Landslide risk in Cairns

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Introduction

Until the Thredbo landslide tragedy in 1997 there had been little public recognition that landslides were a significant threat in Australia. Where landslides occur, their physical impact is typically confined to a few properties or a short length of road or railway, but the effect can be disturbing or disruptive. Insurance policies in Australia do not normally cover landslide, and this can cause anguish to property owners. One landslide blocking a road or railway can cause inconvenience and economic loss.

The quantitative landslide risk assessment (Michael-Leiba *et al*, 1999) and community risk assessment reported here were undertaken in the Cairns area (*Figure 1*) as part of an AGSO *Cities Project* multi-hazard risk assessment (Granger *et al*, 1999). The *Cities Project* undertakes risk assessments aimed at reducing the risks posed by a range of geohazards to Australian urban communities. The objective of the landslide study is to provide information to the Cairns City Council on hazards, community vulnerability and risks for planning and emergency management purposes.

Cairns landslides

A landslide is the movement of a mass of rock, debris or earth down a slope. The most common trigger for landslides is an episode of intense rainfall. The rainfall threshold values for slope failure are in the range 8–20 mm over one hour, or 50–120 mm over a day, depending on geology and slope conditions. In Cairns, rainfall intensities of such magnitude have an average recurrence interval (ARI) of considerably less than one year, and landslides are not rare events.

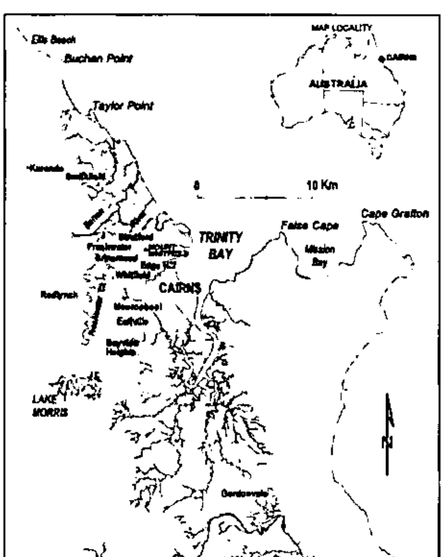

Figure 1: Locality map

The landscape around Cairns is dominated by a series of escarpments that are developing by scarp retreat. Weathering, erosion and removal of debris cause scarp retreat from the slope by two main processes (Michael-Leiba *et al*, 1999):

- on steeper bedrock slopes, and bedrock slopes masked with a relatively thin mantle of broken rock and finer material, weathering and erosion leads to landslides (rock falls, rock slides, debris slides, and small debris flows confined to the slope). By this process rock and soil moves down slope under the influence of tropical rainstorms and gravity
- during the more extreme rainfall events, the combined effect of multiple landslides in the upper parts of gully catchments, and the remobilisation of accumulated debris in the major gully systems, periodically results in large debris flows. These can extend onto the depositional plains at the base of the bedrock slopes.

Debris flows are a type of landslide triggered by the action of torrential rain on loose material on a mountainside or escarpment. The boulders and finer material, mixed with water, flow down the slope as a torrent. The coarser material (the proximal part of the debris flow) is deposited near the base of the slope, while the finer material (the distal part of the debris flow) travels further as a flash flood across the floodplain. Debris flows can be highly destructive. One definite, and two probable, large debris flow events are known to have occurred in the Cairns region since European settlement.

On 12 January 1951, a deluge of about 700 mm of rain in just under five hours triggered debris flows that affected 10 km of the Captain Cook Highway behind Ellis Beach. Huge quantities of debris were swept from the mountainside onto the road and over the precipice into the sea. Boulders up to three metres long were hurled into the Pacific 'like marbles'. Large slabs of bitumen were tilted up from the road and landslide debris was piled up as high as three metres. All culverts and inverts in this area were either damaged considerably or washed away entirely. The highway was not expected to carry normal traffic for at least two weeks (*Cairns Post*, 15 January 1951).

Probable debris flow events happened in 1878 and 1911 on the eastern side of Trinity Inlet. Deposits from numerous debris flows have been identified in this area. On 8 March 1878, a 'flood' followed by a severe cyclone triggered many landslides across the Inlet. They could be heard distinctly in Cairns (Jones, 1976). On 1 April 1911, a big landslide occurred in the Nisbet Range, also across the Inlet from Cairns. The scar could be seen in photos for several years afterwards (A. Broughton, Cairns Historical Society, personal communication, 1997). This landslide brought away trees, rocks and everything else from a considerable distance up the mountain side (*Cairns Post*, 3 April 1911).

Landslides on hill slopes periodically block roads, particularly Lake Morris Road and Kuranda Range Road. The Cairns-Kuranda railway has an even more spectacular history of dislocation by landslides. The most disruptive incident started on 15 December 1910, when a landslide at the Kuranda end of No. 10 tunnel partly closed the tunnel for more than two months. Instances of landsliding have been recorded in the established suburbs, either on cuts behind houses or road cuts or fills. Two houses have been destroyed and several building blocks written off as a result.

In 1927 and again in 1984 or 1985, boulders smashed the water main at the No. 1 and No. 3 crossings respectively of Freshwater Creek. During the latter incident, the water supply pipeline slipped with a mudflow which took out the anchor blocks (Cairns City Council, 1927 and D. Gallop, Cairns City Council, personal communication, 1997).

On 31 May 1900, the landslide that caused the fourth largest number of Australian landslide fatalities happened in Cairns. Five men were killed and one buried alive for ninety minutes when an 8 m deep tramway cutting they were constructing in an alluvial river terrace at Riverstone, for access to the sugar mill at

Gordonvale, caved in spontaneously. The location was 3 km WNW of Walsh's Pyramid.

Quantitative landslide risk assessment

A GIS-based quantitative landslide risk assessment was carried out in the Cairns area (Michael-Leiba *et al*, 1999) to provide information to the Cairns City Council on landslide hazard, community vulnerability and risks for planning and emergency management purposes. This is summarised below.

Magnitude recurrence relations were tentatively established for the two main slope processes: landslides on developed hill slopes; and large debris flows extending out from the gully systems on to the plains. Rare landslides in alluvial terraces, such as the fatal 1900 Riverstone cave-in, were not included. From the recurrence relations, landslide hazard (H) was estimated as the annual probability of a point being impacted by a landslide.

GIS polygons have been used to delineate and characterise the areas that could be affected by landslides. Three main categories were chosen:

- the hill slopes
- areas that could be affected by the proximal portions of debris flows
- areas which could be affected by the distal portions of debris flows

The nature, number (E) and geographic distribution of the elements at risk were obtained by interrogating the GIS, and their vulnerabilities (V) to destruction by the two main landslide slope processes were assessed. From this information, specific risk (= HxV) maps were produced for: people living in houses and flats; for buildings (houses and flats, only); and for roads. The results are summarised in *Table 1*. The results for the hill slopes indicate what the risk would be *if* the slope were to be developed *without adequate mitigation measures being taken*. The risk would be expected to be considerably less on slopes developed with appropriate geotechnical investigation before, and good engineering practice during, development.

A risk map depicting the estimated annual probability of a total road blockage somewhere in a 10 km length of road parallel to the escarpment was also prepared. For the hill slopes, the estimated annual probability is 63% (an ARI of one to two years). For roads in potential proximal debris flow runout regions it is 1.0% (an ARI of 100 years), and in potential distal debris flow runout regions it is 0.4% (an ARI of 200 years).

Total risk (= HxVxE) was also estimated for people living in houses and flats; and for buildings (houses and flats, only). Maps, that quantitatively depict the total risks per km^2 per 100 years for residential people and buildings in each GIS polygon in the currently developed parts of Cairns, were also constructed. The greatest total risk for buildings (houses and flats) is on the hill slopes, where it is estimated that a total of 13 buildings throughout the map area could be destroyed in 100 years, *if no mitigation measures were taken*. The highest total risk for people living in houses and flats is in the proximal parts of debris flows. It is estimated that a total of 16 people in the map area could die over 100 years in these areas.

There are limitations to this study. Two of the most important are:

- the regional nature of this study. Mapping was at a reconnaissance level, only. For detailed site-specific assessments, the broad findings should be checked by geotechnical specialists
- the paucity of the data from which the landslide magnitude-recurrence relations were derived. As the error bars for the data points are, in some cases, more than two orders of magnitude, errors in the risk estimates may be large.

above: This landslide on Barron Gorge Road was triggered by rain brought by Tropical Cyclone Justin in March 1997.

Community risk from landslides

Building destruction

The total risk of destruction by suburb for all types of buildings is given in Table 2 for the ten suburbs with the greatest risk, in descending order of risk. These values do not compensate for the differing areas of the suburbs.

Note that with good engineering practice, such as adequate drainage and retaining walls, commonly used in developing the hill slopes in Cairns, the actual number of buildings destroyed per 100 years would be expected to be

Unit	Specific annual risk of death–resident people	Specific annual risk of building destruction	Specific annual risk of road destruction	Specific annual risk of road blockage
Hill slopes	0.0008% 1 in 100 000+	0.004% 1 in 20 000	0.005% 1 in 20 000	0.02% 1 in 6 000
Units susceptible to proximal debris flow	0.01% 1 in 9 000	0.01% 1 in 8 000	0.01% 1 in 8 000	0.01% 1 in 10 000+
Units susceptible to distal debris flow	0.0005% 1 in 200 000	0.001% 1 in 90 000	0.003% 1 in 30 000	0.007% 1 in 10 000+

Table 1: Specific annual risk of destruction of people living in houses and flats, of houses and flats, of roads, and of road blockage.

Suburb	Total risk	Suburb	Total risk
Redlynch	6	Brinsmead	1
Mooroobool	3	Smithfield	1
Bayview Heights	2	Stratford	1
Freshwater	2	Earlville	0.9
Whitfield	1	Edge Hill	0.8

Table 2: Total risk of destruction by landslide of all types of buildings—estimated number destroyed per suburb per 100 years, if no mitigation measures taken.

above: The raised, cleared land between the power poles is part of a debris flow fan built by debris flows from the mountains in the background.

above: This large boulder was part of a prehistoric debris flow in Redlynch, Cairns.

considerably less that that shown in the Table 2.

These are dormitory suburbs. The portions that are at greatest risk of landslide are in the Freshwater Valley, the lower slopes of the coastal escarpment, or near the base of Mount Whitfield. Usually not the entire suburb is at risk from landslide. The parts at risk are either on hill slopes, or near the base of slopes in potential runout zones for large debris flows.

As the population of Cairns increases, more development will take place in such areas and the landslide risk may increase unless adequate mitigation measures are put in place at the time of development.

However, most of the critical facilities, such as hospitals and emergency services, essential to community recovery after a disaster, are in the older, flatter parts of Cairns that are not susceptible to landslide.

Isolation

Because the Captain Cook Highway, Kuranda Range Road and Cairns-Kuranda Railway, which provide access to Cairns from the north and the Tableland, each pass through country with steep slopes, they may be blocked by landslides in the event of prolonged or intense precipitation. Outside the study area, the Bruce Highway and particularly the Gillies Highway (which links Gordonvale to the Atherton Tableland), may also be blocked by landslide. This makes the Cairns community particularly vulnerable to isolation by land.

Utilities

Flash flooding in Freshwater Creek, or debris flows, have the potential to disrupt the Cairns water supply by blocking intake or destroying sections of the pipeline. There have been two instances this century of the Cairns water main, which crosses Freshwater Creek, being broken by debris flows or flash floods.

Conclusions

In Cairns, landslide has been, and remains, a significant risk. Property damage has occurred on hill slopes, and landslides have repeatedly affected road and rail traffic.

Blockage of roads and railways providing access to Cairns can cause isolation of the community. Flash flooding in Freshwater Creek, or debris flows, have the potential to disrupt the Cairns water supply by blocking intake or destroying sections of the pipeline.

As development extends further on to the hill slopes and the potential runout areas for large debris flows, landslide risk may increase unless adequate mitigation measures are taken. However, critical facilities, such as emergency services and hospitals, essential to the recovery of the community after a disaster, are not in landslide-prone areas.

References

Cairns City Council, 1927, Minutes of a special meeting, 15 February 1927 (unpublished).

Granger K., Jones T., Leiba M. and Scott G., 1999, *Community risk in Cairns. A multi-hazard risk assessment,* Cities Project, Australian Geological Survey Organisation.

Jones D., 1976, *Trinity Phoenix. A history of Cairns,* Cairns, Queensland.

Michael-Leiba M., Baynes F. and Scott G., 1999, 'Quantitative landslide risk assessment of Cairns', *AGSO Record,* 1999/36.

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