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The fatal Cleft Peak debris flow of 3 January 2002, Upper Rees Valley, West Otago

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February 2002

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ABSTRACT

About mid-morning on 3 January 2002, Robin Alan Buxton, 28, was killed by a debris flow while attempting to cross an unnamed headwater tributary of the Rees River, west Otago. The event occurred during heavy rain. The high-intensity rain triggered many shallow landslides in the thin layer of loose, weathered rock debris (regolith) overlying the steeply dipping schist bedrock in many of the tributary headwaters in the area. These, in turn initiated debris flows in many streams. Mr Buxton and Bevan Thrower had the misfortune to be in a stream channel and about to cross one of these streams at the time a debris flow approached them at high speed. Mr Thrower heard it approaching and escaped it by the narrowest of margins.

The fatal debris flow came from one or more of a group of unnamed tributary drainage basins on the north flank of Cleft Peak (2250 m). Probably originating from a small shallow regolith failure, the debris flow grew rapidly in volume as it accelerated down the steep, narrow, and flooded mountain torrent. Travelling faster than the water flow, it picked up further water and sediment from the channel. Within minutes of initiation, a rapidly moving wall of sediment and water about two metres deep and with the consistency of very sloppy wet concrete, had descended the steep mountain slope and poured across the fan at the foot of the slope. After about five minutes it settled down to a raging torrent but left thick, concrete-like debris on the banks.

The fine-grained schist of the area is easily weathered to a fine sandy regolith, that easily gives rise to debris flows during storms. There were no special characteristics of the fatal debris flow. Any of the more than twenty or so debris flows in the upper Rees valley that morning could have been fatal had people been in their way. It is likely that a deer whose carcass appeared in the Rees River was killed in one of these events.

Although the two trampers were aware of a danger of flooded streams, the fatality was not caused by a flooded stream. Debris flows are seldom encountered, and the event was beyond the previous experience and knowledge of the survivor. Mr Buxton simply was in precisely the wrong spot at the wrong time, during a very rare event, and did not act as quickly or decisively as Mr Thrower. A few minutes difference in the timing of Mr Buxton's or the debris flow's arrival at the stream crossing was the difference between life and death. Mr Thrower had just enough audible warning, a fast enough reaction time, and was closer to safety, and so narrowly survived the event unscathed. Had he been less fortunate, two might have perished, and knowledge of the tragedy may not have emerged for some days. The death was a very unusual accident, and not something that could easily have been foreseen or prevented.

KEYWORDS

Debris Flow, Rees River, Cleft Peak, accident, fatality, high-intensity rain, schist regolith

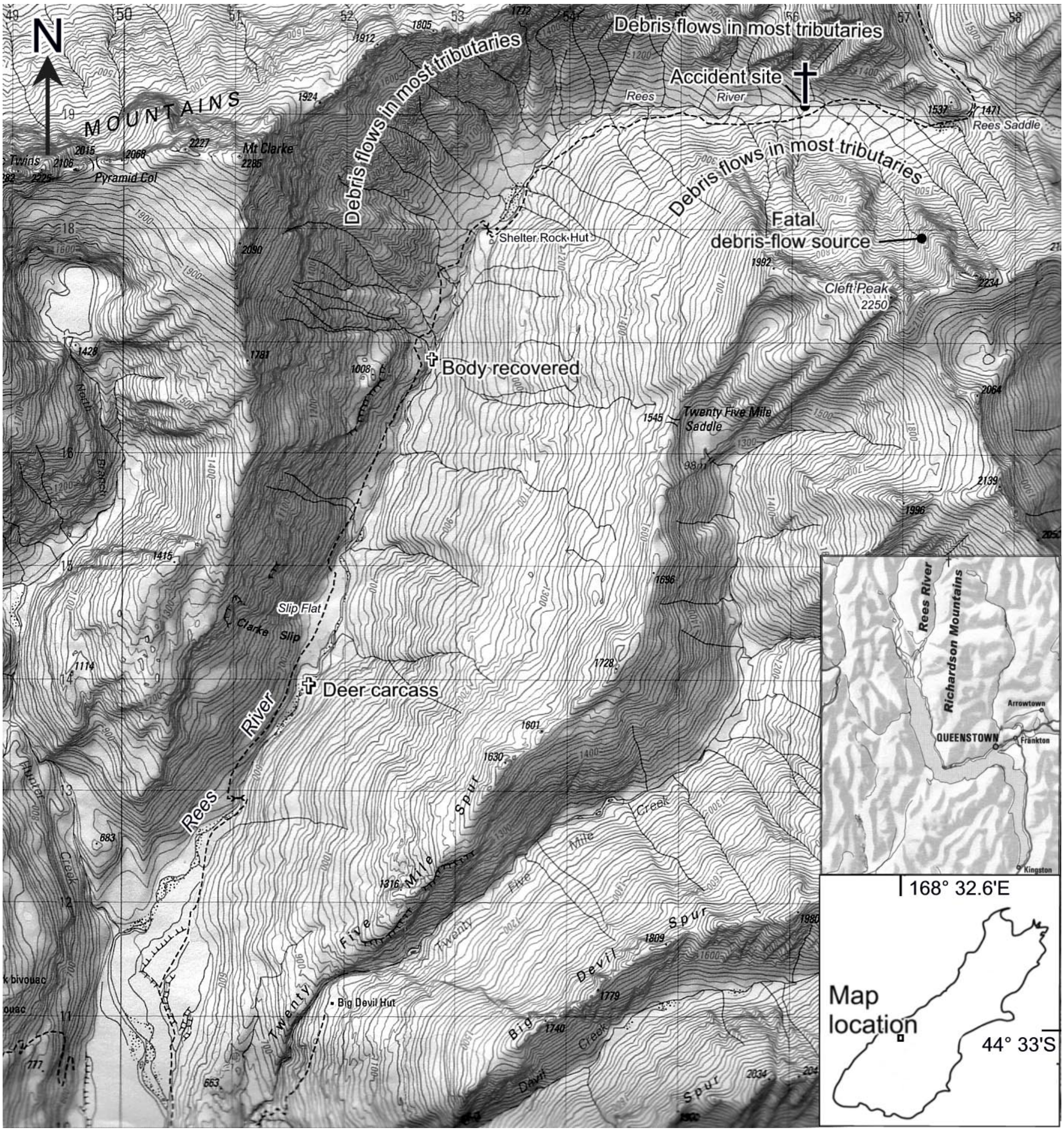

Figure 1 Topographic map of the upper Rees River valley. Grid is 1 kilometre square. From Topographic Map 260-E40 Earnslaw (2000). Fatal debris flow came from the north flank of Cleft Peak (See Figure 2 for details). Track locations (dashed lines) are imprecise, and the fatality occurred on the track route. A deer possibly killed by a debris flow was deposited by the river at the south end of Slip Flat.

1. INTRODUCTION

1.1 Background

At about 10 am on 3 January 2002, Robin Alan Buxton, 28, was killed by a debris flow while attempting to cross an unnamed headwater tributary of the Rees River, west Otago. He was tramping between Shelter Rock hut and the Rees Saddle (Figures 1, 2). The tributary drains from Cleft Peak at the northern end of the Richardson Mountains. The event was witnessed by Bevan Thrower, who narrowly escaped the surging 2m-high wall of rock, water, mud, and debris that overwhelmed Mr Buxton.

1.2 Site inspection

As part of the GeoNet natural geological hazards monitoring contract between the Institute of Geological & Nuclear Sciences (GNS) and the Earthquake Commission, a response team is to investigate any incident of land instability involving loss of life. This investigation was made under this contract. The response team consisted of Dr Mauri McSaveney and Mr Phil Glassey of GNS. We flew to the site by helicopter on 25 January 2002, accompanied by Tony Zimmerman and Richard Kennett of the Department of Conservation (DoC), Glenorchy, and Denis Egerton of Heliworks, Queenstown (helicopter pilot).

On the morning of 25 January, cloud obscured the source area of the fatal debris flow. We inspected and photographed the Upper Rees valley from the air and saw evidence of many, very recent, debris flows in the valley bottom. The DoC staff informed us that most were thought to have occurred on the morning of 3 January during a thunderstorm. We could see the sources of many of these debris flows below and between broken cloud cover. All had similar origins. Although the source of the fatal debris flow was hidden, we could identify which of the upper basins on Cleft Peak was the source of most of its debris. We landed on the debris-flow fan below the source area, where we collected a sample of the debris-flow material (Figure 2), and inspected a small section of the channel through which the debris flow had passed. The section of channel was a short distance upstream from where the fatal accident had occurred. We briefly saw the accident site, and the place where Mr Buxton's body was found from the air, but as these sites preserved no important information with regard to the origins or behaviour of the debris flow, we did not land to investigate them in any more detail.

After our site visit, we visited the Queenstown Police station and briefly spoke with Senior Sergeant John Fookes, who was involved with the search and body recovery. To aid our investigation, Sergeant Fookes arranged for us to see the witness statement and the police scene video. Constable Travis Hughes spoke to Dr McSaveney by telephone (19 February) and provided further information and confirmation of some details of the event. Bevan Thrower also provided further recollections of his experience in the debris flow.

1.3 Scope of report

This report details our findings concerning the debris flow. It is not directly concerned with the fatality. The report is intended to convey useful information about the event to the non-technical reader, and so avoids use of technical terms where this is possible.

1.4 Acknowledgements

We gratefully acknowledge the assistance of the New Zealand Police, particularly Senior Sergeant John Fookes, Sergeant Frank Dowle and Constable Travis Hughes for their assistance in this investigation. Denis Egerton was both a safe pilot and a font of information. We also thank Bevan Thrower for sharing with us his intimate knowledge of the debris-flow experience.

Graham Hancox and Grant Dellow reviewed this report.

2. SITE GEOLOGY

2.1 Geomorphology

The upper Rees River flows in a U-shaped, formerly glaciated valley and drains south into Lake Wakatipu. In the last Ice Age it carried ice that spilled across Rees Saddle from an expanded Tyndall Glacier, which now drains to Dart River, the next drainage system north of Rees Saddle. The bottom of the upper Rees valley south of Rees Saddle (Figure 1) now is occupied by a series of steep coalescing fans from a multitude of minor tributary basins. The accident occurred on the largest of these fans, which has formed from sediment eroded from the northern slopes of Cleft Peak (Figure 2). The abundance of very large boulders and remnants of mostly well vegetated levees marking former channels on the fan surfaces (Figure 3) identify them all as being formed dominantly by infrequent debris flows (of similar and larger sizes to the fatal event). The presence of grey, unvegetated levees alongside more than half of the active channels indicated that many had experienced debris flows very recently (presumed to have been on the morning of 3 January 2002).

Upslope from the site of the accident, the slopes of the northern end of the Richardson Mountains are deeply dissected by a series of narrow gullies leading from minor drainage basins that head at Cleft Peak (2250 m) and several unnamed peaks along the ridge to the north (Figure 2). This is the largest such set of minor drainage basins in the upper Rees valley in the vicinity of Rees Saddle. The presence of fine gravel thinly deposited over live alpine tussock beside the stream channel (Figure 4), identified the active debris-flow source for the 3-January event in this set of basins as being the true rightmost (most easterly) of the minor drainage basins (Figure 2). This basin is a peculiarly elongate basin about 800 metres long and <80 metres wide, perched on the side of the main basin contributing to this tributary of the Rees. Although the shape of the basin contributed some of the character of the debris flow (the precise timing in particular), there was nothing inherently "special" about the basin that led to anything special about the fatal debris flow. On the morning of 3 January 2002, debris flows were the norm, and not the exception, occurring in more than half of the tributaries in the upper Rees valley.

We saw geomorphic evidence of high stream flows and severe channel erosion in the other tributaries contributing to the stream at the site of the fatality, but evidence that these tributaries had carried debris flows was equivocal. The debris-flow fan displayed fresh evidence of only a single debris-flow pulse. The other contributing basins are of different sizes and hence have different times of concentration of flood runoff. Hence we reason that the fatal debris flow originated in only one of the minor basins (as shown in Figure 2). Given the large number of basins around the Rees headwaters that had debris flows that morning, this implies that the larger basins in this locale had had too short a period since their last debris flows, and so needed higher or more prolonged rainfall to induce them, than fell in this storm. There was, however, substantial erosion of sediment from these basins by floodwater.

The accident occurred on the lower slopes of the debris-flow fan, where the channel slope is at the lower limit of the range of slopes on which a debris flow can flow. The profile of the stream channel from the debris-flow source through to the car park in the lower Rees valley is shown in Figure 5. There was nothing unusual about the geomorphology of the accident site, or the site where the body was recovered that might have contributed to their respective roles in the event. The accident site (Figure 6) was a logical and normally safe location to cross the stream.

2.2 Bed-rock geology

The debris-flow source area is entirely cut in metamorphic rock. It is highly erodible schist of the Aspiring lithologic association (Turnbull 2000). It is finely segregated, quartz-feldspar-mica schist. Although thin greenschist bands cut across Cleft Peak, greenschist is not a visibly significant component of the debris-flow deposit. The fine-grained schist is highly susceptible to physical weathering and is easily eroded. It readily yields sediment particles of all sizes from boulders the size of small cars, to sand and silt.

The schist foliation in the bedrock dips steeply to the west-northwest at about 45°. This is about 8° steeper than the general slope of the mountainside.

3. WEATHER CONDITIONS

3.1 General

A northwest airflow covered much of the country on 3 January 2002, caused by a low of <984-hPa southwest of South Island. A series of cold and occluded fronts were embedded in the warm, moist, unstable air (Figure 7). Associated with the fronts were numerous convective cells forming cumulo-nimbus clouds bringing localised very heavy rain.

The accident site lies some 10 km south east of the main divide of the Southern Alps, but well within the zone affected by spillover of westerly rain.

3.2 Weather prior to the accident

There was light drizzle in the Rees valley on the morning of 2 January, but the afternoon was sunny. About dusk, it started to drizzle again, and rained steadily most of the night (Bevan Thrower, Appendix 1).

3.3 Weather at the time of the debris flow

Mr Thrower recollects the rain as "steady" all through the morning of 3 January (Appendix 1). Shortly before the tragedy, however, the rain must have increased in intensity, because he noted that streams then were up slightly and discoloured, whereas along the route to the stream crossing, they had been ankle-deep and clear. One thing that stands out in his memory is "the lack of heavy rain, more showery easing to drizzle with patches of hail hitting off and on."

Although he did not describe thunder in his statement to police, Mr Thrower recollects that it was "rocking and rolling all that morning." Not long before the incident with the debris flow, he "stopped to admire the awesome show being put on." (Bevan Thrower, personal communication 7 March 2002). Sarah Smith, the warden at Shelter Rock hut reported both heavy rain and thunderstorms that morning. Continuing lightning was a concern for the helicopter and the search team most of the day. Having been amidst lightning and thunder all day with others involved in the search for Mr Buxton, it did not seem important to Mr Thrower at the time he made his statement that evening.

It seems likely that a particularly severe convective storm cell, with localised quite torrential rain reached the headwaters of the Rees River, within the moist unstable airflow, between one and two hours after the two trampers had departed Shelter Rock hut and shortly before Bevan Thrower reached the stream crossing – about when he "stopped to admire the awesome show." The particularly torrential part of this cell however does not appear to have crossed Mr Thrower's path.

No details of the rainfall intensities in the Rees valley are known. At Dart Hut, 3.3 km north of debris-flow source area, 240 mm of rain were recorded in the 24 hours between 8:00am 3 January and 8:00am 4 January. Such rainfall is likely to be experienced every two to three years on average (from Tomlinson 1980). The flows of the larger rivers were not unusually extreme events either, and so we reason that the duration of the very high intensity rain was short, perhaps for only 5–10 minutes. This is all that would have been needed to cause shallow landslides in the already-saturated debris on the mountain slopes, but it could have rained heavily for longer. When these landslides entered the steep and now flooded stream channels they could continue down slope as debris flows. The high-intensity rain probably was not spread over a very wide area, but moved as a narrow band (perhaps only 5 km wide) of heavy rain as the convecting storm cell was swept along in the westerly air flow.

The upper Rees valley area lies within a zone where 10-minute rainfalls of 20–24 mm are expected to occur on average about every 5 years (Tomlinson 1980). We judge by the wide extent of extensive landscape damage done by the storm that a similar one had not occurred in the area for much more than 5 years. That is, the extensive amount of landscape change to be seen in the upper Rees valley in the form of many shallow landslides on the steeper slopes, debris flows, and massive deposition along channels in the river bottom, is not something to be seen there very often. From the stature of vegetation extensively damaged in the storm, a storm of this magnitude had not happened previously for many decades. If the event was something likely to be seen on average only every 50 to 100 years, the likely 10-minute rainfalls were in the range 30–50 mm (Tomlinson 1980). Falling on an already saturated landscape, such rainfalls are sufficient to have triggered many minor landslides into flooded stream channels, and so have produced many debris flows.

4. THE DEBRIS FLOW

4.1 The witness account

Although Mr Buxton was travelling alone, he joined with Bevan Thrower to cross the stream where he met his death (Figure 2, 6). The relevant part of Mr Thrower's statement to Police later that day is reproduced in Appendix 1. At the time that they attempted the crossing, the stream was raised, but not in flood. The pair judged it prudent to link arms to make the crossing. Mr Thrower had his parka hood down and heard a loud rumbling roar coming from upstream before they had had time to enter the water. He knew immediately that it was not thunder. Without looking to see what might be coming, he scrambled up the bank of the several-metres deep channel (Figure 6). As he was climbing up the bank on his hands and knees, his feet were washed out from under him. Looking back over his shoulder he saw Mr Buxton, hood up, first standing facing upstream, then turning to move. With black water rising up his body, Mr Thrower kept scrambling up the bank. When he reached the top and felt safe, he looked back to see Mr Buxton's pack disappear. He did not see him again.

Trying to spot further sign of Mr Buxton, Mr Thrower ran along the river bank, but found that a creek they had crossed safely earlier in the morning, some 200 metres downstream, was now washed out and impassable (Figure 8). He had to ascend some 300 metres up its fan before finding a place to cross it. He then returned to Shelter Rock Hut along the walking track to notify others of the loss.

Mr Thrower recollects that between the time the two were considering crossing the stream, and his reaching safety, the water had gone from dirty brown to black, from all the rock in it. The noise was a deafening grinding and banging. He had a "tide mark" of sand in his pack and clothes. The debris flow had all but ripped off his gaiters and jammed pea-sized gravel and sand into his boots. He recollects the flowing material that surrounded him as being like extremely sloppy, wet concrete (Bevan Thrower, personal communication, 7 March 2002). Afterwards, he found that the wet debris left on the stream banks was like wet concrete, up to his knees, and almost impassable. When we saw similar deposits 3 weeks later, they had "set" firmly like partly cured concrete, and were difficult to disturb with a boot to obtain a sample – due to the high silt content.

4.2 Inferred origin of the debris flow

Although the source area of the fatal debris flow was not seen because of cloud, the formation of debris flows in this type of alpine, schist landscape is well understood. Similar rare high-intensity rainstorms have triggered debris flows elsewhere in the region, such as in the vicinity of Makaroroa River and Lake Wanaka in January 1994 when five bridges on SH6 were destroyed (McSaveney 1995).

The lower slopes of the upper basins around Cleft Peak had been accumulating detritus from the physical weathering of the exposed schist bedrock on the slopes above them since they had last been emptied by debris flows some decades earlier. This weathering would be from a mix of freezing and thawing, wetting and drying, and differential expansion of minerals during heating and cooling. There would have been some minimal chemical weathering (which is unimportant to the debris-flow development here). This process would have developed layers of loose rock debris over bedrock on the lower slopes in and adjacent to the ephemeral stream channels. These layers would vary in thickness from place to place, and may have been several metres thick, consisting of boulders and cobbles in a matrix of sand and silt.

The schist bedrock is relatively impermeable to water, and the overlying debris is both porous and permeable. Storm runoff from such steep alpine basins is extremely rapid. Under very high-intensity rain, the loose debris can become locally saturated and this can lead to initiation of a landslide of the loose layer over the bedrock. Local landsliding also can be initiated when the stream flow is high enough to erode the loose debris in its bed, and so undercut the stream banks. Whatever the exact cause of the collapse, the collapsing wet loose debris can form a slurry, much like wet concrete, that is able to flow downslope, including down stream channels. This moving slurry is dense (up to 90% by weight of rock) and highly erosive. It can move faster than the stream flow and pick up further debris from the stream channel, including all of the water.

The exact mix of water and sediment in the debris flow, and the exact range of debris particle sizes present in it are relatively unimportant, because both were changing rapidly as the flow progressed down valley. On the lower flanks of the debris-flow fan, as the flow approached the track crossing, it was depositing sediment and not significantly eroding its bed: it was picking up water, and so it was becoming more fluid than it had been while confined in the channel of the upper fan. At the track crossing, a few tens of metres above the tributary's junction with Rees River (here a stream of similar size to the tributary), the debris flow was described as extremely sloppy concrete while flowing. On standing, it quickly firmed up as the water drained out, but remained unable to support the weight of a man for some minutes.

The range of sediment particle sizes forming the matrix of the debris flow a few hundred metres upstream of the track crossing (Figure 9) is within the range expected for debris flows formed from failure of schist regolith. The sample contained 63% pebbles, 25% sand, 11% silt and less than 1% clay particle sizes. It has no unusual or distinguishing characteristics. The extreme range of particle sizes present (Figure 9, 10, 11) are typical of schist debris flows, and indeed of any debris flow where there is a large range of sediment particle sizes present in the stream channel to be picked up by the flow.

Although the debris flow contained some fragmented plant remains, these were an insignificant component, as expected from the high alpine source of the flow, and the small stature of the riparian vegetation on the debris-flow fan.

4.3 Dispersal of the debris flow downstream

There is a marked change in the character of the fresh sediment deposits alongside the stream channel at the junction of the tributary with the Rees. Alongside the tributary, the deposits are set like lobes of concrete, but beside the Rees, they are loose and friable, because they have much less silt in them. This change (Figures 6, 8) indicates that the debris flow did not continue beyond the junction. There appears to have been sufficient water volume in the Rees River at this point to dilute the slurry to what is known as a *hyper-concentrated* flow, and then to a "normal" raging water torrent in full flood, hence the deposits alongside the Rees contain less silt and are less cohesive.

The raging torrent in the Rees moved a very large quantity of sediment. Much of this was delivered to the river by the many debris flows, and other flooded tributaries. Some of the coarser components of the sediment were deposited in the bed of the river channel. The raised bed, in addition to the increased water volume, contributed to the high water surface of the flooded river (Figure 8). Downstream of Shelter Rock hut, the flooded river undercut the riverbanks in many places and tore out many riverside trees, contributing to an increasing load of large woody debris being carried in the flood.

Mr Buxton's body was carried swiftly downstream, initially in the frontal wave of the debris flow, but later simply by the flow of the torrent for most of its journey. Eventually the body lodged on the outside of a bend in the river flow, by a cluster of large boulders where a substantial flood flow was pouring through a scrubby tree which filtered out all of the larger floating debris passing its way (Figure 12). The large amount of woody debris covering the body, suggests that much of the bank erosion and addition of wood to the floodwaters occurred after the body had passed by.

5. CONSEQUENCES OF THE DEBRIS FLOW

5.1 Damage to life, property and the landscape

The primary damage from the Cleft Peak debris flow was the killing of Robin Buxton and the destruction of the gear he was carrying. His body and pack were recovered on 7 January about 4 km downstream of where he had attempted the stream crossing.

The body damage as seen on the Police video (not illustrated here) appears to have been largely percussive (extensive bone fractures), as if from impacting boulders. There is little evidence of massive abrasion of skin, or puncture wounds from woody debris. Although all clothing was torn from the body, avulsion of body tissue was relatively minor (loss of right lower forearm, and part of head). Likewise, Mr Buxton's pack was surprisingly little damaged externally, although some of the more exposed contents (such as the sleep mat) had been torn away. Given the nature of the debris flow, and how he was caught in it, we believe that his escape was impossible and death was close to instantaneous. Mr Thrower was exposed only to a much slower velocity of flow at the edge, and was uninjured.

The debris flow did no lasting damage to the walking track or any other DoC infrastructure. It created many new geomorphic surfaces within the landscape and destroyed many plants, but being a natural process in the ecosystem, no lasting damage was done.

It is notable, as an indication of the sudden onset of the landscape damage on 3 January, that an adult deer was also killed by an event (probably another of the many debris flows) somewhere in the upper Rees that morning. Its carcass was deposited at the lower end of Slip Flat (Figure 1).

5.2 Secondary economic impacts

Although it was evident from the outset that a death had occurred, substantial effort was put into recovery of the body. This involved a number of helicopter flights and several search teams. Because of the high probability that the body might have been buried, trained dogs were brought in to assist the search. Some of the deceased's close relatives travelled from Christchurch to Queenstown to assist in the search although the body was recovered before they could participate. Subsequently, there have been Police and Search and Rescue debriefings and report preparation. There also is to be a coroner's inquest into the cause of the death.

DoC staff mentioned that some realignment of the track route would be undertaken to lessen the exposure of people to flooding on the valley bottom. This exposure results from bank erosion by the Rees River, and is not a result of the debris flow. It will not change the exposure to the risk of injury from debris flows, because this risk occurs at every tributary stream crossing regardless of the track alignment.

Judging from the numbers of people seen on the Rees Valley track on 25 January, the event has not affected the popularity of the route.

The nominal value of an adult human life currently used in costing road accidents is $4,000,000. If this value is accepted for Mr Buxton, the economic cost of the 3 January 2002 Cleft Peak debris flow is likely to be about $4.2 million.

6. DISCUSSION

6.1 Recognition of areas with debris-flow potential

Debris flows are significant erosion and deposition processes in the shaping of the New Zealand alpine landscape. Although they occur infrequently, marks of their occurrence in the landscape are widespread and persistent. Although we describe many steep channels as stream channels, in reality, they are mostly shaped by debris flows, and are occupied by streams that do little geomorphic modification between debris flows. Debris flows are not rare, they just occur infrequently in any one stream – unless there are particular conditions that lead to frequent debris flows (not present in the upper Rees valley). The repeated occurrence of debris flows leads to a channel form with a characteristic U shape, much like a U-shaped glacial valley, but in miniature. Most of the steep tributary channels in the upper Rees valley are shaped by debris flows and have this distinctive U-shaped cross profile where they are cut in the schist bedrock.

Another debris-flow characteristic that leads to clear geomorphic evidence of them in the landscape is their ability to transport enormous boulders where these are available. Typically, these may range in size from a large daypack to a small car, and are far larger than can be transported by any stream in flood. These may litter the surface of a cone-shaped fan where the channel issues from the mountainside onto the valley floor. The combination of a steep fan covered by scattered large boulders, such as seen everywhere across the valley floor in the upper Rees valley is highly characteristic of alpine terrain subject to a severe debris-flow hazard.

6.2 Probability of the debris-flow fatality

Debris-flow fatalities are not new in New Zealand. Lahars are simply debris flows on volcanoes, and so New Zealand's greatest single-event death toll from a debris flow (151 deaths) was in the 25 December 1953, Tangiwhai rail disaster. Previous debris-flow fatalities to trampers have occurred when people have been inadvertently exposed to a debris flow through their choice of a site to spend the night, or to shelter from a storm. These include fatalities when a debris flow struck the Lake Daniels hut in the early 1970s, and when a debris flow struck a tent at Klondike Corner in 1978. More recently, a debris flow from a side stream carried away a hut in the upper Motueka River, Nelson, killing the two occupants. These backcountry fatalities arise through the inappropriate siting of a few mountain huts and campsites in areas exposed to a danger of debris flows. This recognised problem is being rectified by systematic geological hazard assessment of DoC huts (Hancox 2000, 2001), and several huts have been removed from potential debris-flow paths.

Although there are many more sites where roads and tracks cross debris-flow paths than there are huts and campsites in debris-flow paths, it is unusual to learn of people being killed by debris flows because they have inadvertently strayed into their path. There are a number of reasons for this. The total exposure to debris-flow danger is shorter when people move through the danger zone than when they rest in it. Also, the storm conditions when debris flows tend to be generated may inhibit many people from travelling. But also it is unusual for evidence linking the person to the debris flow to survive. Had Mr Buxton's death not been seen, there is little or no other surviving evidence to link him to the stream crossing or the debris flow. There may have been other similar deaths in New Zealand, but we do not know such details of them.

Robin Buxton's death would appear to be a particularly rare and unavoidable accident. The more remarkable event appears to have been the survival of Bevan Thrower. Although he demonstrated that it is possible to escape from a debris flow through vigilant personal awareness of one's surroundings, and quick appropriate reaction to an unusual warning, his survival was also partly a matter of good luck. He probably came very close to meeting much the same fate as befell Mr Buxton. Had he not survived to report the loss and its location, a search for the missing trampers would not have arisen until they were reported overdue and missing somewhere between the Shelter Rock and Dart huts. The deaths then would likely have been attributed to the two having been washed away while attempting to cross a flooded stream.

There are many rare and unusual way to meet one's death in New Zealand's mountains, and death by being swept away by a debris flow while crossing a mountain stream is one of the more unusual. Of similar low likelihood are being killed by lightning strike, falling tree, or earthquake-triggered landslide. Avoidance of these dangers while tramping is a personal and not a societal responsibility. Statistically, to die in a debris flow on a tramp is more likely to occur while asleep in a tent, or a mountain hut, than while crossing a stream.

6.3 Map inaccuracy

The accident site (Figure 6) was a logical and normally safe location to cross the stream. Had the crossing been located higher on the fan, in the position where it is marked on the topographic map for example (Figures 1 and 2), this particular accident might not have happened, because Mr Buxton would have taken longer to reach the crossing, and hence would not have been in the stream channel at the time the debris flow passed through it. However, the debris flow spread more widely in this area, and had the two been crossing there at the time the flow passed through, it is less likely that anyone would have been able to escape. Equally, if Mr Buxton had left Shelter Rock Hut some minutes earlier or later, or if he had walked faster or more slowly, the accident might not have happened.

It is well recognised that track routes are not accurately positioned on topographic maps, and the map inaccuracy did not contribute to the accident.

6.4 Warnings, cautions, and awareness of danger

The DoC staff that accompanied us on 25 January believed that people at Shelter Rock hut had been warned of the danger of undertaking the journey to Rees Saddle during the storm on 3 January. Their belief is consistent with statements made in the news media on 5 January that "There was heavy rain and thunder storms on the morning he [Robin Buxton] left and trampers were advised of the danger." The witness statement does not mention a warning. The rain was not unusually heavy, nor the streams in spate, at the times that Mr Buxton and Mr Thrower departed from the hut. Subsequent to their departures, others too departed for Rees Saddle. If the weather deteriorated to the extent that people at the hut were warned of any danger, it was after Robin Buxton and Bevan Thrower had departed. Also, it is likely that any intended warning would have related to the potential danger of crossing flooded streams, and the extreme rapidity with which mountain torrents can rise in level during rain. It is not likely that the warning would have covered the danger of being overwhelmed by a debris avalanche or a debris flow.

But it also is possible that no warnings were issued prior to tragedy. In a media statement of 5 January, Sarah Smith is quoted: “People [at Shelter Rock hut] were very solemn and I think it hit home the seriousness of the river” With a search underway about 10 trampers decided to head back down the river. About six continued towards the saddle yesterday, she said. “I’ve just told them to be very careful and turn back if they’re feeling unsafe.” This appropriate warning may well have been the origin of other media reports about trampers being advised of the danger.

Both Mr Buxton and Mr Thrower were experienced lone trampers. It is evident from their choosing to cross the side stream together because it was in fresh, that Bevan Thrower, at least, was aware of, and experienced with doing such things. Tramping in heavy rain was not likely to have been new to either of them. They likely saw the inclement weather as a challenge and not as an inhibition to their journey. Further, it is likely that had they heard a warning earlier at the hut, they would have taken it as a caution – and treated it much as they would earlier in life have treated a caution from their mothers about crossing roads on their way to school. The event that took Robin Buxton’s life was not a flooded stream, but a very much rarer and more extreme event – a debris flow. It came upon them with little warning. It happened through conditions that arose only tens of minutes before tragedy struck: it was not something that could have been predicted an hour or so earlier.

While it might be useful for more trampers to be aware of the possibility of debris flows, and of the signs to look for in the landscape and the weather to warn of their likelihood, such knowledge has little prospect of saving lives. The event is too rare, too sudden, and too dangerous for such knowledge to be particularly useful. The witness to Mr Buxton’s death survived because of the speed of his instinctive reaction to a loud noise perceived as a danger. Mr Thrower’s reaction is unlikely to have been different had he known about debris flows.

We also note that Mr Thrower’s parka hood was down giving him unimpeded, directional hearing, whereas Mr Buxton’s hood was up – as might be expected in intermittent squalls of hail.

The specific conditions that gave rise to the potential for debris flows came upon the two while they were traversing a series of debris-flow fans. Since the size of a debris flow is somewhat independent of the size of the event that triggers it, they were at risk of being overwhelmed by a debris flow for several kilometres along their route, and so had no useful opportunity to take shelter even if they had been aware of the danger. Some of the debris flows of 3 January did not follow stream channels, and so once the trampers had begun crossing the wide expanse of debris-flow fans leading to Rees Saddle, they were as safe from debris flows while continuing their journey as they would have been had they chosen to shelter beside a rock until the rain had eased.

7. CONCLUSION

On the morning of 3 January 2002, Robin Alan Buxton, 28, was killed by a fast-moving debris flow when he was unable to get out of its way while preparing to cross a stream. His death was a very unusual accident, and not something that he or others could easily have foreseen or prevented.

Bevan Thrower survived the event because of the speed of his instinctive reaction to an unfamiliar loud noise that he perceived as a danger. But he narrowly escaped death, and his survival without injury was as much a matter of luck as it was of survival instinct.

8. REFERENCES

Hancox, G.T. 2000. Geological hazard rating system for DoC backcountry huts: revision 1. Institute of Geological & Nuclear Sciences client report 2000/6. Lower Hutt, New Zealand. Institute of Geological & Nuclear Sciences Ltd. For Department of Conservation.

Hancox, G.T. 2001. Baseline geological inspections of 65 DoC backcountry huts. Institute of Geological & Nuclear Sciences client report 2001/43961B.120. Lower Hutt, New Zealand. Institute of Geological & Nuclear Sciences Ltd. For Department of Conservation.

McSaveney, M.J. 1995. Debris flows and bridge losses at Waterfall Creek, SH6 at Lake Wanaka, New Zealand. Institute of Geological & Nuclear Sciences science report 95/21. 35 p. Lower Hutt, New Zealand. Institute of Geological & Nuclear Sciences Ltd.

Tomlinson, A.I. 1980. The frequency of high-intensity rainfalls in New Zealand. Water & Soil technical publication 19. National Water & Soil Conservation Organisation. 36 pp.

Turnbull, I.M. 2000. Geology of the Wakatipu area. Institute of Geological & Nuclear Sciences 1:250 000 geological map 18. 1 sheet + 72 p. Lower Hutt, New Zealand. Institute of Geological & Nuclear Sciences Ltd.

APPENDIX 1 – EXTRACT FROM POLICE WITNESS STATEMENT BY BEVAN THROWER

The following is extracted from a five-page statement given at the Queenstown Police Station on Thursday 3rd January 2002; beginning at 5:31 pm. Mr Thrower is an experienced South Island tramper. He had taken mountain-safety courses. Description of activities unrelated to the incident on 3 January is omitted from this extract. Some typographical, grammar and punctuation errors have been corrected from the original.

"At about dusk it started drizzling again.

It was about this time also that another tramper turned up. He was by himself and made himself known to the hut warden Sarah. He went straight out and bivvied by the hut. He didn't have a tent, just a bivvy bag. Since the incident I have found out that this tramper's name was 'Robin'.

I didn't hear any of the conversation he had with the hut warden. He didn't talk to anyone else in the hut that I am aware of. There were about 25 people staying in the hut overnight.

I went to sleep at about 10:30 p.m.

I got up the next morning at about 7am. It was Thursday 3rd January 2002. I had some breakfast and then packed up my gear to continue on with my tramp. I noticed that 'Robin' packed up and left the hut area at about 7:45am. He left by himself. I don't know if he talked to anyone else before leaving. If he did, I didn't see him.

I was the next to leave at about 8:00am. It had been raining most of the night and was still raining steadily. I was walking from the Shelter Rock Hut to the Rees Saddle.

I crossed numerous creeks that were ankle deep at most. They were clear and not muddy.

At about 9:30 - 10am I caught up with 'Robin'. I am not sure on the time because I don't wear a watch when I tramp.

I said hello to him and commented on the weather. It was just niceties that you say to people in passing on a track. It was raining steadily at the time, and not the time to stop and have an in-depth conversation.

I carried on up the track and came to a creek crossing. It was about 15 minutes since I saw 'Robin'. This crossing is at the fork where two creeks meet. The crossing is right at the fork. I am pretty sure you are facing north as you look at the crossing.

I decided that I shouldn't cross the creek because of the rapid flow of it. The creek was up slightly and discoloured. I waited at the crossing for 'Robin' to catch up to me.

When he got to the crossing about a couple of minutes later, I discussed with him what we should do. He agreed that we should cross it together. We didn't talk about anything else other than the crossing point. We had no conversation of a personal nature.

I was down on the creek bed and he joined me where we were discussing options of how to get across the creek.

The creek was flowing in front of us and we were standing on gravel at the edge of the creek bed.

I was pointing to a crossing point and we agreed to link arms to cross it. ‘Robin’ was standing to the left of me, which is also the downstream side. We hadn't entered the water at this point.

It was at that point that I heard a loud rumbling roar coming from up the creek.

I knew immediately that it wasn't thunder and I had to get out of the creek bed. I didn't see anything unusual but I knew I had to move.

I can't consciously recall thinking about having to move but was moving up the bank instinctively. As I started climbing up the bank on my hands and knees, I turned to say something to ‘Robin’ and my feet got washed out from under me. The force of water was indescribable. I turned and grabbed hold of what was on the bank.

I kept scrambling up the bank and could feel the water getting higher up my body.

When I turned, I saw ‘Robin’ standing facing upstream and then turn to move.

When I got to the top of the bank and felt I was safe from the water, I looked back and saw ‘Robin's’ pack disappear into the water. I didn't see him again.

I stood up, and ran down the bank trying to spot ‘Robin’. I got as far as the previous creek we had crossed, which was about 200 metres downstream.

I couldn't go any further as it had washed out as well, and was impassable.

I would describe what happened with the creek as a two-metre-high wave that just came down like a slurry of concrete, full of debris. After about 5 minutes, it settled down to a raging torrent but left this thick, concrete-type debris on the banks.

I have never seen anything like it. I hoped ‘Robin’ would be able to get out, but I knew that it was pretty near impossible. It was like a fluid landslide.

I was now trapped between the two creeks so I climbed about 300 metres upstream until I found a point I could cross. I crossed that, and headed back to the track, which took me back to the hut.

On the way to the hut, I met up with other groups coming up. I told them that I had just lost a guy and didn't recommend them carrying on because of the river. Most of them continued on to see what the river was like.

When I got back to the hut I told Sarah, the Hut warden, what had happened. She immediately got on the radio and called DoC who got a search under-way.

We looked at the map, and from where I indicated the incident occurred, Sarah obtained a grid reference. Between the two of us, we got together a clothing description and relayed that to the searchers.

We then waited for the helicopter to pick Sarah and I up. When it arrived, Sarah and I went up with the helicopter to find the site. I pointed out where it happened to the helicopter crew. The helicopter eventually returned me to Queenstown.

I would describe 'Robin' as male, Caucasian, late 30s/ early 40's, about 5ft 6in tall, medium and fit build. He had dark hair.

He was wearing a blue gore-tex rain jacket, black and blue gators, brown leather tramping boots, and shorts. I recall he had exposed legs from above his gators to below his parka. I didn't see the colour of his shorts. He was wearing a black backpack with a green sleep mat attached to it. It was possible that the black colouring was a backpack cover. He wasn't wearing glasses. I didn't notice anything else distinctive about him."

8:15 p.m. 03/01/02

We gratefully acknowledge Bevan Thrower for granting us use of this statement.

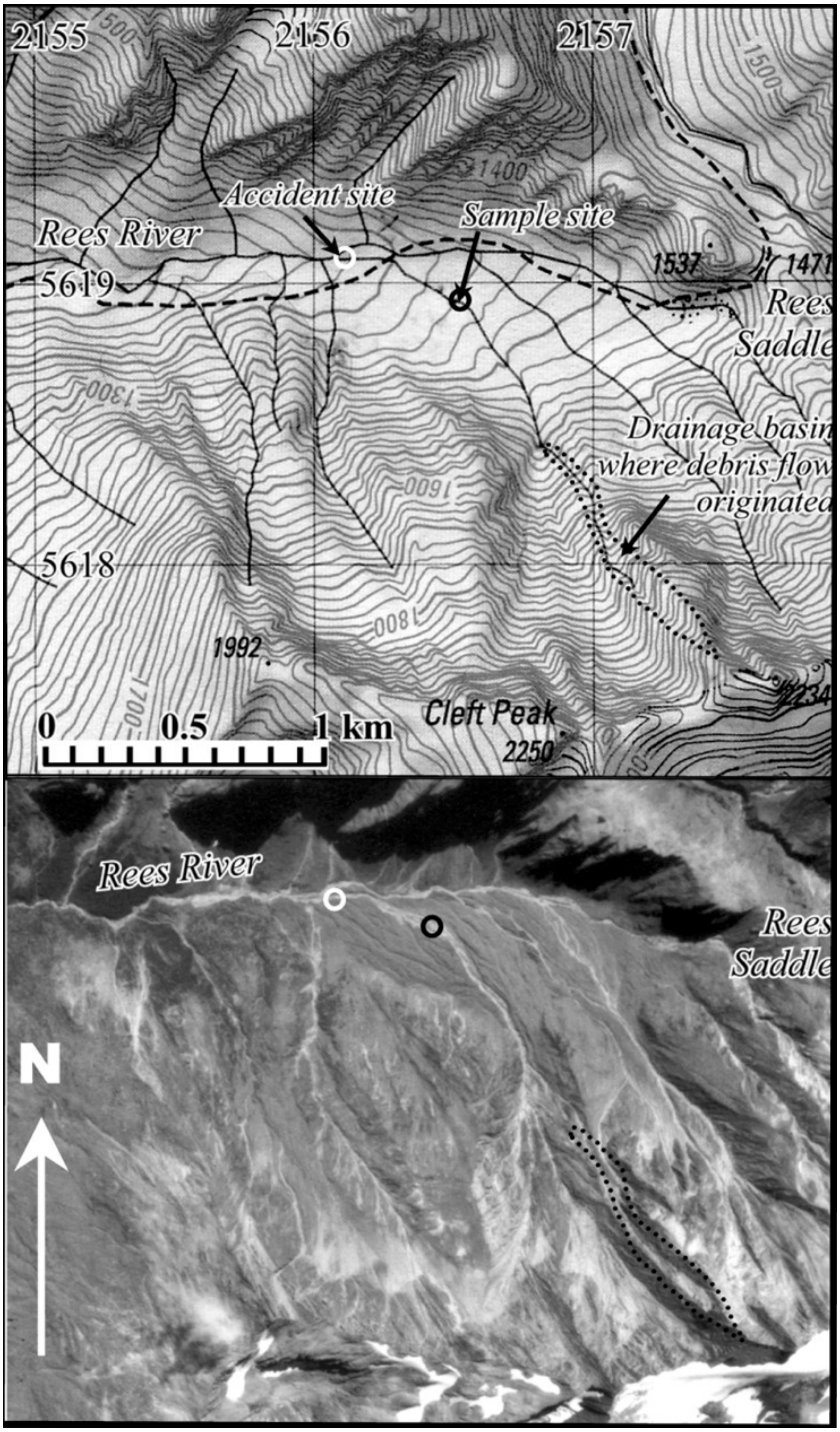

Figure 2 Detailed topographic map and vertical aerial photograph of the site of the fatal Cleft Peak debris flow of 3 January 2002. Note that the walking track location shown on the map is inaccurate: on the ground, the track passes through the marked accident site. Neither the inaccuracy, nor the true location of the stream crossing contributed to the fatality. Grid on map is New Zealand map grid. North is uppermost. Aerial photograph (part of SN3982/18 of 12 March 1966) is only partly rectified for distortion and topography.

Figure 3 Oblique aerial view of some of the upper Rees valley debris-flow deposits upvalley from the accident site, towards Rees Saddle (background). The tussock-covered, bouldery surface forming the foreground is northeast margin of the debris-flow fan where the accident occurred. The mid-ground debris flow has spilled debris widely down many channels in the storm of 3 January 2002. Note how the fresh deposit from the debris flow below Rees Saddle fills the entire width of the upper valley. Had people been in these parts of the valley during the height of the storm, the debris flows would have been harder to escape from.

Figure 4 The path of the Cleft Peak debris flow of 3 January 2002 down the upper portion of the debris-flow fan. The debris flow appears to have originated from the true right (left in photo) tributary at the head of the fan. The debris flow remained confined to the stream channel in the upper portion of the fan, but spilled out of the channel on the lower fan where the channel was less confined. Inset is close view of the tributary that shows clear evidence (debris over live plants) of the passage of a large debris flow.

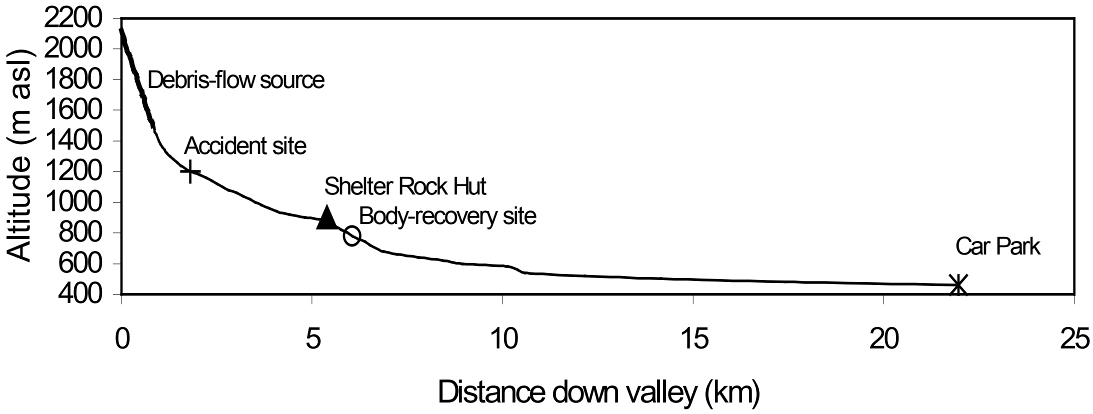

Figure 5 Profile of the Upper Rees valley from the source of the Cleft Peak debris flow to the Car Park in the lower Rees valley. Topographic data from Topomap 260-E40 at 20-m contour interval.

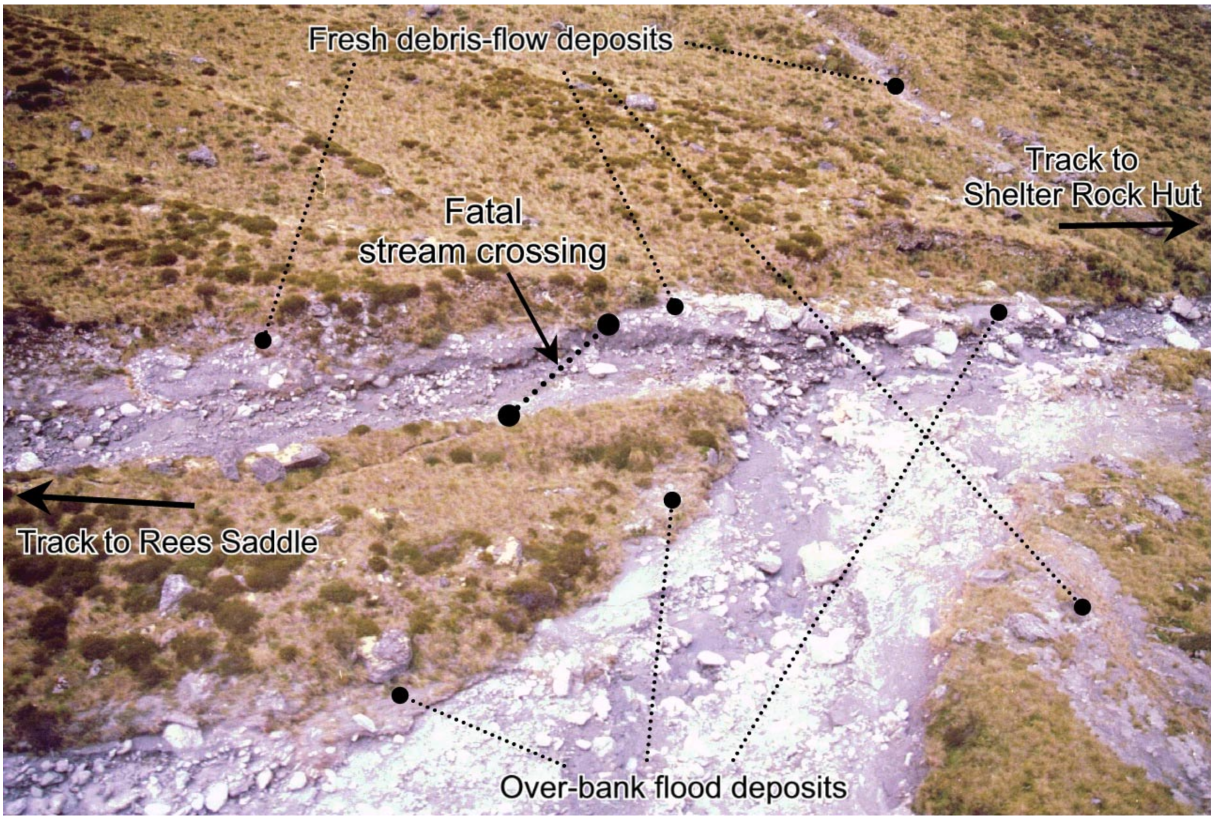

Figure 6 Site of the fatal stream crossing on the track between Shelter Rock hut and Rees Saddle. Rees River flows from centre foreground to right centre of photograph. The tributary stream where the accident occurred enters from the left centre. This photograph was taken on 25 January and does not represent the state of the crossing on or before 3 January 2002.

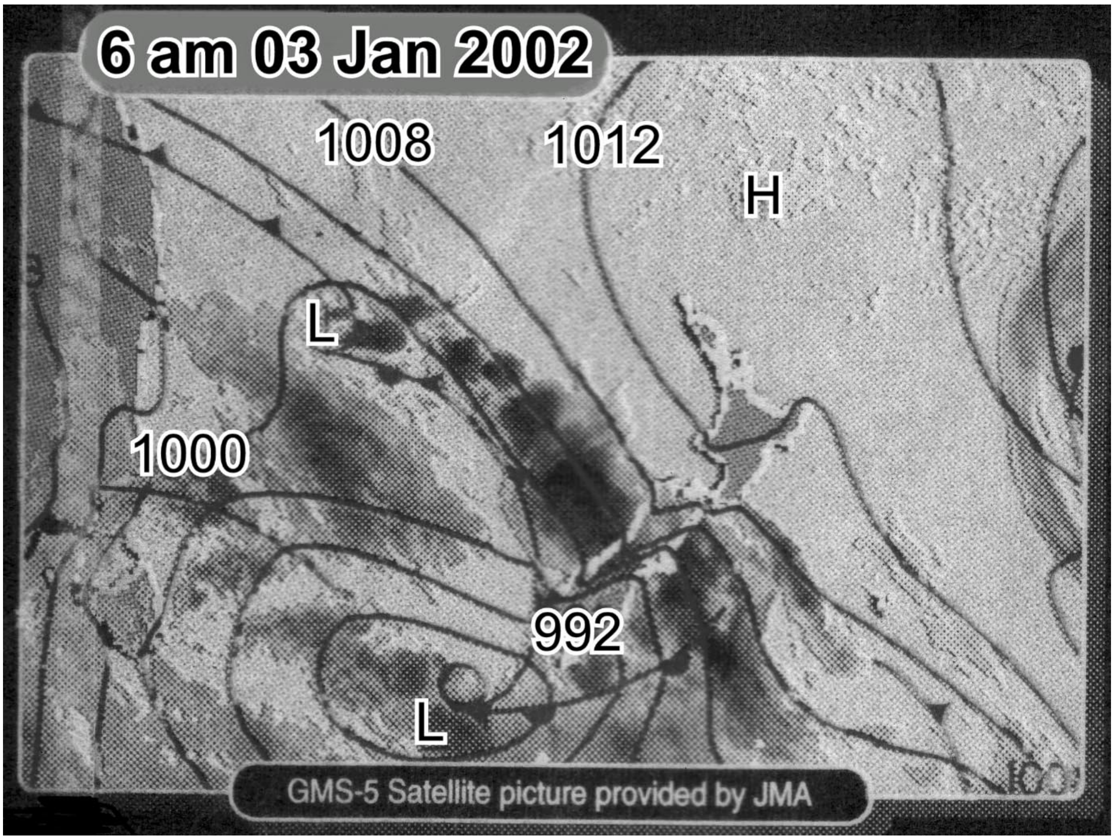

Figure 7 Annotated satellite image (negative), showing the New Zealand weather situation at 6 am, 3 January 2002, approximately 4 hours before the fatal accident (Image modified from the Evening Post of 3 January 2002). The centre of the depression (L) southwest of South Island is at >984 hPa.

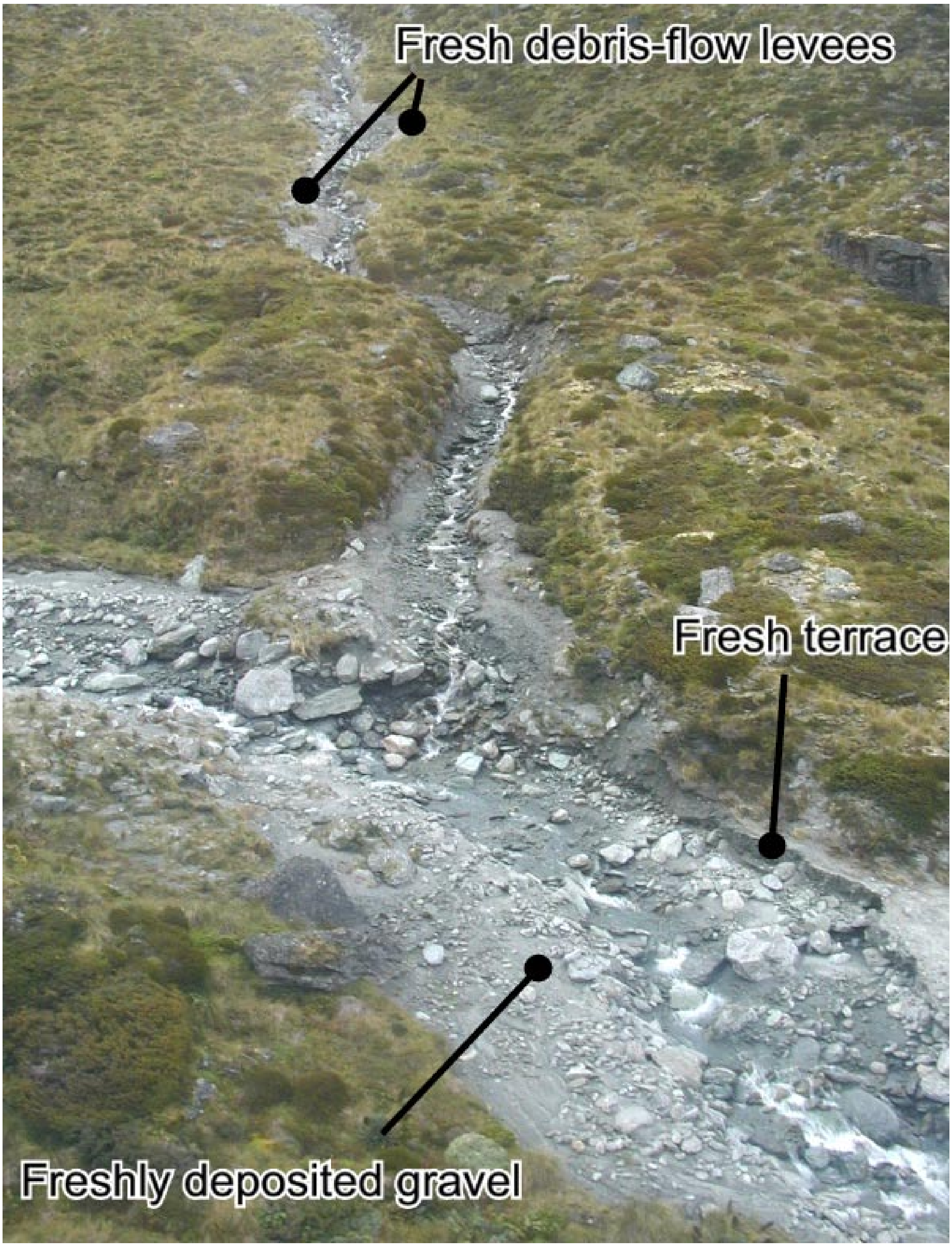

Figure 8 Tributary stream between Shelter Rock hut and the fatal crossing, that Bevan Thrower found to be washed out and impassable within minutes of the fatality. It too shows clear evidence of the passage of a debris flow, one of many triggered during a brief episode of very heavy rainfall about 10:00 am on 3 January 2002. Track between Shelter Rock hut and Rees Saddle crosses the tributary about 20 metres above the junction with the Rees River. Note the freshly deposited gravel and cut terrace in the Rees River channel from deposition during the storm of 3 January. Such deposition of sediment in the streambed contributed significantly to the high water surface level during the flood.

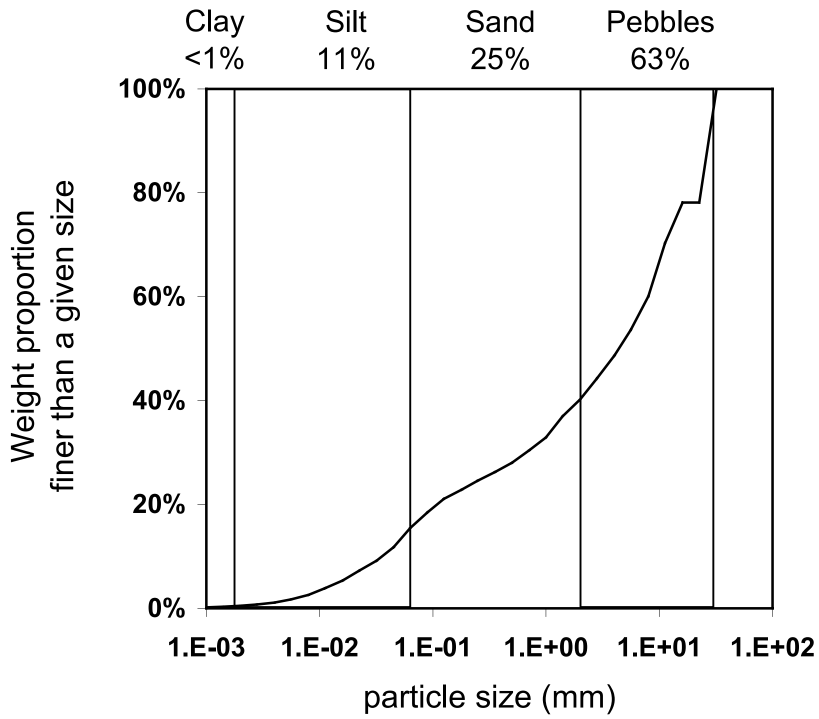

Figure 9 Particle-size distribution for sediment forming the matrix of the 3 January, fatal debris flow.

Figure 10 Close-up photograph of the debris-flow material where it spilled out of its channel onto surrounding plants here, largely *Aciphilla* (Speargrass, Spaniard).

Figure 11 Example of the extremely large boulders moved hundreds of metres by the debris flow on the upper fan. Here a group of boulders have accumulated as a stable cluster when each became buttressed against the powerful debris-flow current by its surrounding boulders. In the background are other large boulders from a past debris flow, now overgrown by dense subalpine plant cover. The sample of the debris-flow matrix (Figure 9) came from this site.

Figure 12 Site where body was recovered after the debris-flow fatality. Note that live trees were trimmed from here during the recovery. It appears that along with much other floating debris, Mr Buxton's body and pack were filtered out of the flood flow on the outside of this bend when the floodwater passed through a shrubby tree while flowing around several boulders.