THE ALPINE MEADOWS AVALANCHE TRIAL:

CONFLICTING VIEWPOINTS OF THE EXPERT WITNESSES[1]

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Abstract.--In 1982, an unexpected avalanche at the Alpine Meadows ski area killed seven people, and the ski area was subsequently sued for wrongful death. During the court battle a number of avalanche consultants were called upon to help resolve fundamental questions concerning the adequacy of forecasting and control procedures performed by Alpine Meadows. Their testimony reflects a dramatic split of opinion within the international avalanche community. The jury decision in this trial may have profound affects on future avalanche forecasting and control procedures in the United States.

INTRODUCTION

In 1985, a courtroom in Auburn, California convened a jury of 12 men and women to decide either guilt or innocence in a wrongful death suit against the Alpine Meadows ski area for an avalanche which killed seven people when it overran the base area facilities on March 31, 1982. A number of respected avalanche scientists and technicians were formally called upon to act as expert witnesses and consultants to help the attorneys and the jury resolve fundamental questions concerning the adequacy of the ski area's avalanche forecasting and control procedures. The testimony shows a dramatic schism in the international avalanche community over accepted procedures in these areas. For the plaintiffs, Arthur Mears and Ed LaChapelle were called as expert witnesses with Ron Perla and V. G. Schleiss consulting. For the defense Liam Fitzgerald, Andre Roch, and Chris Stetham were called as expert witnesses with Norm Wilson, David McClung, and Peter Schaerer consulting.

This paper describes avalanche control procedures at the ski area, the climatological and human events leading up to and including the avalanche, and summarizes the testimony of each expert witness. The Summaries of Testimony are written from the author's notes as taken during the trial and have been checked against the court transcripts for accuracy. The opinions of the consultants were not formally presented in court and are therefore, not presented. Only the direct examination of each expert witness is summarized because it is felt that this offers the clearest representation of the opinions heard by the jury. The names of the experts have been disassociated from the summaries so that the arguments of each expert can be weighed objectively by the reader.

AVALANCHE CONTROL AT ALPINE MEADOWS

Built in 1962, Alpine Meadows is classified as a Class "A" (high number and frequency) avalanche area by the U.S. Forest Service and annually records the largest number of avalanches of any ski area in the United States. Under the terms of a special use permit with the U.S. Forest Service, Alpine Meadows is responsible for all forecasting and avalanche control for the ski area. As of March 31, 1982, the Site Safety and Operations Plan employed three methods of avalanche control with explosives which included artillery control, with both a 75mm recoilless rifle and a 75mm pack howitzer, and hand charging. Manned closures were also employed during explosives control when necessary.

CLIMATOLOGICAL AND HUMAN EVENTS

The storm which preceded the March 31 avalanche began at approximately 1600 PST on the 26th, leaving a trace of new snow on a basal snowpack of 87" (221cm) as observed at the day lodge. By March 28, winds of up to 50 mph (80km/hr) had been recorded with gusts in excess of 90mph (144km/hr). By March 30, 64" (163cm) of new snow had fallen for a total snowpack depth of 135" (343cm). Many of the ski lifts at Alpine Meadows and at other nearby areas were closed as a

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result of the severe weather. On the morning of March 31, an additional 25" (64cm) of new snow had fallen for a total of 87" (221cm) from the storm. The water content of the new snow was 7.83" (19.89cm), and the total snowpack depth was 145" (368cm). Snow continued to fall during the day at an average rate of 1.4"/hr (3.5cm/hr) with wind gusts of up to 120 mph (192km/hr). Precipitation intensity averaged 1.1"/hr (2.79cm/hr). On the preceding storm days temperatures had remained generally cold, but on March 30, a warming trend began which caused a gain of 10^{o}F (5.55^{o}C) over the previous day.

Avalanche control operations which began on March 28 produced many artificial releases, with crown depths of from 1' to 3' (30cm-90cm) being common. On the afternoon of the 30th, ski patrollers controlling avalanche paths above the Alpine Meadows access road observed one unexpected delayed action, sympathetic release. The Pond and Buttress slopes above the west parking lot were not controlled on that day. During the entire storm only surface avalanches had been observed on these two slopes.

At 0720 on March 31, a high avalanche hazard was declared, and the decision was made to close the Alpine Meadows ski area. The parking lot and access road remained open, however, except during avalanche control operations which were conducted between 0720 and 1300 using the recoilless rifle and pack howitzer. With visibility limited at times to approximately 30' (9m), blind firing procedures were instituted for the Beaver Bowl, Kangaroo, and Poma Rocks shot points. Visual firing of the pack howitzer on the Pond and Buttress slopes was also performed with extra shots placed in both. On a drive-by to check results in the runout zones of these two slopes later in the morning, Don Huber (U.S.F.S. Snow Ranger) claimed to have seen a small amount of debris below the Buttress. The ski area remained closed, but soon thereafter, the hazard rating was reduced and the parking lot was reopened.

At approximately 1530 that afternoon, the Alpine Meadows Ski Patrol was informed that at 1515 a large avalanche on an uncontrolled, southeast-facing slope in nearby Squaw Valley, had inundated a residential area.

THE ACCIDENT

Unexpectedly, at approximately 1545 on Wednesday, March 31, a massive release over 2900' (870m) wide with estimated crown depths of from 7' to 10' (213cm-305cm), involving the east-facing Pond and Buttress slopes and the Poma Rocks area roared through the Alpine Meadows base facilities. The avalanche started 700' (210m) above the valley floor, and within seconds the Summit Lift Terminal Building which housed the Ski Patrol Headquarters, had been completely destroyed. Of the seven people in the building, three were killed. The avalanche also caused major damage to the day lodge, and buried the west parking lot in 10' to 12' (300cm-366cm) of debris. One employee, and three other people in the parking lot were also killed. The law suit against Alpine Meadows was brought by the families of these latter three people.

SUMMARIES OF TESTIMONY

Opinions of Plaintiff's Expert A

Avalanche Hazard Forecasts are Unreliable

In a lecture to the jury, this expert explained the complex nature of the mountain snowpack in order to support his contention that there are inherent limitations in the ability to predict avalanches. He added that the ability to forecast avalanches is further limited by a sampling dilemma, explaining that data gathered from a small area such as a snowpit or a weather plot must be used to derive forecasts and may not always provide a representative sample. He claimed that the only "real solid piece of information" upon which to base a hazard forecast is an actual avalanche occurrence, and that one can only guess when a specific event will happen. He concluded that in high exposure areas such as the Alpine Meadows parking lot, safety is of primary importance, and the limitations of any avalanche forecast must be considered by leaving a "margin of safety".

Runout Distances and Sympathetic Releases Were Foreseeable

To determine potential runout distances for the Pond and Buttress slopes, he conducted a dry-land terrain study and analyzed aerial photographs and other historical documents. His intent was to arrive at a consistent determination of theoretical runout distances using available resources and a variety of analytical techniques. Comparing patterns in tree growth from 1939 and 1977 aerial photographs of the runout of the March 31 avalanche, he inferred that a large avalanche had run into the area of the parking lot prior to 1939. To help confirm his photographic analysis he compared characteristics of the Pond and Buttress slopes to other known slopes in the area and concluded that the runout distances of these two slopes were well within the known performance parameters of the others. Table 1 shows his findings.

Table 1 Relative Slope Performance Parameters

Location	Length of Slope	Runout Slope Angle	Alpha Angle
Beaver Bowl	1380'(420m)	6.0^{o}	18.1^{o}
Sherwood S.	1250'(380m)	4.5^{o}	18.1^{o}
Ward Creek	1120'(340m)	9.5^{o}	18.7^{o}
Ward Peak S.	720'(220m)	9.5^{o}	20.9^{o}
Buttress	633'(193m)	3.8^{o}	26.5^{o}
Pond	150'(46m)	3.8^{o}	25.6^{o}
Poma Rocks	380'(116m)	4.2^{o}	21.4^{o}

Using the "Swiss Application Equations of Motion" (Voellmy Equations) and the later modifications by Ron Perla and others, he then

calculated mathematically, the potential runout distances for the Pond and Buttress slopes to be as great or greater than was seen on March 31. As additional support for his calculations he referred to as many as ten instances he had noted in reading the depositions of Norm Wilson (former Mountain Manager), Don Huber (U.S.F.S. Snow Ranger), and Tim Sullivan (former Area Manager), where avalanches had deposited debris in the parking lot.

He then produced a topographic map drawn by Bernie Kingery (Mountain Manager) showing the upper boundaries of the Pond and Buttress slopes to be separated, and the theoretical runout distances to be shorter than his own calculations, and some of the recorded runout distances of March 31. He contended that the twenty years of observations which showed that these two slopes had never avalanched sympathetically nor for as long a distance, was an insufficient data base upon which to make reliable performance predictions. Based on his own experience and observations, he concluded that the March 31 avalanche was not an unlikely event, and inferred that Alpine Meadows had not recognized the full hazard potential of these slopes.

Avalanche Hazard Foreseeable

According to an analysis of weather data dating back to 1967, he found that snowfall for the three and four day storm period that ended on March 31 and April 1, was the largest ever recorded at Alpine Meadows for such periods. With a total snowfall of 87" (221cm) for the three days ending on the morning of March 31, and 97" (246cm) for the four days ending April 1, the average snowfall was 1.2"/hr (3.03cm/hr) and 1"/hr (2.45cm/hr) for the three and four day periods respectively. For water content, his compilations showed this storm to be the second largest on record. Very strong wind speeds were also recorded, along with an increase in snow density at the end of the storm.

He concluded that to an avalanche forecaster, the combination of record snowfall, high winds, and increasing snow density should constitute overwhelming evidence that severe avalanche hazard conditions were to be expected.

Inadequate Control Measures: Incorrect Results Interpretation

This expert stated that the west parking lot created a serious hazard by concentrating large numbers of people in a known avalanche runout zone. Although he felt that the parking lot should not have been built in that location, he offered the following methods of avalanche control for the area:

A. Complete avoidance of the area.
B. Evacuation when avalanche hazard exists.
C. Continued exclusion using specific signs and barricades.
D. Structural anchors in starting zones and/or protective structures.
E. Explosives

He concluded that avalanche control was inadequate on March 31 because (1) the parking lot acted to concentrate people in a foreseeable avalanche area; (2) evacuation was not performed in a comprehensive manner using only posted guards; (3) neither signs, barricades nor structures were employed to discourage re-entry into the parking lot once evacuated; and (4) no protective structures existed.

In his opinion, only explosives control had been used on March 31, 1982, but because no large avalanches were observed, the results were inconclusive and reopening the area was unwarranted.

Opinions of Plaintiff's Expert B

Correct Hazard Forecast and Control Procedures

From an examination of meteorological records, and from talking with Bob Blair (Ski Patrol Director), Jim Plehn (Avalanche Forecaster), and Tim Sullivan (former Area Manager), Plaintiff's Expert B determined that Alpine Meadows' record keeping and monitoring of the storm was satisfactory. He concluded that sufficient data was available to make an appropriate hazard forecast, and because of the large quantities of new snow and the continuing storm, that the forecast of high hazard on the morning of March 31 was correct. He also agreed with the use of artillery control.

Avalanche Hazard Foreseeable: Incorrect Results Interpretation

With what he felt to be Alpine's sound estimates of runout distances as predicted on Bernie Kingery's topographic map, and the accurate weather data that was collected during the storm which showed overwhelming amounts of new snow, he felt that Alpine Meadows should have foreseen a potential for the large avalanche which occurred on March 31.

He stated that the purpose for control with explosives on a frequent basis was to produce smaller avalanches instead of larger, destructive ones. He contended that to reduce the hazard forecast with either no observed results or evidence of only small quantities of debris from the Pond and Buttress slopes, was inappropriate in light of the fact that the storm had not yet ended.

With a diagram of his so called, "Danger Curve", he explained that as snow falls during a storm, the potential for avalanches increases along a rising curve. Somewhere along this curve is a "critical level" where an avalanche will occur. As snow stops falling, the curve levels off and over time, begins to dip away from the critical level. When explosives are used in an attempt to trigger an avalanche, the effect is to bump the curve up momentarily toward this level. If the bump occurs at a point on the curve which is close enough to raise it to the critical level, an avalanche will result. If the bump occurs too far away, no avalanche will result. When no release occurs on the up side of the curve, as was the case on the Pond and Buttress slopes the morning of March 31, the indication is that the curve has not reached a

point where explosives can bump it to the critical level. Only when this failure to trigger an avalanche occurs on the down side of the curve, after snowfall has ceased, can a negative result be considered a conclusive indicator of stability. If snow continues to fall heavily the slopes can not yet be considered safe, and explosives must be used again at a later time.

No Margin Of Safety

He contended that an evolution in avalanche control methods has taken place in the United States whereby the principles have remained the same, but the practice has changed. A faster paced ski industry has led to a general decline in the level of skill in forecasting and a greater dependence on a technique used by Alpine Meadows and many other ski areas which he called "blanket bombing". On the down side of the danger curve, "blanket bombing" can have good results, but on the up side it cannot be trusted. Although good in some ways, he claimed that the use of this technique has resulted in a more complacent attitude among avalanche forecasters.

He stated that timing is critical, and whereas ski areas generally like to conduct avalanche control operations in the morning before opening, the critical time may not always occur then. When the timing of control is inflexible, a margin of safety is necessary. With respect to the west parking lot on March 31, he stated that a large safety margin was necessary, but none was provided. Closing the ski area assured the necessary safety margin for the ski slopes, but failing to close the parking lot left that area exposed to a potential hazard as heavy snow continued to fall. He felt that this situation represented a "double standard" of avalanche control.

He also pointed out what he termed a "technical error" in control procedures on March 31 when the parking lot area was not protected from a possible sympathetic release as artillery was fired into the Poma Rocks area, adjacent to the Pond and Buttress. He expressed concern that no avalanche control had been conducted on these two slopes on March 30.

Misleading Hazard Warning Signs

He said that during his investigations he discovered the first case of avalanche zone gerrymandering that he had ever seen. Placer County was responsible for posting signs warning of avalanche zones on Alpine Meadows Road, while Alpine Meadows and/or the U.S. Forest Service took responsibility for the parking lot. The county sign which existed at the beginning of the parking lot on March 31, declared the "end" of the avalanche area, but in reality, was only intended to indicate the "end" of county jurisdiction. Alpine Meadows posted no signs, but rather used manned closures for the parking lot and other locations along the access road during times of high hazard and during avalanche control operations. This expert claimed that, in the absence of a manned closure, anyone entering the parking lot from the county road and seeing the sign could have been mislead into thinking that no hazard existed beyond in the parking lot.

Opinions of Defendant's Expert A

Negative Results Indicate Stability

From page 57 of Snow Avalanches, U.S. Department of Agriculture (1961), this expert pointed out that the stated goal of most avalanche control programs is to test the hazard forecast, not to produce avalanches. If avalanches do occur, then the emphasis of avalanche controls shifts from testing the forecast to producing avalanches and thereby reducing the hazard. If most slopes produce avalanches, then control efforts are considered to be effective. If no avalanches occur, the indication is that the snow is stable. He emphasized that intuition and experience with local weather and snow conditions are among the attributes of most successful forecasters, and he considered experience to be more relevant than theory for hazard forecasting.

Correct Forecast, Control Procedures, and Results Interpretation

After talking to Jim Plehn (Avalanche Forecaster) and reviewing the weather data from the storm, this expert concluded that, on the morning of March 31, the forecast of "high hazard" and the subsequent avalanche control procedures were correct.

He stated that the sympathetic, delayed action avalanche observed on the slope above the access road was not necessarily a good indicator of high avalanche hazard on the Pond and the Buttress slopes because of a significant difference in the performance histories between the two areas. The Pond and Buttress slopes often did not release when this area did. He also judged that the avalanche debris observed by Don Huber (U.S.F.S. Snow Ranger) below the buttress slope was inconclusive.

He determined that the interpretation of results from avalanche control was correct, and that the reduction of the hazard rating was warranted when no significant avalanche activity was observed on the Pond and Buttress slopes. In his own experience with storms of the same intensity, he stated that the use of explosives did not always trigger avalanches on all slopes. He then praised the record-keeping of Alpine Meadows and stated that, as an avalanche forecaster, his own records had not been as complete.

Opinions of Defendant's Expert B

Use of Voellmy Equations Inappropriate

This expert claimed that, as applied by Plaintiff's Expert A, the Voellmy equations are not reliable in determining runout distances because assumptions or "guesses" had to be made as to the velocity and the coefficient of friction of moving snow.

Correct Forecast, Control Procedures, and Results Interpretation

He stated that the fact that snow had fallen rapidly and in great quantities was reason enough to forecast high avalanche hazard on the morning of March 31, but that the danger could have been expected to pass quickly because of the rapid rate of settlement. He felt that artillery fire was one of the best tests that could have been used, and that the observation of small amount of debris below the Buttress slope was a good indicator of stability. He also felt that removing the road guards upon completion of avalanche control was appropriate. He concluded that, on March 31, he would have made the same decisions as Alpine Meadows.

Avalanche Hazard Not Foreseeable

Because of the large mass of new snow, he eliminated skiers, temperature variations, cornices, and the new snow which fell after control was completed, as possible triggers of the March 31 avalanche. He calculated that the amount of new snow that had fallen after control in the morning only constituted 8% of the total weight of the slab.

He theorized that the March 31 avalanche may have been caused by differential rates of creep in the snowpack. He explained that where areas with trees and other anchors which retarded creep, lay adjacent to areas where the rate of creep was unchecked, zones of great stress may have been created in the snowpack. A band of rock at the approximate location of the crownline on the Buttress slope and sharp changes in slope angles elsewhere also may have created zones of stress from differential rates of creep. With the rapid rate of settlement which was taking place aiding the creep process, he concluded that, an avalanche resulting from such forces could not have been foreseen.

Opinions of Defendant's Expert C

Avalanche Hazard Not Foreseeable

This expert stated that key inputs used by avalanche forecasters in making accurate stability evaluations, and therefore correct hazard forecasts, are the meteorological conditions observed at any given time, and the historical performance patterns of avalanche paths based on those conditions. Beginning with records from December 1966 (one year earlier than the data used by Plaintiff's Expert A) he compared historical storm data to recorded avalanche activity in order to establish an historical precedent for the March 31 avalanche.

In his analysis of the weather data, the moderate to high wind speeds during the March 31 storm could not be accurately compared to earlier storms because of the recent replacement of an unheated anemometer which rimed heavily, with a heated model that gave more accurate readings. He found a clear record of wind direction, however, and concluded that the southwest direction during the storm was typical for most storms observed at Alpine Meadows.

Temperature patterns of the March 31 storm were also found to be typical of storms at Alpine Meadows. Temperatures at the beginning of the storm were above freezing, then decreased, fluctuated, and increased to just below freezing near the end of the storm. A pattern of occasional, day-time fluctuations above freezing also caused wet snow crusts to develop within the new snow over several days. He found that this pattern, and the general cooling trend of the March 31 storm historically lead to a well bonded snowpack.

Comparing the records for total snowpack depth, he discovered that with the exception of the drought years of 1974-77, Alpine Meadows normally recorded deep snowpacks with a potential for avalanches running on old snow surfaces. He also concluded that Alpine Meadows had a typically coastal climate with heavy precipitation from frequent storms.

His analysis of precipitation rates during storms focused on water content rather than the depth of new snow in order to compare rates of loading. Only storms which produced totals of 5" (12.7cm) of water or more were considered, of which there were fourteen. Precipitation data from these storms were then plotted for 24 hour interval to approximate as realistically as possible the manner by which Alpine Meadows would have been collecting and analyzing it's data during the March 31 storm. In four bar graph charts, the relative ranking of the fourteen storms for consecutive 24 hour precipitation intervals showed that (1) for single 24 intervals, the March 31 storm ranked fourteenth largest; (2) for two consecutive 24 hour intervals, the March 31 storm ranked tenth largest; (3) for three consecutive 24 hour intervals, the March 31 storm ranked sixth largest; and (4) for four consecutive 24 hour intervals, the March 31 storm ranked fourth largest.

He then examined avalanche occurrence data from 1968 to 1982 (no Alpine Meadows avalanche occurrence data was available from before 1968), and found that although there had been many artificially triggered releases on the Pond and Buttress slopes, and several natural wet snow slides from spring and rain conditions, there had never been a single, recorded, naturally triggered, dry snow avalanche on these same slopes. He also found that no sympathetic releases or deep slab avalanches containing layers of old snow had ever been recorded on the Pond and Buttress slopes, and that the deepest crown had not exceeded 3' (90cm). In fact, prior to 1982, the Buttress slope had only on occasion deposited small amounts of debris into the west parking lot while the Pond slope had never done so. There was also no record of the two paths releasing sympathetically with each other or with the Poma Rocks area.

In light of the fact that storms of as great or greater intensity had not produced avalanches of the type and size of the March 31 avalanche, he concluded that the avalanche could not have been foreseen by Alpine Meadows.

Correct Control Procedures and Results Interpretation

The manned closure of the west parking lot and the use of artillery on the Pond and Buttress slopes was considered by this expert to be the correct avalanche control procedure on March 31. He also determined that because the control results from the previous days showed a generally stable situation with only a small avalanche on the Pond Slope on the 29th, no activity on either slope on the 30th, and evidence of some small amounts of debris from the Buttress either at the time of avalanche control on the morning of March 31, or soon thereafter, it was also appropriate to lower the hazard rating and remove the road guards upon completion.

DISCUSSION

There are several points of contention among the expert witnesses, but two questions clearly seem to stand out as major issues. Was it possible to forecast the avalanche of March 31, and were the control measures that were used appropriate for the conditions observed? The plaintiff's witnesses said "yes" to the first question and "no" to the second, standing on theoretical ground to support their opinions. They claimed that, in light of the precipitation data, it was wrong for Alpine Meadows to completely ignore the theoretical possibilities by assuming stability with negative results from explosive tests.

The defense's witness said "no" to the first question and "yes" to the second, standing on practical ground to support their opinions. They claimed that it was preferable to depend on the tools and indicators that consistently worked for them, and to accept the fact that on occasion, Mother Nature is going to hand out a few surprises, no matter how much one tries to analyze her.

The schism between theory and practice is not a new phenomenon, and the testimony in this trial clearly illustrates how far apart the two camps can be. Avalanche forecasts remain educated guesses derived from imperfect tools and incomplete data. The accepted methods for avalanche forecast and control procedures still lend themselves to individual interpretation and remain a combination of art and science.

No jury decision is likely to change this fact in the foreseeable future, but in light of the growing liability question in the United States, jury decisions may force standards that favor one camp over another. Such is the significance of this trial.

CONCLUSION

After several days of deliberation, a deadlocked jury was instructed by the judge to assess the actions of Alpine Meadows for standards of "ordinary care" with respect to the avalanche hazard in the parking lot. As a result of those instructions, the jury quickly found for the defense. Alpine Meadows was found non-negligent in their hazard forecasts and avalanche control procedures. The subsequent appeal by the plaintiff was settled out of court along with a pending law suit against the U.S. Forest Service.

Because of the settlement, this decision will not become legal precedent, but the message from the jury was clear: with respect to natural avalanche hazards, the line which separates acceptable public exposure to risk from unacceptable is determined by the limits of proven, operational tools and techniques, not simply theoretical probability. The available data showed that the avalanche of March 31, 1982 was an unprecedented event resulting from a precedented storm.

This case and future cases involving avalanche accidents, whether constituting legal precedent or not, will nevertheless affect the way in which avalanche forecasting and control is conducted in the United States. The courtroom is where both theory and practice ultimately will be held accountable.

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