The recognition and identification of debris flow hazards for proposed development sites in New Zealand

Elisabeth Bowman
Department of Civil and Natural Resources Engineering, University of Canterbury, NZ.

Tim Davies
Department of Geology, University of Canterbury, NZ

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ABSTRACT

This paper discusses how debris flows, a commonly occurring natural hazard in mountainous regions of New Zealand, may be recognised and identified from field and desk studies for sites that are being considered for development. Use is made of a particular case study from the Southern Alps in which the previous occurrence of debris flows was seen to be a possibility from an initial site inspection. The paper highlights that a combination of simple tools and techniques, from digging trial pits to examination of historical photos, may enable a reasonably detailed picture to be drawn regarding the potential debris flow hazard at a site, despite the relatively poor records that are available in many remote areas of New Zealand.

1 INTRODUCTION

Debris flows, gravity driven rapid mass movements of soil, rock and water, are one of the most frequent mass movement processes in areas where steep relief co-exists with rainfall and/or glacial runoff. Their high flow velocity, high degree of runout and potential for impact loading combined with uncertainty as to their temporal and spatial occurrence render them one of the most hazardous of landslide types (Legros, 2002).

In New Zealand, the potential for damage from debris flows has come into public consciousness since the disaster which destroyed or damaged 114 houses at Matata in the Bay of Plenty in May 2005 (McSaveney et al. 2005). Further, the increasing settlement of land that was once deemed “marginal”, particularly in regions of natural beauty, has resulted in a heightened awareness of the hazards posed by debris flows in recent years.

The recognition of potential debris flow hazards in the field is now an added responsibility for those geotechnical engineers and engineering geologists who undertake field surveys for potential development purposes (McSaveney & Davies, 2005). This paper discusses the tools and techniques that may be used to assist such surveys, with reference to a particular study undertaken by the authors in conjunction with consultants URS for a site that was being considered for a housing development. The study site in question was at a relatively isolated location in the Southern Alps. It will be referred to in the text as Lake X.

2 CASE STUDY

2.1 Walk-over

After an initial gathering of data about site at Lake X, a field walk-over survey was carried out. This revealed the site to be on the alluvial fan of Creek Y which fed into the lake (Figure 1 – site circled), and the site was therefore subject to normal alluvial fan behaviour of avulsion and aggradation, both of which would affect its western half. In addition, the site was within approximately 15m of lake level and approximately 15km from the Alpine fault trace. There was, however, no apparent surficial evidence of debris-flow activity (i.e. no particularly hummocky terrain or presence of boulders in the fields or boulders used in construction / ornamentation of nearby habitations), while the gradient of the fan was found to be approximately 1/15 or 4°, which is at the low end for typically reported debris flow fans (Jakob, 2005).

A small concrete road bridge gives access around the lake across Creek Y. There was no evidence of recent impacts on the bridge or high water levels from an examination of the bridge piers. Taking a path alongside the creek to its head, a small hydroelectric installation was found to feed water from a small waterfall at the creek head via a channel and penstock that crossed the creek approximately 200m above the bridge.

Given the local geomorphic setting – adjacent to a small, steep stream with a shallow gradient and with the possibility of substantial sediment inputs from high moraine cliffs in a high rainfall area close to the Alpine Fault, it was recommended that further work be carried out to establish the past behaviour of the creek, in order to quantify its avulsion and aggradation and (if present) the debris-flow hazard. This further work included a study of stereo air photos from the earliest that were available to the present, the digging of six approx. 2-3m deep trial pits within and around the survey area to examine the deposits and search for dateable material and a closer examination of the course and banks of Creek Y from immediately below the waterfall to the lake.

2.2 Aerial / stereogram survey

Stereo aerial photography for mapping purposes is available for most sites from the late 1930s or early 1940s. The frequency of coverage is variable, but in the best cases roughly decadal. Six stereo pairs were available for this site.

Even without the use of stereoscopy, from Figure 2 it is evident that there is much activity along the route of Creek Y. In particular it can be noted that the 1942 aerial photo shows the channel of Creek Y almost completely covered with vegetation from the base of the waterfall (indicated as “A” on 1942 photo) to about 200m above the bridge. Subdued grassed-over debris-flow lobes (arc-shaped ridges) lead from upstream of the bridge, across the site towards a small subfan at point “B” and the central part of the fan toe is in a position significantly inland of its 1964 position between the subfan at B and the active Creek Y subfan.

The 1964 aerial photo appears to show several recent slips in the upper catchment; a large slip in the true right moraine wall just downstream of the waterwall; a broad, unvegetated stream channel all the way down Creek Y; Creek Y widely braided downstream of the bridge, and occupying a wide area NW of the proposed development site; and advance of the fan toe between the two subfans, indicating substantial sediment deposition on the distal fan.

Aerial photos since 1964 show gradual revegetation of the channel, with minor erosion events (some photos are omitted from this paper).

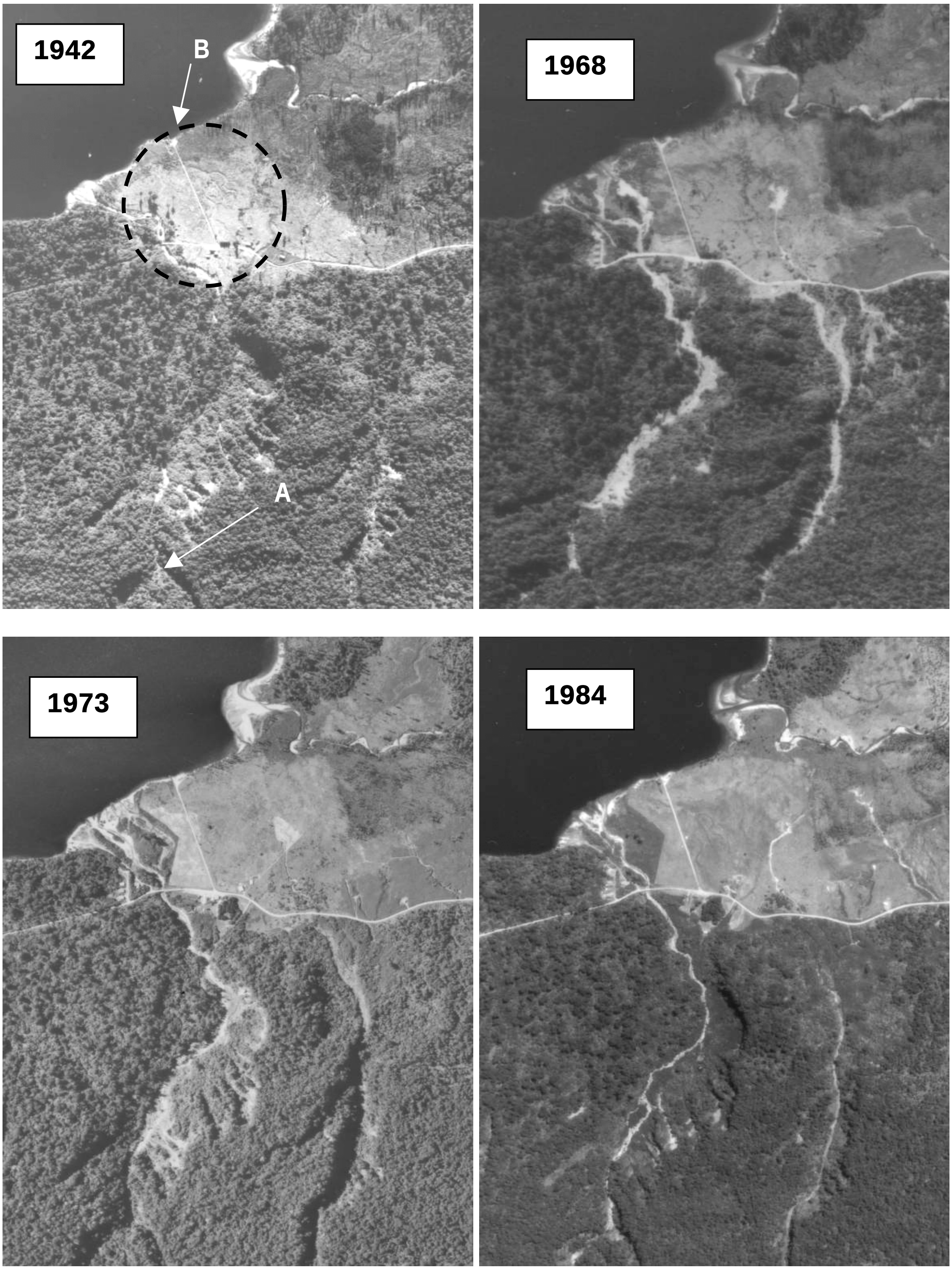
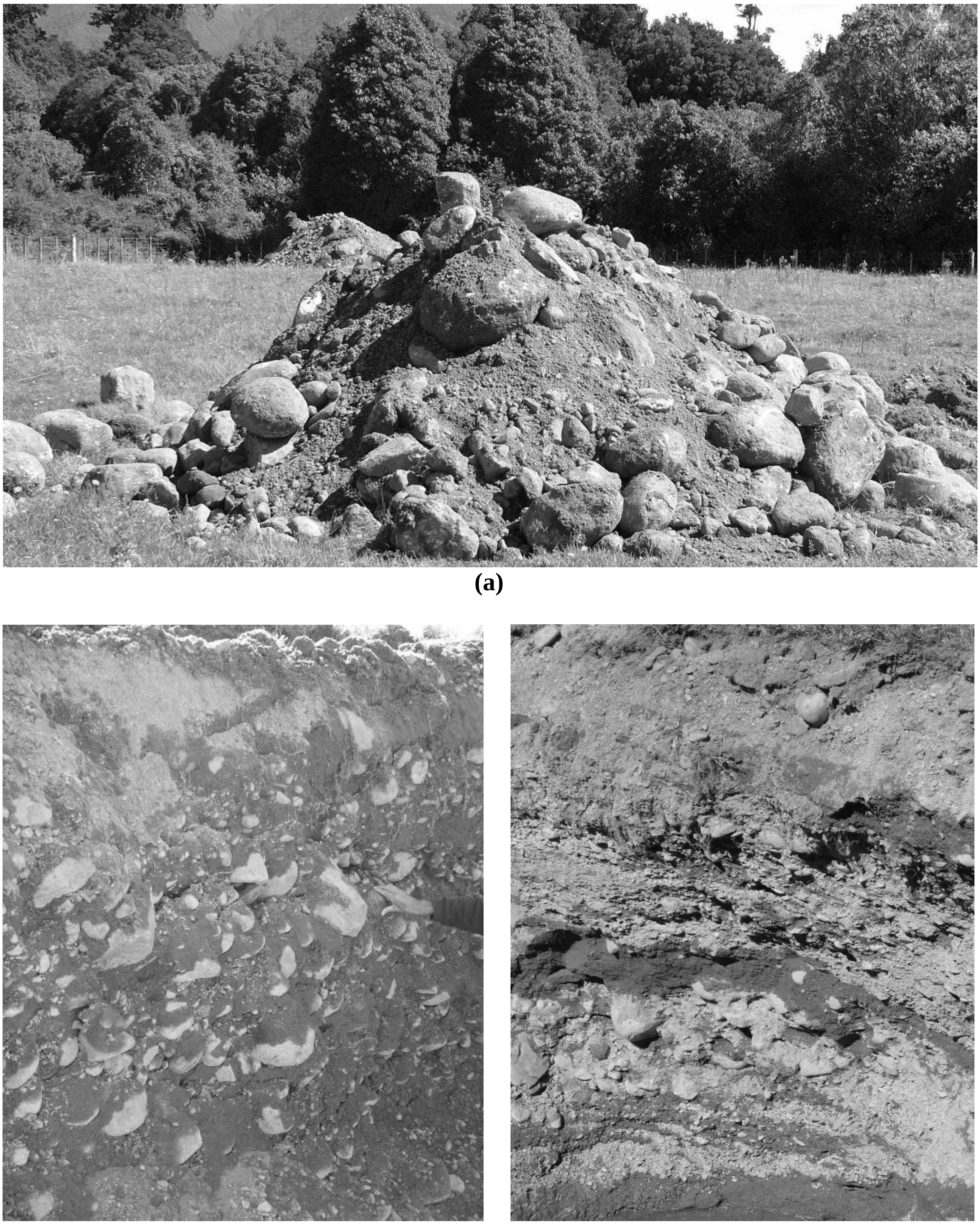


Figure 1: Selected aerial photos spanning approx. 40 years at site, showing erosion and revegetation of Creek Y and fan development into Lake X.

2.3 Trial pits

The six trial pits (TP) dug at the site showed large rounded boulders (up to 1 m diameter) in all but the pit about 50m from (closest to) the lakeshore. Boulders were apparent in the surface soils of locally high points. There was also evidence of some shallow buried soil in a pit midway down the proposed subdivision site. Organic material was taken from this pit at a depth of 1m for dating, although the results of tests were inconclusive. The presence of large clasts in the TPs clearly showed that debris flows had occurred at the site in the past and were likely interspersed with flood events, as indicated by the finer sediment bands. The debris flow hazard appeared to reduce with proximity to the lake.



(a) **(b)** **(c)**

Figure 2: (a) Debris removed from TP located furthest from lake; (b) Side of TP in (a) with alternating bands of coarse material and finer alluvial deposits; (c) TP closest to lake with large bands of alluvial material and little coarse sediment

2.4 Creek survey

A channel survey was undertaken by walking up Creek Y from the bridge, taking into consideration the safety of the activity with regard to the season and the weather that had been dry in the preceding several weeks. The channel of the creek showed clear evidence of debris flows several metres deep in a reach about 100-300m upstream of the bridge. Prominent levees of rounded boulders up to 1m diameter bounded the outside of bends, a common deposition zone of debris flows. The most downstream of these levees appeared to be about a decade old, based on the extent of revegetation.

The hydro penstock that crossed the Creek in this reach showed signs of repair. It also had apparently been replaced on the top of the levee of the debris flow that had damaged it. Before this damage, it was sited on a lower levee surface, as determined from location of the original supports and cables and from locating the original damaged pipe in the bush to the sides of the creek (Figure 3).

Figure 3: Debris flow levee with partially buried cable (RHS) & original pipe

2.5 Historic view

No historic memory existed of debris flows occurring in this catchment, although some minor flooding had been reported from long-term inhabitants. This lack of recognition of debris flows by the public is rather common, and is often not an accurate reflection of the situation (Jakob, 2005). Therefore, historic data were examined to try to date the debris flow event that partially destoyed the penstock pipe and to date its subsequent repair.

From the aerial photos, it is clear that a large debris flow event occurred between 1942 and 1968. Examination of landslide reports in the general vicinity suggested the year of 1958 to be a good candidate with usually high rainfall events reported throughout February to May (>150mm over 24 hours in nearby areas) resulting in multiple landslide and mudslide events. Further, the pipe repair (a spiral welded pipe abutting the original rivetted conduit at the stream cross-over point – Figure 4) could be dated to the late 1950s or early 1960s (Mullenger, 2006).

Figure 4: Spiral welded pipe abutting original riveted cast iron pipe

2.6 Recommendations

Recommendations were made that the development of this site could not be guaranteed to survive a 500-year event, since the evidence of recent debris-flow surges ~3m high in the creek 200m above the bridge appeared to reflect a non-post-seismic ~20-year event, most probably occurring in the late 1950s, along with smaller events thereafter. With the proximity of the site to the Alpine Fault, a post-seismic 500-year event would be expected to be much larger (>>5m) as a result of the recharge of sediment into the catchment that would occur during shaking.

3 CONCLUSIONS

This study shows that, while historic memory is relatively short in New Zealand, by combining a variety of approaches from desk study to field survey, a picture of debris flow risk can be developed for a given site, despite its possible remoteness from large settlements. Data on debris flow behaviour in the New Zealand context is currently rather sparse, which means that there is considerable reliance on experience derived from international cases. While this is clearly necessary, the use of “typical” or average behaviour should be made with caution, since, for example, the gradient of the debris flow fan in the case of Lake X was found to be rather shallow compared to the global average. The study highlights the importance of carrying out specific trial pits and detailed walk-over surveys of sites, since the evidence of prior debris flows may not be readily ascertained, particularly if fields have been cleared for agricultural use.

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