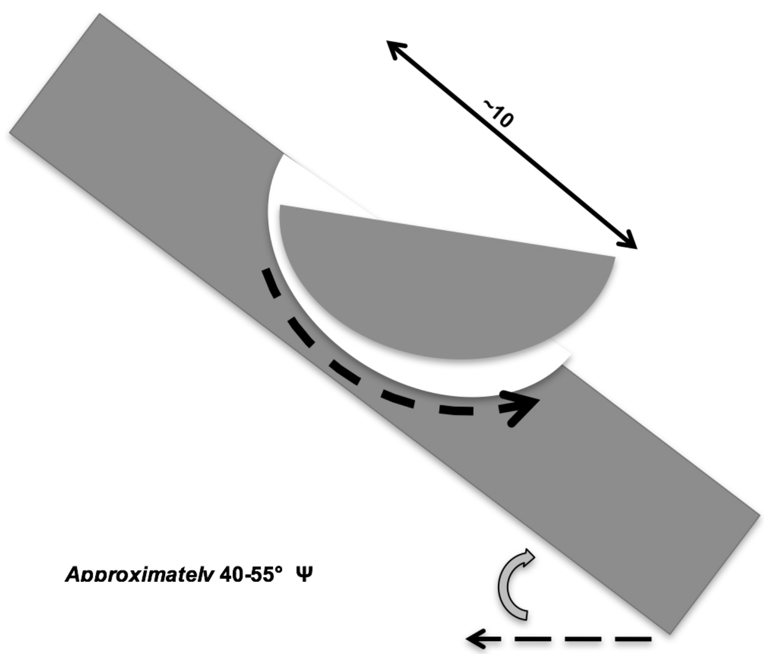


FIGURE 1. LOSS OF COHESION AT THE SNOW SURFACE

34 McClung, D. and Schaerer, P. The Avalanche Handbook, 3rd ed. (Seattle, WA: Mountaineers Books, 2006): Chapter 4.

A brief summary of factors that promote triggering loose dry snow avalanches includes:

- Steep terrain with a start zone incline approximately ≥40°.
- Loose new snow.
- Rapid snowfall rates (>4cm/hr) and slow settlement (cool temperatures).
- Mechanical action that can also trigger the initial loss of cohesion includes rockfall, rolling snow chunks, and skier/snowboarders.

FIGURE 2. LOOSE WET SNOW SURFACE

Loose wet snow avalanches also release as a result of localized loss of cohesion at the snow surface. Wet snow is defined as snow at 0°C. This avalanche type can be more destructive than loose dry snow avalanches, as the release can entrain denser, wetter snow with more destructive potential. Loose wet snow avalanches (Shown in the image right) may be the trigger for larger, more destructive, slab avalanches.

Observers note that it may be hazardous to travel on steep slopes subject to a wet snow avalanche condition. Timing is critical when forecasting the problem and avoiding the hazard.

The factors that promote triggering of wet loose snow avalanches include:

- Rapid warming of the snow surface, rocks, or trees, from radiation (sunny aspects during a diurnal cycle) or rainfall.
- Continued temperatures (day and night) of above 0°C (cloud cover at night) resulting in surface snow temperatures reaching 0°C.

DRY SLAB AVALANCHES

Slab avalanches form when a cohesive snow layer forms over a less cohesive and weaker snow layer.

Under the influence of gravity a snow slope settles in a vertical (settlement) and down slope (creep) direction. Larger, angular grains (facets, depth hoar) settle and creep at a different rate than smaller, uniform grain types (fragments and rounds). Natural flaws develop between grains at the interface of layers with different grain type, size, stiffness, and mass.

When avalanches are not occurring, the snowpack deforms slowly and reduces the strain rate at the weak layer interface. In other words, the snowpack adapts well to slow change.

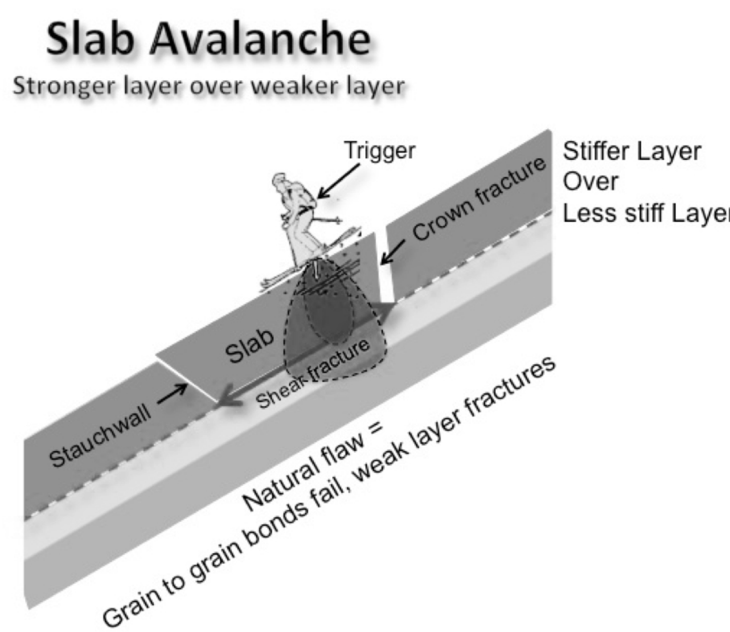


FIGURE 3. SLAB AVALANCHE RELEASE

However, when a trigger is introduced, a rapid loading of the weak layer occurs. Grain-to-grain bonds fail in rapid succession at the weak layer interface and a crack propagates along this natural flaw (shear fracture) displacing the slab downslope over the bed surface.

On the snow surface shooting cracks are visible to the observer as the cohesive slab displaces as a unit from the mountain slope. The shooting cracks are also called tensile fractures that fracture through the thickness of the slab as it breaks away and moves downslope. The displaced slab leaves behind identifiable features including the crown fracture indicated by the breakaway wall at the top of slope. The flanks mark the left and right fracture line on each side of the slab, formed as the slab moves downhill. The lowest feature is called the stauchwall, where the toe of the slab fractures and is displaced over the more stable snow below. Often the stauchwall fracture is obliterated by slab material moving downhill.[35]

Slab avalanches can be small or they can be very large and destructive.

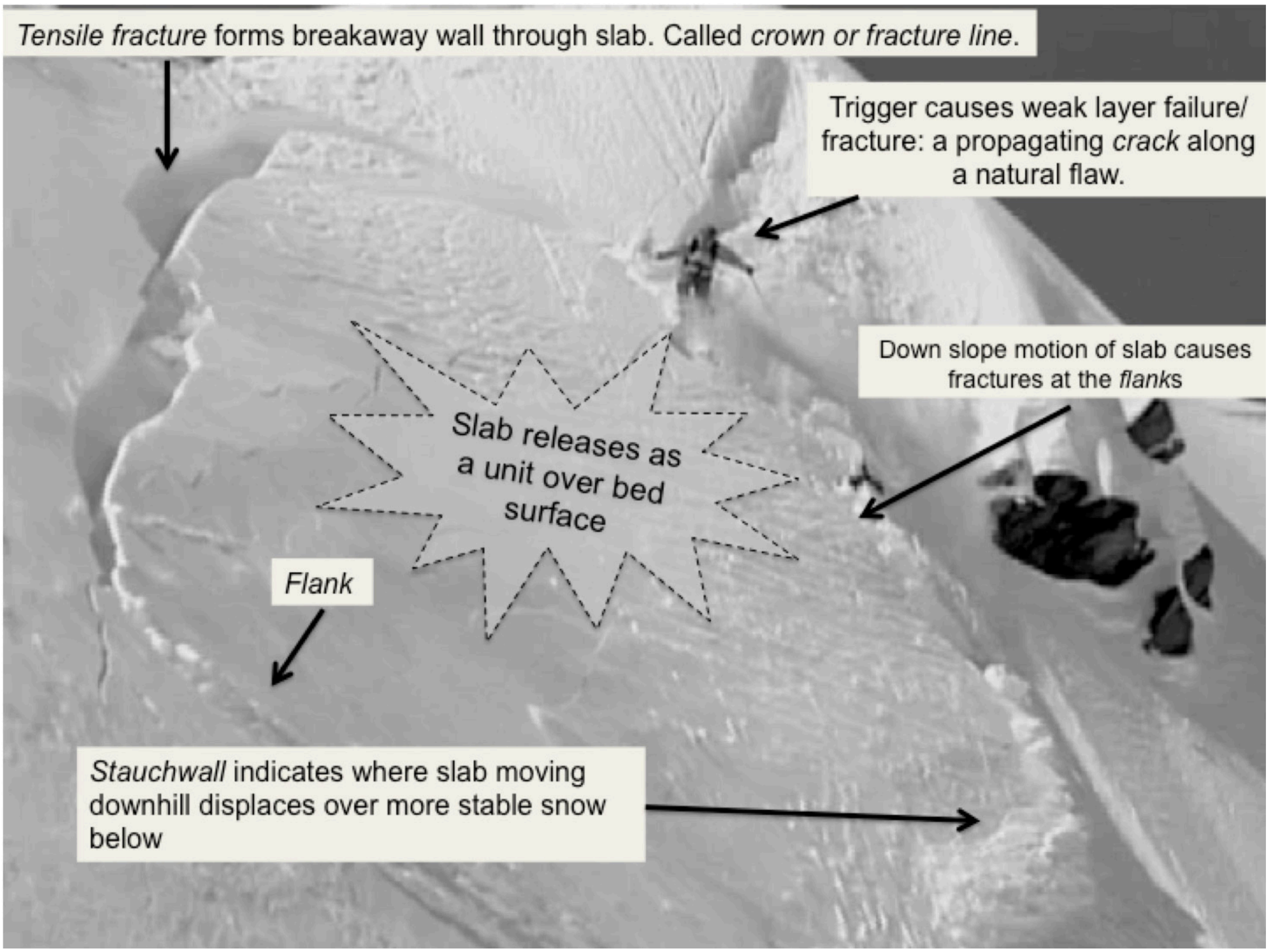


FIGURE 3. PERSISTENT SLAB AVALANCHE

35 McClung, D. and Schaerer, P. The Avalanche Handbook, 3rd ed. (Seattle, WA: Mountaineers Books, 2006): Chapter 4.

Public avalanche bulletins refer to different types of avalanches (described as "the avalanche problem") by their forming characteristics. Storm slab avalanches are defined as a release of a soft cohesive layer (a slab) of new snow that breaks within the storm snow, or on the old snow surface. Storm slab problems typically last between a few hours and few days. Storm slabs that form over a persistent weak layer (surface hoar, depth hoar, or near-surface facets) may be termed persistent slabs, or may develop into persistent slabs. Wind slab avalanches differ in that the cohesive layer of snow (a slab) is formed by the wind. Wind typically transports snow from the upwind sides of terrain features and deposits snow on the downwind side. Wind slabs may have a smooth or wavy snow surface, and may sound hollow under a skier's weight, and can range from soft to hard. Wind slabs that form over a persistent weak layer (surface hoar, depth hoar, or near-surface facets) may develop into persistent slabs, and may be termed a Persistent slab avalanche,. Persistent layers include: surface hoar, depth hoar, near-surface facets, or faceted snow. Persistent weak layers can continue to produce avalanches for days, weeks or even months, making them especially dangerous and tricky. As additional snow and wind events build a thicker slab on top of the persistent weak layer, this avalanche problem may develop into a persistent deep slab.

Therefore, a Deep slab avalanche involves an underlying persistent weak layer, deep in the snowpack or near the ground. The most common persistent weak layers involved in deep slabs are depth hoar, deeply buried surface hoar, or facets surrounding a deeply buried crust. Deep slabs are typically hard to trigger but may be remotely triggered where the weak layer is less deep. Deep slabs are very destructive and dangerous due to the large mass of snow involved, and can persist for months once developed (from CAIC, CAC, Parks Canada and others).

Each avalanche problem can be identified by specific field observations and specific tests. Refer to the AIARE Avalanches and Observations Reference (Appendix B and pages 56-58 of The AIARE Fieldbook) to help target, and manage the hazards associated with slab avalanches.

FACTORS TO CONSIDER WITH REGARDS TO DRY SLAB AVALANCHE RELEASE

Naturally occurring slab avalanches

Observing natural slab avalanches is always an indicator that conditions are unstable and prone to natural or human triggers. Unfortunately persistent and slab avalanches can be sensitive to triggering for long periods of time, and, may not release naturally.

Timing and sensitivity to triggering

Storm slab and wind slab avalanches commonly have a "window of opportunity" where they are more reactive to triggers. Avalanche control teams take advantage of this knowledge and attempt to control the problem soon after it forms. The storm slabs and wind slabs are formed by either deposition of new snow or wind deposit. Once the weak layer (often decomposed or fragmented grains or graupel) is buried roughly 25cm deep, the slab becomes reactive to a trigger. As the slab thickens with additional snow or wind deposit, it remains sensitive to triggering for anywhere from a few hours to 48 hrs, though in certain conditions up to a week. Weight from overburden and time encourages the weak layer to decompose, settle, bond and stabilize. In contrast, persistent weak layers, however, can stay unstable for days, weeks and even months.

Studies[36] relating the depth of the weak layer and character of the slab to avalanche release and the *Avalanche Handbook*[37] suggest that the majority of skier triggered avalanches are 50cm deep or less. However a significant portion of "unexpected" avalanches reported by avalanche professionals[38] were 50-100cm deep. This suggested that unexpected slab avalanches were thicker than most skier triggered avalanches. Consider two compelling factors when triggering slabs: 1) A deeper weak layer (>1m) is less likely to be triggered by a "skier", and 2) Slightly stiffer, thicker slabs, while harder to initiate, favor propagation and result in larger, more destructive avalanches. When observing deeper weak layers, observers recognize that the weak layer may be remotely triggered, or triggered from a shallow area.

36 Jamieson, JB and Schweizer, J. Using a Checklist to Assess Manual Snow Profiles. Avalanche News, 72. (Revelstoke, B.C.: Canadian Avalanche Association, 2005): 57-61.

37 McClung, D. and Schaerer, P. The Avalanche Handbook, 3rd ed. (Seattle, WA: Mountaineers Books, 2006): Chapter 4.

38 Jamieson, B. The compmression test – after 25 year. The Avalanche Review, 20-5. (Victor, ID: American Avalanche Association, 1999): 14-15.

Most "skier" triggered slabs are 4F (and 4F+) stiffness, and increasing in stiffness adjacent to the weak layer interface. These are recorded as "soft" slabs. Yet, many (less than half in a survey of professionals by Jamieson) "unexpected" events were described as "hard" slabs (1F or stiffer). It has been suggested (S. Thumlert, ASARC, University of Calgary) that the presence of stiff crust layers on the snow surface or "mid pack" reduces the likelihood of skier/snowboard triggering.

Preliminary work by Thomas Exner (ASARC, University of Calgary) suggests that as the slab warms (sun or heat) the stress applied by a human trigger doesn't penetrate any deeper into the snowpack. However his studies suggest the human applied stress affects a "wider" area of the weak layer, and given the penetration of the stress to the depth of the weak layer, can increase the likelihood of initiating the weak layer failure/fracture.

Relating the weak layer / interface characteristics to potential for avalanche release

The Snowprofile Checklist helps to identify the weak layer and interface characteristics most often associated (67-75%) with skier triggered slab avalanches.[38] If the underlying weak layer and interface has five or six of the following properties, the weak layer is more likely to be human triggered.

Weak layer properties:

- Persistent grain type (V, DH, FC)
- Grain size >1mm
- Weak layer <1F

Interface Properties:

- Grain size difference >0.5mm
- Hardness difference >1
- Depth of the interface 25-85cm

Relating fracture character in column tests to the possibility of avalanche release

Sudden fractures in compression tests and deep tap tests (and whole block fractures in Rutschblock tests) have been correlated to increased likelihood of skier triggering (Jamieson, Campbell, Cameron and others).

Observing propagating cracks while testing the weak layer, and shooting cracks on the snow surface
Extended Column Tests and Propagation Saw Tests that produce results for propagation have also been correlated to skier triggering of slab avalanches (Birkland, Simonhoise, Gauthier, Cameron, Jamieson, and others).

Whumping under a rider's weight indicates the presence of a large, persistent grain types (DH, SH), and propagating fractures in the weak layer. Shooting cracks visible on the snow surface, and initiated by a rider's weight, are tensile fractures indicative of slab fracturing and displacement without slab release (low angled slope or a localized area of unstable snow).

Relating localized loading to the potential for avalanche release

Scott Thumlert (ASARC, University of Calgary) has compared localized dynamic loading on a mountain snowpack. His measurements suggest that snowmobiles exert considerably more stress to the snowpack (3 to 5x) than skiers increasing the probability of a slab release. In addition, the sled penetrates stress 3x deeper into the snowpack. There was a significant decrease in stress with increased depth (this agreed with previous studies), and an observed "bridging effect" from supportive snow layers (stiff crusts) that reduced the measured depth of the applied stress.

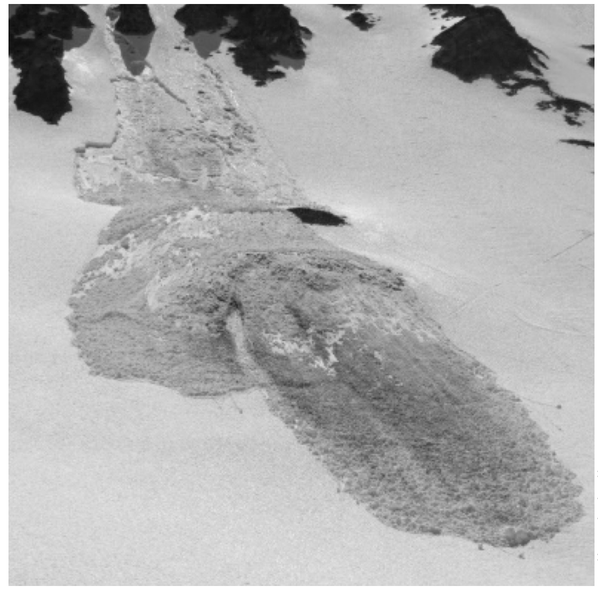
Mr. Thumlert's findings importantly suggest that, understanding the transmission of stress due to localized dynamic loads may help people avoid situations in which they can trigger avalanches".[38]

38 Jamieson, JB and Schweizer, J.

39 Thumlert S, Exner T, and Jamieson B. Measurements of localized dynamic loading in a mountain snow cover. Cold Regions Science and Technology vol 85 (2013). https://doi.org/10.1016/j.coldregions.2012.08.005.

WET SLAB AVALANCHES

Wet slab avalanches occur from the release of a cohesive layer of snow (a slab) that is generally moist or wet from a rain on snow event or a prolonged period of sun and warm air temperature. Wet slabs release when liquid water weakens the bond between the slab and the bed surface. Wet slabs can be very destructive. This problem may be difficult to forecast and observe. It is dangerous to cross or conduct tests on steep slopes suspected to be prone to wet slab conditions. Timing is critical as wet slabs can quickly stabilize during cooling trends, and quickly become unstable when subject to additional heat and/or rain.



Colin Mitchell

Factors that contribute to triggering:

- Rain on snow provides the most common trigger. Rain simultaneously weakens surface snow, provides additional load, and rapidly transmits heat into the snowpack (via latent heat exchange). Continued rainfall can percolate through the snowpack to a weak layer.
- Often loose wet snow avalanches precede and/or trigger wet slab releases.
- Prolonged periods of above freezing temperatures. During spring months, there is longer and more intense daytime solar radiation. Nighttime cloud cover can keep air temperatures above freezing and cause a portion of the snowpack to become isothermal (at zero degrees Celsius) and lose cohesion and strength.
- Nearby exposed rock and vegetation. Dark objects absorb radiation. Exposed rock and vegetation also inhibit snowpack settlement and provide channels for water percolation to the ground or lower snowpack layers.

GLIDE AVALANCHES

A glide avalanche is defined as the release of the entire snow cover as result of gliding over the ground. Glide avalanches can be composed of wet, moist, or almost entirely dry snow. They typically occur in very specific paths, where the slope is steep enough and the ground surface is relatively smooth. They are often preceded by full depth cracks (glide cracks), though the time between the appearance of a crack and an avalanche can vary between seconds and months (TAR article in press, Lazar et al).

Martin Volken

FIGURE 4. GLIDE AVALANCHE AT ALPENTAL, WA

Factors that contribute to triggering:

- Glide avalanches are unlikely to be triggered by a person, are nearly impossible to forecast, and thus pose a hazard that is extremely difficult to manage.
- Rain on snow, and rapid warming can increase glide rates and contribute to a full depth release

CORNICE HAZARDS

Cornice fall is described as a release of an overhanging mass of snow that forms as the wind moves snow over a sharp terrain feature, such as a ridge, and deposits snow on the down-wind side. Cornices range from small wind lips of soft snow to large overhangs of hard snow that are 30 feet (~10 meters) or taller. They can break off the terrain suddenly and pull back onto the ridge top and catch people by surprise even on the flat ground above the slope. Even small cornices can have enough mass to be destructive and deadly. Cornice fall can entrain loose surface snow or trigger slab and deep slab avalanches.

Factors that contribute to triggering:

- More common triggers include rain or heat (daytime warming) on the cornice top.
- Less common triggers include new snow or wind deposited snow load.
- Other factors include weakening of the cornice "root" or cornice attachment point on the windward side from scouring or radiation. "Reversed" winds effect can scour and undermine the scarp and face below the cornice and create an unstable overhanging mass of snow.

CONCLUSIONS

In order to predict, anticipate, and make terrain choices, the observer must understand how snowpack layering occurs and how these layers combine (weak and strong layers) to form unstable snow.

The beginning of this Appendix on avalanche Release described how near surface unstable snow forms loose dry or loose wet snow avalanches. Additionally, if the unstable snow is buried underneath a slab of more cohesive stronger snow, slab conditions were described in terms of how dry and wet slabs form and release. Also key are factors that promote triggering of either loose or slab avalanche problems.

Importantly, these concepts link to the forecasting of the avalanche problem. The understanding of 'how avalanches form and release' is inextricably linked to being able to name and describe the problem, including matching field observations to avalanche characteristics.

An understanding of how layering changes over time and varies over terrain is crucial to understand the notion of snowpack instability. Weather, snow and avalanche observations should begin with an objective that is created from the forecaster's knowledge of the history of the weather, snowpack and terrain.

The relevancy of weather, snow and avalanche observations depends on the site selection, craftsmanship, and interpretation of the observation. Much of the AIARE 2 program introduces the importance of quality observations in the process of evaluating snow stability and avalanche hazard.

Introducing snowpack characteristics into the hazard evaluation process shouldn't distract from the most important tool: historical and current avalanche observations. Snowpack characteristics are merely one more piece of the puzzle. Carefully observed and recorded observations as to where in the terrain avalanches are likely to occur—especially relating to seasonal weather patterns and seasonal snowpack development—assist the observers with making prudent and sensible terrain choices and creating terrain options. Field exercises during the AIARE 2 Course will link the theory, the techniques, and the observations into terrain choices as part of the decision-making process.

By the end of this course each student may ask themselves the following questions, each time they travel in the backcountry:

“Given the conditions, what types of avalanches are likely to occur?”

“What are the observations that help me understand whether the snow is unstable?”

‘Where in the terrain are avalanches likely to occur? Where in the terrain are avalanches likely to be triggered?

“If avalanches occur, what could be the consequence?”

RECOMMENDED READING

The Avalanche Handbook, 3rd ed. by David McClung and Peter Schaerer (Seattle, WA: Mountaineers Books, 2006). Selections from Chapter 4

- Deformation in the Alpine Snowpack, Snowpack Creep, Snow Gliding, p. 73-79
- Loose Snow Avalanche Formation, p. 87-90
- Characteristics of Dry Slab Avalanches & Dry Slab Avalanche Formation, p. 91-98
- Wet Slab Avalanche Formation, p. 100-103

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