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Landslide-dambreak floods at Franz Josef Glacier township, Westland, New Zealand: a risk assessment

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Abstract

Recently information has been published on the magnitude and frequency of non-earthquake-triggered landslides in Westland and on the probability of an earthquake on the Alpine Fault. This information, together with data on simulations of dambreak floods in the Callery River gorge and observations from a 1999 landslide-dambreak flood in the Poerua valley, Westland, are used to calculate an annual probability of a landslide-dambreak flood of the order of 3000 m^3s^{-1} from the Callery gorge. Such a flood would threaten areas of the township of Franz Josef Glacier, Westland. The risk to human life from landslide-dambreak floods of about this size in the vicinity of the SH 6 bridge at Franz Josef is several orders of magnitude greater than that internationally considered acceptable for loss of life from landslides and dam failures. Neither physical protection nor warning systems appear feasible as effective measures to reduce these risks.

Introduction

Davies and Scott (1997) drew attention to the hazard to the township of Franz Josef Glacier, Westland, New Zealand, posed by floods from the Callery River (Figures 1, 2) caused by the failure of landslide dams. At that time little was known about the probability of occurrence of such events within the particular hydrological and geological setting of Westland, and the estimates of flood peak discharge, frequency and effects were based on a large number of assumptions. In particular, Davies and Scott (1997) assumed that the most likely cause of a landslide damming the Callery River was a major earthquake on the Alpine Fault, with an estimated annual probability of about 0.03, and the risk of a flood from a landslide-dambreak was derived from that figure.

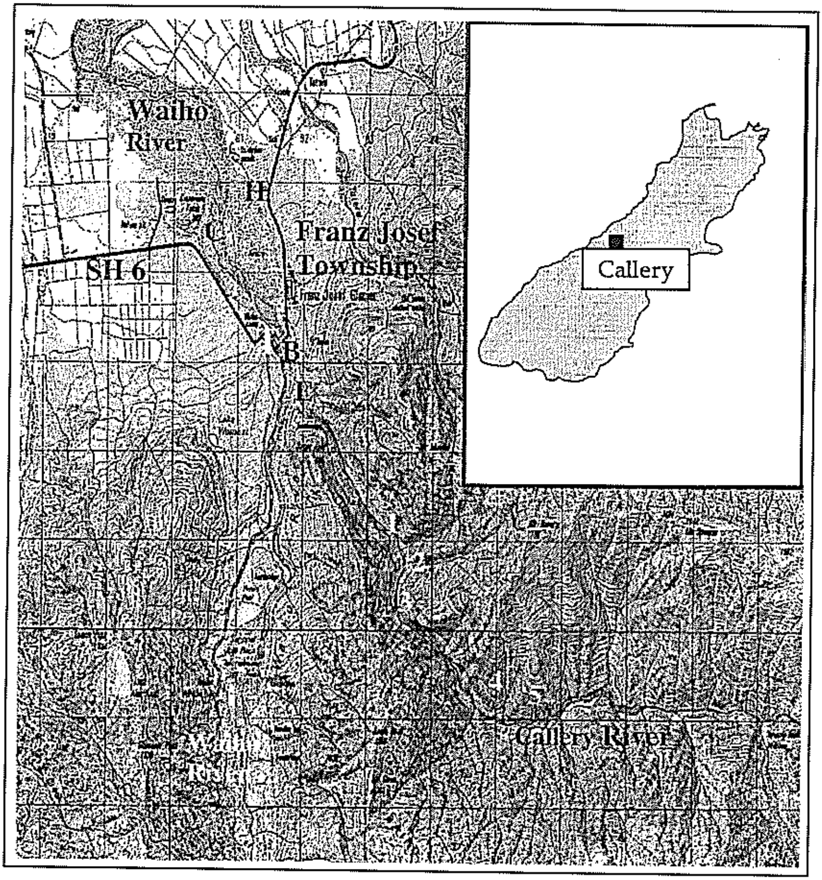

Figure 1 – Callery gorge, Franz Josef Glacier Township and environs (NZ Infomap 260 – H35; 1994)
C = Canavan's Knob, H = hotel, T = tourist accommodation,
B = SH 6 bridge, E = Callery gorge exit, 1, 2, … = landslide dam sites

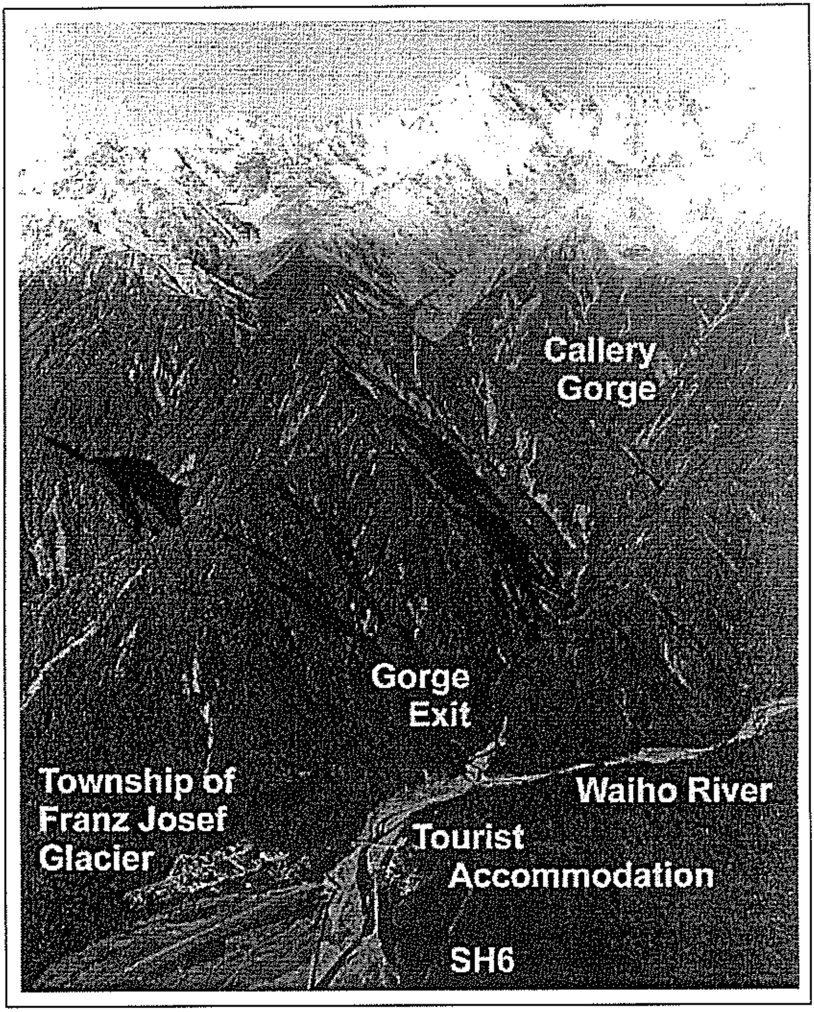

Figure 2 – Aerial view looking up the Callery catchment, showing the steep-walled gorge of the lower catchment and the accommodation facilities most at risk due to their proximity to the gorge exit. Photo taken in about 1982 by Lloyd Homer.

Since this previous work four additional sources of information have become available.

- Hovius *et al.* (1997) presented a magnitude-frequency relationship for aseismic landslides in Westland, based on analysis of aerial photographs. This allows the annual probability for a landslide of given size from a given land area in the region to be estimated.
- Ollett (2000) used computer models to calculate the hydrographs resulting from failures of landslide dams of various sizes at various sites in the Callery Gorge. This information complements earlier estimates based on studies of overseas empirical data by Costa and Schuster (1988).
- A landslide from Mt Adams into the Poerua River gorge (Figure 3) in October 1999 (Hancox *et al.*, 2000) provided an example of the type of event that Davies and Scott (1997) proposed for the Callery Gorge. The subsequent dambreak flood, though ungauged and sketchily monitored, demonstrated the destructive potential of such events close to the gorge exit.
- Yetton *et al.* (1998) obtained more precise estimates of the probability of a major earthquake on the Alpine Fault than were previously available, and from these estimates Berryman (1998) derived earthquake probabilities for the Franz Josef area.

This further information may be used to make a more rational assessment of the risk to Franz Josef Glacier Township from the failure of dams created by landslides into the Callery River gorge. The annual probability of a 1 million m^3 landslide into the Callery (causing an outburst flood of about 3000 m^3s^{-1}) now appears to be of the order of 0.01–0.02. Since large numbers of lives are put in danger by such floods, this risk is far too great to be acceptable and realistic measures are needed to reduce it. The warning times possible for dambreak floods from rainfall-triggered landslides in the Callery are however as little as one hour in all but the unlikely event of a landslide during low river flow. Warning times for dambreak floods from earthquake-triggered landslides are likely to be longer, and thus such floods present less of a danger.

Magnitudes and frequencies of aseismic landslides in Westland

Hovius *et al* (1997) measured the surface areas of landslide scars in Westland, New Zealand from aerial photographs taken over a 60-year period. The area surveyed included both the Poerua and Callery catchments, so the data are applicable to these drainage basins. During this time there were no significant earthquakes in the area, so the data relate to aseismic, mainly rainfall-triggered, landslides. A well-defined relationship was demonstrated (their Figure 1) for the frequency of landslides with scar areas between 0.01 and 1.0 km^2; the frequencies are summarised in Table 1.

Table 1 – Aseismic landslide frequency – after Hovius *et al.*, 1997

Landslide area (km^2)	**Frequency (km^{-2}a^{-1})**
1.0	6×10^{-5}
0.1	8×10^{-4}
0.075	10^{-3}
0.01	10^{-2}

A further empirical relationship, that the thickness of a landslide is about 0.05 times the square root of the plan area, was derived from field surveys elsewhere and used by Hovius *et al.* (1997) to calculate volumes from the landslide areas. This relationship is clearly a generalisation; for example, the Mt Adams landslide scar had an area of about 1 km^2 and the landslide a volume of about 15 million m^3, so its average depth was about 0.015 times the square root of its area. Care is thus needed translating the area relationships of Table 1 into landslide volumes, particularly in the case of large landslides.

The 1999 Mt Adams landslide and landslide-dambreak flood in the Poerua River

Description and effects

These events are described in detail by Hancox *et al.* (2000). A landslide of 10–15 million m^3 fell from the upper north face of Mt Adams during a very short time on a calm, rainless night with no recorded seismic activity. The debris fell 1800 vertical metres into the Poerua gorge about 5 km upstream of the head of the Poerua valley (Figure 3). The crest of the natural dam thus formed was about 100 m above the original level of the river bed. The dam volume was about 10 million m^3, as a large quantity of debris fell into an embayment in the true left slope of the gorge. The volume of water impounded in the lake peaked at about 5–7 million m^3 at overflow level.

About a week after the landslide, and several days after first being overtopped in a minor fresh, the dam failed during a larger flow. A breach about 50 m deep was eroded in the dam, and the volume of the lake was reduced by about 3–4 million m^3. The event was not observed, although a flood wave was seen advancing over the valley floor. Inspection the following day revealed that overbank flow had occurred in the uppermost 2–3 km of the valley, and that this flow had deposited sand and silt across much of the

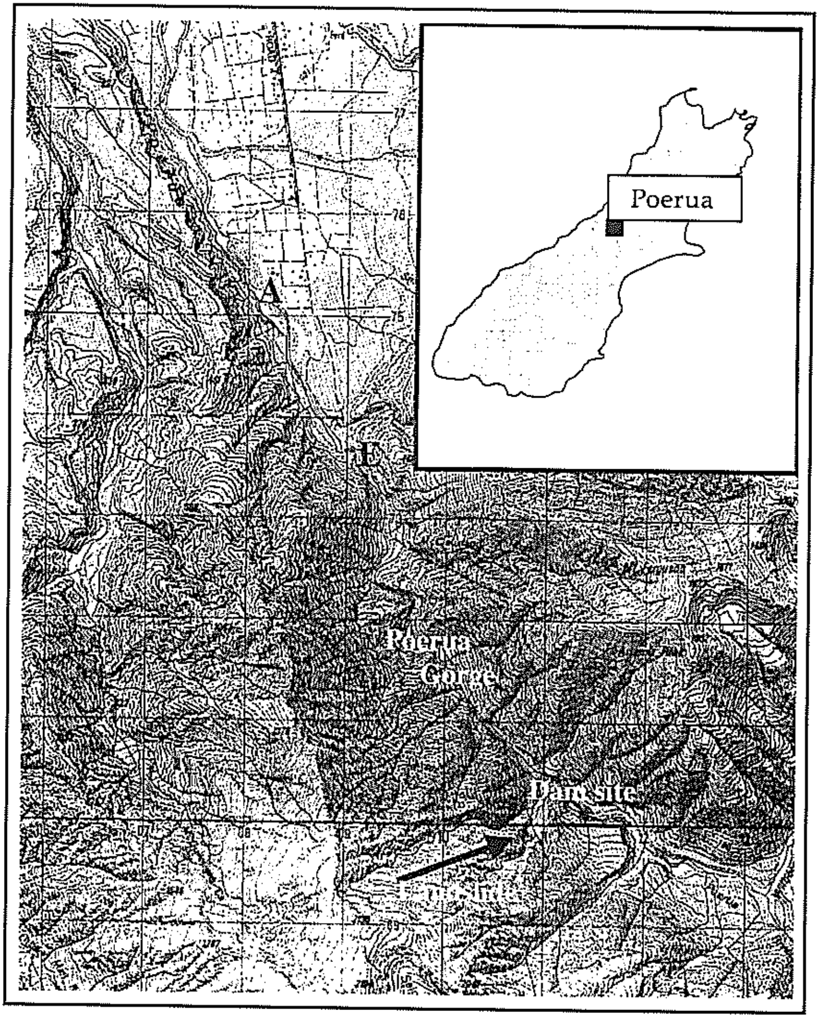

Figure 3 – Poerua gorge and valley (NZ Infomap 260 – H34; 1994)
A = damaged trees (see Figure 4), E = Poerua gorge exit

Photo by K.A.Hodgson

Figure 4 – Trees damaged by Poerua landslide-dambreak flood of October 1999. The trees are located about 2 km downstream of the exit from the Poerua gorge, and damage extends to about 4 m above ground level or 6 m above the pre-existing river bed level. The event removed a strip of riverside trees several metres wide.

valley width, with some damage to deer fences. A remnant of native forest on the river bank about 2 km downstream from the gorge exit was severely damaged and probably eroded by the flood wave (Figure 4). Little damage was evident more than about 20 m into the remaining forest, though substantial quantities of sediment were in evidence there.

The aggradation due to the dambreak flood wave was not immediately surveyed, but a survey carried out in November 1999 showed about 2 m of aggradation 1 km below the gorge exit. Several further inspections of the gorge exit have shown that much of the aggradation there occurred during the dambreak flood itself; this section has degraded slightly since December 1999. Aggradation is still continuing, however, farther downstream.

Peak flow rate

The day after the dambreak flood a site inspection suggested that at the gorge exit the flood flow depth was of the order of 5 m (based on vegetation trimlines and bed levels) at a section about 25 m wide. Allowing for a very steep slope giving a velocity of the order of 5 ms^{-1}, a peak discharge of the order of 750 m^3s^{-1} was estimated. Initially this estimate appeared to agree with the estimate of a peak flow rate of the same order at the SH 6 bridge. Further consideration, however, suggests that the flow rate for the gorge exit is an underestimate.

Hancox *et al.* (2000) reported the peak flow at the SH 6 bridge (about 5 km downstream of the gorge exit) to be 500–1000 m^3s^{-1}. However, the flood peak must have attenuated considerably as it spread out at the head of the valley flats and 5 km down the flats, so the peak flow rate at the gorge exit must have been much greater than this figure. Hancox *et al.* (2000) estimated this attenuation to have been about 40%, giving a peak flow rate of about 1400 m^3s^{-1} at the dam.

The duration of the dam breach was estimated by Hancox *et al* (2000) to be about 20 minutes. Hydrographs from physical and computer models of dambreak floods, and from field records (Davies, 2001; Ollett, 2000; Plaza-Nieto and Zevallos, 1994; King *et al.*, 1989; Costa, 1991; Parkin *et al.*, 1993) are commonly sharply peaked and roughly triangular. If the dambreak component of the flood hydrograph at the dam was similar, with a total time of 1 hour (3600 s), and if about 3–4 million m^3 of water discharged from the dam, then the peak flow rate at the dam must have been of the order of 2000–2500 m^3s^{-1}. The *average* outflow rate on this basis would have been about 1000 m^3s^{-1}.

Computer modelling reported by Hancox *et al.* (2000) suggested a potential peak flow rate of 3000 m^3s^{-1} at the dam, but the authors then suggested that this figure should be reduced because the breach depth was less than the height of the dam. This reduction appears to be unrealistic: due to the hypsometry of the lake, most of the water is released by the drawdown of only a small proportion of the total depth available. Thus the peak flow occurs early in the flood event, a deduction supported by empirical data (e.g. Plaza-Nieto and Zevallos, 1994; King *et al.*, 1989; Costa, 1991; Parkin *et al.*, 1993) and model studies (Ollett, 2000; Davies, 2001). The peak flow occurs before the breach has achieved anything like its full development, and it is therefore not likely to be affected by the final depth of the breach. Ollett (2000) showed that attenuation of dambreak flood waves in gorges is negligible, again suggesting that the peak flow at the gorge exit would have been of the order of 3000 m^3s^{-1}. Considering all these factors, a peak flow rate of the order of 3000 m^3s^{-1} at the gorge exit seems reasonable.

This, however, would indicate that the initial estimates of either flow velocity or cross-section (or both) at the gorge exit were in error. It seems very unlikely that the flow velocity at the gorge exit could have exceeded 5 ms^{-1} by the amount needed to yield the required discharge, even with a very steep bed slope, so attention must be focussed on the possible flow cross-section during the peak of the flow. Aerial photography (NZ Aerial Mapping Ltd., 1976, 1985; Air Logistics Ltd., 2001) shows that the river bed at the gorge exit in January 2001 was very substantially aggraded (of the order of at least ten metres) by comparison with its pre-event (1976/1985) level. Ground-level photographs taken by the writer demonstrate that the bed level at the gorge exit in January 2001 was slightly *lower* than in December 1999. A site visit the day after the dambreak showed that the river was still aggrading rapidly. Allowing for some residual aggradation between 1985 and 1999 (including from the small landslide dambreak flood in the Poerua in 1997), it is clear that many metres of aggradation occurred during and shortly after the 1999 dambreak flood. This deduction is supported by the personal recollection of the farmer (K. McKenzie, Poerua Valley, Westland, *pers. comm.* 2001). Since the peak flow in a dambreak flood occurs early in the outflow event, before a substantial sediment volume has been eroded from the dam, it must occur before much aggradation has occurred downstream. Thus the bed level at the gorge exit during the 1999 event when the peak flow occurred could indeed have been much lower than originally estimated, and the flow cross-sectional area and thus peak flow rate much greater.

It is clear that the original peak flow estimate of less than 1000 m^3s^{-1} at the gorge exit was too low. The actual peak flow must have been significantly greater than this, probably in the region of 3000 m^3s^{-1}. This is also the order of magnitude indicated by the application of the Costa and Schuster (1988) methods. The lack of widespread damage farther down the valley can be attributed to the very rapid attenuation of the high but very short (i.e. low volume) flood peak, as the river spread out across its wide floodplain following its exit from the gorge.

Return period

Table 1 indicates that the frequency of a landslide of about 1 km^2 surface area, such as that from Mt Adams in 1999, is about 6×10^{-5} $km^{-2}a^{-1}$. Since the area from which a landslide can originate to block the Poerua gorge is about 25 km^2, the annual probability of the 1999 Mt Adams landslide was about 1.5×10^{-3}, or once every 600–700 years or so. This relatively low frequency corresponds with the magnitude of the post-dambreak aggradation, which had by June 2001 overtopped 4–6 m high terraces about 1 km downstream of the present gorge exit, indicating that the sediment volume involved in the 1999 event is substantially larger than that from the earlier event that formed the terraces. This previous event was probably the result of a landslide-dambreak, and not of a flood from a severe rainstorm, as the terrace sediments are very angular. Soil profiles in the Poerua valley also suggest that dambreak floods occur periodically in this valley.

Landslide-dambreak floods in the Callery River – computer modelling

Ollett (2000) used numerical modelling, based on aerial photographs and 1:50,000 contour maps, to identify five potential landslide sites in the Callery

River gorge (Figure 1) and to calculate dimension of potential landslides. He then generated hydrographs of the resulting dambreak floods down to the confluence with the Waiho River about 0.5 km upstream of the bridge over SH 6. He used MIKE 11DB and BREACH models to derive hydrographs at the dam site, and at the Waiho/Callery confluence, together with travel times. A key parameter is the time taken for the breach to form; Ollett (2000) developed his own routine for this, based on existing models and on the assumption that the breach will deepen to no more than 70% of the dam height, due to aggradation immediately downstream. The routines tested satisfactorily against published data.

The major conclusions of his study were that the peak flows at the Waiho/Callery confluence varied according to site and landslide volume. Peak flows ranged up to 14 000 m^3s^{-1} for an extreme case: a dam of the size indicated by a dam remnant identified by Davies and Scott (1997), close to the downstream end of the gorge. That dam would have been 180 m high, with a volume of 22×10^6 m^3, impounding a lake of 75×10^6 m^3. The maximum attenuation of flood peaks in passing down the gorge from all of the sites was only about 1%. Table 2 lists the dam characteristics, peak flows (Q_{max}, Q_{cs}) and warning times (T_{w1}, T_{w2}), based on the times for the lake to fill at mean annual flow and 5-year flood flow respectively plus flood wave travel times, for each of the sites modelled.

Table 2 – Characteristics of floods from landslide dam failures in Callery Gorge

Site	Dam Height (m)	Dam Volume ($m^3 \times 10^6$)	Lake Volume ($m^3 \times 10^6$)	Q_{max} (m^3s^{-1})	Q_{cs} (m^3s^{-1})	T_{w1} (hrs)	T_{w2} (hrs)
1	180	22.1	74.4	14000	11000	850	6
2	76	1.6	5.7	1800	2500	70	2
3	77	0.8	5.2	1500	2400	60	1.5
4	171	44.8	45.4	12000	9000	630	14
5	98	3.4	16.3	3800	4300	230	1

Notes: (i) T_{w1} is based on mean annual flow; T_{w2} is based on 5-year flood flow: the flows are calculated using the Regional Flood Frequency method of McKerchar and Pearson (1989). Data are order-of-magnitude only because the river is ungauged and regional flood parameters for this area are poorly defined.

(ii) Q_{max} is peak discharge from MIKE11DB

(iii) Q_{cs} is peak discharge estimated using method of Costa and Schuster (1988)

(iv) Dam site locations are shown on Figure 1.

The medium-sized dams, with volumes of the order of 1 million m^3, pose the greatest threat to life. The filling times for larger dams are long enough that sufficient warning can be given for evacuation, even with fairly high river flows, assuming the dam is detected as soon as it is emplaced, as would probably be the case for a daytime landslide. The dams at sites 2, 3 and 5 (Figure 1), however, if emplaced during a rainstorm (as is very likely to be the case), could deliver a significant flood to Franz Josef before any effective evacuation could be organised. So would a dam at site 1 if it occurred during a stormy night.

The peak discharges estimated using the method of Costa and Schuster (1988) are of the same order of magnitude as those calculated using the much more detailed modelling method. The differences in peak flows predicted by the two methods vary from +31% to –37%. At a sixth site very high up the Callery gorge only a very small lake would form because of the very steep valley gradient: it did not yield a significant peak flow using MIKE11DB modelling, but the method of Costa and Schuster (1988) predicted a peak flow of 570 m^3s^{-1}. It is concluded that for landslide dams with dam and lake volumes of the order of 1 million m^3 or greater, the Costa and Schuster (1988) method is adequate for a preliminary estimate in emergency situations. The peak flow in the 1999 Poerua dambreak event was probably of the same order as that calculated using the Costa and Schuster (1988) method.

Callery gorge dambreak flood hazards

Probability

Based on the data of Hovius *et al.* (1997), a landslide of about 1 million m^3 would have a scar surface area of about 0.075 km^2, and so has a probability of occurrence in Westland of about 10^{-3} $km^{-2}a^{-1}$. The area from which landslides can originate to block the Callery River is about 50 km^2, so the annual probability of an event of this size in the Callery is about 0.05. The probability of both a 1-million m^3 landslide and a simultaneous 5-year flood (annual exceedence probability = 0.2) is greater than the product of their individual probabilities, because a major rainstorm is very likely to be the cause of a major landslide. Some recent major aseismic landslides however have occurred in dry weather: Mt Cook (McSaveney *et al*, 1992), Mt Fletcher (McSaveney, 1993), and Mt Adams (Hancox *et al,* 2000), so major landslides need not be accompanied by heavy rain. It thus seems reasonable to reduce this joint probability to about 0.02–0.03 per annum.

In well over 100 years of history, only one dambreak flood has been officially reported from the Callery (Davies and Scott, 1997). This tends to suggest that the calculated annual probability of 0.05 is on the high side, and the precision of the data used to generate the figure is such that this might well be the case. There may well, however, have been events in the late 19th and early 20th centuries that were not reported, because the Waiho River was then so incised that any floods could pass through without damage to the sparse facilities in the area. It is also noteworthy that there were two landslide-dambreak floods in the Poerua within three years—in 1996 and 1999; clearly landslides are not uniformly distributed in time.

If the coefficient of 0.05 used by Hovius *et al.* (1997) to relate landslide scar area to volume were 0.015, as it was for the 1999 Mt Adams landslide, then the annual probability of a 1 million m^3 landslide in the Callery Gorge would become 0.015 instead of 0.05. The calculated figure of 0.05 thus indicates a likely order of magnitude, but realistically might be as low as 0.01.

Following from the above, the annual probability of a rainfall-induced landslide in the Callery gorge causing a dambreak flood of about 3000 m^3s^{-1} (an event with a very short warning time) is conservatively assumed to be of the order of 0.01–0.02.

Probability of a dambreak flood from an earthquake-induced landslide

Davies and Scott (1997) estimated the annual probability of a major earthquake in the Callery catchment as 0.03. This figure was based on the work of Bull (1996) and Adams (1980), who indicated that large-scale movement on the Alpine Fault was probably overdue. Yetton *et al.* (1998) subsequently confirmed this surmise; Berryman (1998) used the data of Yetton *et al.* (1998) in a hazard assessment of the Franz Josef area to suggest that there was a 16% chance of a fault rupture occurring within 10 years, or an annual probability of 1.6%. It thus appears that Davies and Scott (1997) overestimated the current probability of a major earthquake in the Franz Josef area by a factor of about two, so their estimate of the annual probability of a flood from the breaching of a seismically-triggered landslide dam ($p(F) = 0.012$) should be halved. Adding the annual probability (0.006) of a dambreak flood from a seismically-triggered landslide to the probability from an aseismic landslide (0.01–0.02) increases the total annual probability to 0.016–0.026. However, it is unlikely that a dambreak flood from a seismically-triggered landslide would be unexpected—the earthquake itself would act as a warning, even if it were to occur during a severe rainstorm leading to rapid filling and failure of the landslide dam. In reality, then, it is questionable whether the seismic and aseismic probabilities should be additive if they are used to calculate risks to life. For the present, the seismic risk is (conservatively) *not* added to the aseismic risk, so the total annual risk remains at 0.01–0.02.

Flow rate

A 1-million m^3 landslide in the Callery would form a dam that, according to the independent methods of Ollett (2000) and of Costa and Schuster (1988), should yield peak flows of the order of 2000–3000 m^3s^{-1}. The larger 1999 dam in the Poerua (which has a much lower probability of occurrence) also yielded this order of peak flow. The lake volume for a dam of a given height in the Callery is much greater than that of a corresponding dam in the Poerua, because the gradient of the Poerua valley is steeper: 8.3% at the lake site (Hancox *et al.*, 2000) compared to an average of 2.5% in the Callery.

Damage

The effects of a dambreak flood from a 1-million m^3 landslide-dam in the Callery should be similar to those from the 1999 dambreak flood from the Poerua dam, because both floods have similar peak discharges. In addition, the geological and hydrological characteristics of the Callery and Poerua gorges are similar, as are the catchment areas and the gross topography downstream of the gorge exits (Figures 1, 3). The damage caused by the Poerua flood about 2 km downstream of the gorge exit (Figure 4) would therefore be similar to that expected in the corresponding location in the Waiho—this would be at about the position of Canavan's Knob or the Douglas Wing of the Scenic Circle Hotel (Figure 1). The accommodation facilities adjacent to the SH 6 bridge, approximately 1.2 km closer to the Callery gorge exit, would therefore be exposed to potentially greater damage. They are closer to the gorge exit, with less opportunity for the flood to attenuate, and dambreak flood flows from the Callery would be added to any concurrent flood flows of the Waiho River.

There is thus good reason to expect that a 1 million m^3 dam in the Callery could cause much greater damage in the vicinity of the SH 6 bridge across the Waiho than the 1999 flood in the Poerua did to the forest remnant illustrated in Figure 4. It is very unlikely that either the SH 6 bridge over the Waiho or the nearby accommodation facilities would survive such a flood, which would be carrying with it a large volume of tree trunks and boulders.

Acceptable risk

The highway bridge and adjacent accommodation at Franz Josef are at serious risk of destruction with little warning from landslide-dambreak floods in the Callery River; and the annual probability of this event is of the order of $1\text{–}2 \times 10^{-2}$. There are commonly of the order of 100 people occupying the accommodation any night during the spring, summer, and autumn periods. World-wide, the acceptable annual risk levels for loss of life due to landslides (Finlay and Fell, 1997) range between 10^{-5} and 10^{-7}, *three to five orders of magnitude less than the calculated probability at Franz Josef.* Acceptable risks for failures of constructed dams causing substantial loss of life (100 lives) are in the same range (10^{-5}–10^{-6}; Gillon, 2000), again some orders of magnitude smaller than the calculated risk levels at Franz Josef. The acceptable risk levels are so small by comparison with the calculated risk of 0.01–0.02 at Franz Josef that any possible imprecision in the latter is clearly insignificant.

Other parts of Franz Josef township would also be threatened by a dambreak flood of 2000–3000 m^3s^{-1} in the Callery, but less severely than the facilities adjacent to the SH 6 bridge. Overtopping of stopbanks is likely, with consequent damage to the road, the heliport, the lower part of the township, the Douglas Wing of the Scenic Circle hotel and the oxidation ponds (Figure 1).

Mitigation

As warning times are very short (Table 2), it may not be possible to evacuate a large number of people to safety from the accommodation in the vicinity of the SH 6 bridge during a rainstorm in the time available. The threatened facilities would have to be physically protected by river control banks (stopbanks in local parlance). The height of banks required to contain a flow of the order of 3000 m^3s^{-1} at the approximately 100-m-wide SH 6 bridge would be of the order of 10 m, even if the river bed did not aggrade during the flood. However, landslide dambreak floods inevitably contain very high sediment concentrations and very large boulders, so rapid aggradation is certain to occur, as it did at Poerua. Reliable engineering protection against such an event would be prohibitively expensive.

In the case of a dambreak flood from an earthquake-triggered landslide, the likelihood of a simultaneous high flow rate is smaller and so warning times would probably be correspondingly longer. The risk of loss of life is thus substantially less than in the case of aseismic landslides and, although in principle is additive to the aseismic risk, to a first approximation does not add significantly to that risk.

The economic and social consequences of a disaster of this nature at Franz Josef could be catastrophic. SH 6 would be closed until the Waiho bridge could be replaced, and the cost of rebuilding facilities would be significant. Aggradation following the dambreak flood would threaten many of the facilities and river control works at Franz Josef. It would take the people and businesses in the area a long time to recover from substantial loss of life.

The full spectrum of this hazard to Franz Josef comprises not only that from a 1-million m^3 landslide, but also the hazards posed by greater (but less frequent) and smaller (and more frequent) landslides. The order of magnitude of the risks and effects is however so great that a more exhaustive analysis of the situation is unnecessary. The picture is very clear, as is the urgent need for mitigation measures.

Commentary

The above analysis is inevitably approximate, and many of the quantities are liable to significant, and in some places substantial, errors. However the approach taken has been a conservative one, that is, to use the part of the likely range of values that contribute to a lower assessment of risk. Thus the resulting figures are in the lower part of the likely range of risks. The calculated risks are nevertheless unacceptable by several orders of magnitude.

Conclusions

1. Tourist accommodation, the SH 6 bridge and other facilities at Franz Josef Glacier township, Westland, New Zealand are at risk of severe damage or destruction with little warning by dambreak floods from landslides into the Callery River. The annual probability of an event capable of causing such damage is about 0.01–0.02, which is several orders of magnitude greater than that considered acceptable worldwide.
2. This conclusion is based on a conservative analysis of recent data describing landslide frequency, simulations of dambreak floods, the recent landslide-dambreak flood in the Poerua River, and the probability of a major earthquake in the area.
3. The risk of loss of life attending a dambreak flood from an earthquake-triggered landslide is considerably less than that associated with a rainstorm-triggered landslide.
4. Urgent measures are needed to reduce these risks. However physical protection is prohibitively expensive, and warning times are too short to allow reliable evacuation.

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