Impacts of Climate Change on Urban Infrastructure & the Built Environment

A Toolbox

Tool 2.3.1: General information on the causes of rainfall-induced landslides

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1. Introduction

Landslides cause millions of dollars of damage every year in New Zealand and have been responsible for at least 412 deaths since 1840. EQC Insurance claims for landslide damage to New Zealand's domestic housing stock alone account for more than NZ$16 million per annum in direct costs over the period 2001-2008. This figure does not include repair of landslide damage to commercial buildings, transport and utility networks and the loss of productive agricultural land. Indirect costs increase these losses substantially.

Landslides can be divided into four groups for the purposes of determining the probability of a landslide occurring at a site. The four groups are rainfall-induced landslides, earthquake-induced landslides, endogenetic landslides (no external trigger) and pre-existing landslides. Landslides may have a wide range of underlying causes but there are two dominant triggers of movement – rainfall and earthquakes. About 90% of all landslides are triggered by rainfall and different rainfall patterns produce different types of landslides.

1.1 Purpose of this Tool

This Tool is a general introduction to the causes of rainfall-induced landslides. More information on modelling rainfall-induced landslides and the potential effects of climate change on landslides is presented in [Tool 2.3.3].

2. Why do Landslides Occur?

Using the principles of physics, a slope can be seen as experiencing two sets of stresses, one set holding the slope together (shear strength) and the other (shear stress) acting to move material down-slope. Shear strength is produced by friction on potential failure surfaces (generated by the weight of overlying material), slope angle (the lower the stronger), and cohesion (resulting from cement or attractive forces between particles). Shear stress is produced by the weight of material involved, and slope angle. When a landslide occurs, the balance of shear strength to shear stress (referred to as the factor-of-safety) is altered, either by a decrease of shear strength or an increase of shear stress. When shear strength becomes less than shear stress the hill-slope fails.

Hill-slopes are stable most of the time. Some inherent conditions (preconditions) of a slope (e.g. its steepness, rock type and structure) can make a slope susceptible to failure (predisposing factors). These conditions can exist for hundreds or thousands of years without an actual landslide occurring. However, slopes can be gradually weakened by a range of processes (preparatory factors) such as deforestation, weathering, and undercutting by river flow, waves, or human activity (as at Abbotsford, Dunedin).

Whilst these preparatory factors may lead to failure, in most instances, a final trigger can be recognised as setting-off the landslide. The most common landslide trigger is storm rainfall. When this infiltrates into the ground faster than it can drain, water builds up in the slope. As all the pore spaces in the slope become filled with water, a positive pore water pressure develops that produces a hydraulic uplift force that reduces the stabilising effect from the weight of overlying material. In other situations, the stabilising effect of weight can also be momentarily reduced by ground shaking, making earthquakes the second most common form of landslide triggering in New Zealand.

3. Rainfall patterns

Three rainfall patterns triggering different types of landslide movement are:

- The storm cell: short duration (less than 6 hours), high intensity (e.g. 1 mm/min for at least one hour), often highly localised cells (1-10 km^2) within a larger storm. This type of rainfall is often associated with thunderstorms and produces very fast debris flows and flash flooding.

- The storm system (e.g. typhoon): moderate duration (commonly 6-72 hours) moderate intensity (cumulative rainfall totals in the range 200-600 mm) and often regional in extent. This type of rainfall produces many shallow landslides and a few large landslides. Typically these landslides fail rapidly.

- The wet season: longer periods (1-6 months) of wetter than average weather, no one event dominates but the cumulative rainfall totals are well in excess of the mean rainfall for that time period. This type of rainfall is often associated with the reactivation of pre-existing large landslides as well as a few rapid shallow landslides.

3.1 A storm cell example: The Matata debris flows

On 18 May 2005 between 4.00pm and 6.00pm a localised storm cell stalled over two stream catchments covering an area of about 10 km^2 in the hills behind the village of Matata in the Bay of Plenty (McSavaney *et al.*, 2005). In the space of two hours over 125 mm of rain fell in the stream catchments. This rainfall resulted in a series of debris flow pulses down the streams. Where the streams exited the hills onto the edge of the

Rangitaiki Plains the debris flows deposited their load of sediment and vegetation onto debris flow fans (Figure 3.1).

The village of Matata was built on the debris flow fans to avoid flooding on the low-lying Rangitaiki Plains and to provide views to the sea, across the low dune system on the coastline. The debris that impacted Matata destroyed 27 homes and damaged a further 87 properties as well as closing the main highway and rail link for many days (Figure 3.1). There is both historical and geomorphic evidence of previous debris flows at the site (McSavaney *et al.*, 2005).

Figure 3.1: Debris deposition on the debris flow fan of the Awatarariki Stream. (Photo: G.T. Hancox)

3.2 Manawatu Floods: the weather system

Over three days between the 14 and 17 February 2004 heavy and prolonged rainfall caused widespread landsliding over 16,000 km^2 of the southern North Island of New Zealand, extending across the Wanganui–Manawatu area to southern Hawke's Bay, Wairarapa, and Wellington (Hancox and Wright, 2005). Tens of thousands of small, shallow soil slides and flows occurred (Figure 3.2).

Mostly these landslides occurred on steep slopes in pasture (Figure 3.2). Slopes covered with woody vegetation were less affected by landslides with only a few isolated landslides observed in forested areas (Figure 3.2). However, recently-milled areas with tree stumps still in the ground were landslide-damaged. State Highway 3 through the Manawatu Gorge was closed for 3 months by several large landslides. Some slips came close to houses and buildings causing minor damage (Hancox and Wright, 2005).

Figure 3.2: Landslides on slopes in pasture from the February 2004 storm in the Manawatu, New Zealand. Note the lack of landslides in areas under woody vegetation. (Photo: G.T. Hancox)

3.3 Taihape Landslide: the wet climate

Prolonged wet periods (months to decades) can result in the reactivation of large, pre-existing landslides. An example from the soft rock terrain of New Zealand is the Taihape landslide. The Taihape landslide first moved between 1,800 and 11,000 years ago. It is located on the west side of Taihape town-ship and covers 45 hectares with 209 houses and a school (http://www.geonet.org.nz/resources/landslide/taihape/about-the-landslide.html).

Figure 3.3: Landslide deformation causing extension and cracking of concrete slabs within the Taihape landslide complex. These cracks have developed as the result of the cumulative effects of many rainstorms. (Photo: C. Massey)

Historical information from ground surveys (dating back to 1985) indicate that landslide movement is triggered by rainfall, and to a lesser extent erosion caused by Otaihape Valley Stream, located along the toe of the landslide. Periods of prolonged rainfall cause groundwater levels to rise, which lead to a reduction in strength of the materials forming the landslide slip plane (clay layer). It is this reduction in strength that leads to movement of the landslide. Movement in response to each rainfall event is often less than a few millimetres, with the cumulative movement from many rainfall events causing damage (Figure 3.3). Movement of the landslide can therefore be linked to rainfall events.

4. Identifying the hazard

Understanding the landslide processes that occur in response to different types of rainfall can help identify susceptible areas and lead to appropriate mitigation strategies being developed.

Debris flow sites can be identified using geomorphic criteria that characterise the source area, the flow path (steepness) and the depositional area. Again by looking for places in the landscape that meet these conditions the debris hazard can be identified and its impacts mitigated.

Research at GNS Science has found that pre-existing large block landslides are often associated with soft rocks. Preferentially searching for and mapping large landslides in soft rock terrain allows areas susceptible to movement during extended wet periods to be identified.

[Tool 2.3.3] focuses on the more widespread landslides triggered by a weather system over two or three days. The landslides often have a characteristic size distribution (based on area). This allows the total number of landslides that are likely to occur and where they will initiate to be determined in relation to the predicted or actual rainfall. We know roughly what size the biggest landslides will be and how many are likely to occur but we cannot yet predict exactly where they will occur.

5. References

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