Ongoing movement of the West Taihape Landslip, New Zealand

Kate Williams
Doug Johnson
Nick Rogers
Tonkin and Taylor Limited, PO Box 5271, Auckland, New Zealand

Keywords: landslip, field investigation, shear surface, monitoring, drainage works

ABSTRACT

The West Taihape Landslip is an ancient landslip located on the western edge of Taihape Township, Rangitikei District, encompassing more than 200 residential properties and a school. The landslip covers an area of approximately 45 hectares. The landslip was first recognised in 1971 when the toe of the wider landslip became active and has been infrequently monitored since the mid 1980's. In 2005, ongoing routine slope monitoring of the landslip detected more widespread displacements at a number of locations within the toe region. Monitoring installed in 2005 has confirmed the 1971 toe slope failure has reactivated and is presently creeping, albeit slowly, primarily in response to rainfall. The current movements are affecting a school and at least 15 residential properties. Monitoring of the wider slide area over the past 12 months indicates the larger landslip may be at a critical point where ongoing widespread toe movement may result in reactivation of the wider landslip.

This paper presents the results of the field investigation, ongoing monitoring, causes of the landslip movement and provides comment on the effectiveness of preliminary remedial drainage works.

1 INTRODUCTION

The West Taihape Landslip is situated within the western urban area in the township of Taihape, located in the Central North Island, New Zealand (Figure 1). The landslip is estimated to have occurred between 1,800 and 11,000 years ago (Thompson, 1982) and includes an area of land that extends from the O'Taihape Stream in the south (the toe of the landslip) approximately 750 m towards the north where the head scarp is located in the vicinity of Ruru Road. The landslip spans across approximately 750 m east to west and encompasses more than 200 residential properties and a school (St Joseph's Primary School). Taihape Rural Hospital is located close to the eastern margin of the landslip.

The purpose of this paper is to provide an overview of the West Taihape Landslip.

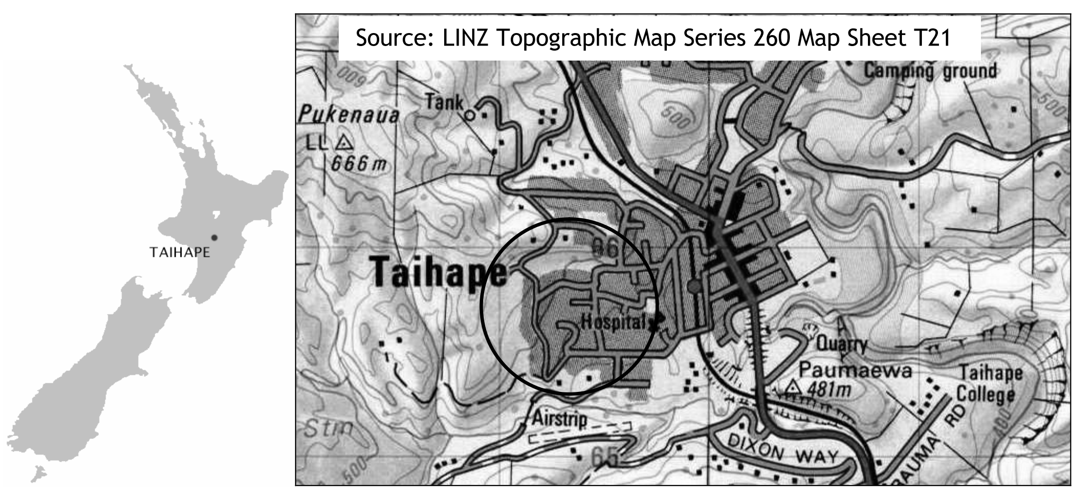

Figure 1: West Taihape Landslip (black circle denotes site location)

2 BACKGROUND

The landslip was first recognised in 1971 (Brickell Moss Rankine and Hill, 1971) when significant instability in the toe of the slope became active, south of Kaka Road, resulting in claims to the then Earthquake and War Damages Commission (EWDC). Although the reports on the landslip identified that the 1971 movement was part of the wider landslip area it was not until 1982 that the area was mapped (Thompson, 1982) and the full scale of the landslip was identified (Johnson, 1983). A number of studies and investigations followed and the landslip was monitored intermittently from the mid 1980's including three inclinometers, one multi level piezometer and a survey network over the toe slope area. Movements recorded between 1984 and 2004 have averaged up to 15 mm per year (Landcare Research, 2005) in the toe area.

In February 2004, during a flood event, erosion of the O'Taihape Stream bank at the toe of the landslip caused a small slope failure resulting in the loss of O'Taihape Valley Road and regression into the playing fields of St Joseph's School. Following this event, in May 2005 ongoing routine slope monitoring (Landcare Research, 2005) of the landslip detected more widespread displacements at a number of locations about the toe of the landslip in the same area as the 1971 movements. Their report concluded that movements up to 74 mm per year had occurred around the St Joseph's School area. Although there have been no recorded movements measured over the wider landslip area, the magnitude and location of the deformations nearby the School raised concerns in regard to the wider landslip slope stability.

As a result of the increased levels of recorded movement Rangitikei District Council (RDC) requested government assistance through the Earthquake Commission (EQC), formerly EWDC. EQC is New Zealand's primary provider of natural disaster insurance to residential property owners. Tonkin and Taylor Ltd (T&T) were engaged by EQC in July 2005 to proceed with an initial site assessment followed by site investigations and assessment of the active toe area.

3 GEOLOGICAL SETTING

The geology of the study area was most recently mapped by Thompson (1982). This map indicates the site is predominantly underlain by the upper Taihape Sandstone unit with the lower Taihape Siltstone unit below all forming part of the Utiku Sandstone Group. The Taihape Sandstone contains concretions of calcareous sandstone which are gravel to boulder size and form in layers that correspond with bedding. Bedding generally dips throughout the region at approximately 5° to 8° towards the south-southeast. Along the northern flanks of the O'Taihape Stream a covering of River Terrace Gravels is present overlying the Taihape Sandstone.

Faulting in the region is significant with tectonically active faults to the west and east of Taihape. The Taihape Fault is located along the western margin of the landslip and the Rangitikei Fault is situated approximately 1.5 km to the south east of Taihape Township. These faults have been classified as 'active faults' (GNS Science, 2007) and are generally trending NNE – SSW, which is common throughout the region. Four earthquakes of Richter magnitude between 3.2 and 5.3 have been recorded between December 2005 and January 2007 in the Taihape area.

4 FIELD INVESTIGATION

Field investigations were carried out under T&T supervision and were initially scoped to specifically address the 2005 active toe slope movements (Tonkin & Taylor Ltd, 2005), which were subject to insurance claims at that time. In 2006 further investigations were undertaken across the wider Taihape Landslip (Tonkin & Taylor Ltd, 2007) to extend the monitoring area in collaboration with the GeoNet Research Project conducted by GNS Science (Massey et al., 2007). Site investigation works consisted of five fully cored machine boreholes drilled to a maximum depth of 63 m along with five wash drilled boreholes for multilevel piezometer installation drilled to a maximum depth of 38 m. Slope Indicator 70 mm APS plastic inclinometer casings were installed to the base of the fully cored drillholes BH1 – BH5. Locations of the borehole and piezometer (BH1A – BH5A) positions are shown in Figure 2.

As a part of the field investigation, geomorphological mapping was undertaken in detail over the toe slope area of the landslip (1971 failure area) and more generally over the wider area (Figure 2).

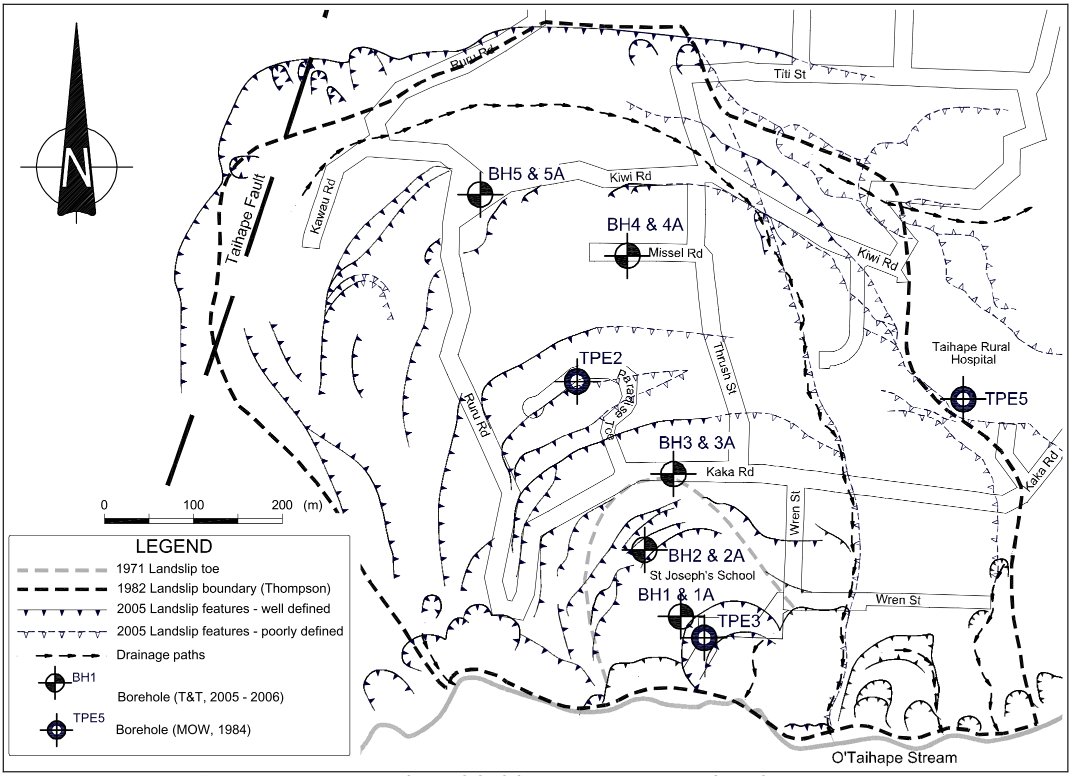

Figure 2: Location plan of field investigations and preliminary mapping

4.1 Site geology

The site specific investigation generally confirms the geology as mapped. Landslip Debris (disturbed Taihape Sandstone) was encountered in all of the boreholes drilled. This unit is composed of medium dense to extremely weak, dark grey, silty fine sand/ silty sandstone generally of a disturbed nature with some intact blocks of cemented sandstone. Four boreholes encountered shear surfaces within and at the base of the disturbed material. Basal shear surfaces in BH1 – BH5 are described below.

- BH1 at 22.7 m – highly fractured zone of sheared material (crush zone, 150mm thick) with some clay gouge directly overlying bedrock at 22.85 m.
- BH2 at 23.0 m to 25.5 m – highly disturbed sheared zone of silty sand/ sandstone with a 10 mm thick layer of clay bands (2-3 mm thick) at 24.5 m.
- BH3 at 24.15 m – sharp sheared contact between disturbed landslip debris and bedrock. Shear surface encountered consisted of a clay band (2-3 mm thick) within a crushed zone exhibiting polished slickensided surfaces.
- BH4 at 33.25 m - sharp sheared contact between disturbed landslip debris and bedrock. Shear surface encountered consisted of a wavy clay gouge contact (up to 20 mm thick).
- BH5 showed no obvious shear surface, however RQD and rock mass strength improved from 36 m where it is considered the disturbed Landslip Debris is in contact with the underlying Taihape Sandstone.

4.2 Depth of the landslip

From the subsurface investigations undertaken across the landslip it has been identified that the depth of the landslip failure surface ranges from between 22 m below ground level in the toe of the landslip (St Josephs School) to 36 m below ground level near the back scarp graben of the landslip (Kiwi Road). The landslip failure surface when modelled is found to be a relatively uniform planar surface which is subparallel to the poorly developed bedding, dipping approximately 5-8° downslope with the movement direction of the landslip towards the south-southeast (approximately 140°-165°). This is consistent with the regional direction of dip for the bedding and movement direction (140°) recorded by Thompson (1982).

5 MONITORING

Monitoring of the inclinometers and piezometers has been ongoing since September 2005 (BH1, BH2 & BH3) and June 2006 (BH4 & BH5). RDC record piezometer levels and collects rainfall data from the Taihape weather station for the National Institute of Water and Atmospheric Research.

5.1 Piezometer groundwater monitoring

Initially groundwater levels were recorded by hand approximately once daily. The groundwater levels were generally recorded at less than 1 m below ground surface, with the lowest groundwater levels recorded up to 2 m below ground. Since July 2006, monitoring of selected piezometer installations has been undertaken by the GeoNet Research Project (Massey et al., 2007) using vibrating wire piezometers and data loggers to allow near-real time monitoring. Monitoring has shown that groundwater levels respond significantly to rainfall, with some levels recorded, from screens across the failure surface, above or at the ground surface.

5.2 Inclinometer monitoring

Monitoring of the inclinometers has been generally undertaken on a two weekly basis (Figure 3). Discrete movement (up to 8 mm) within BH1 and BH2 inclinometers was detected across the failure surfaces within the first month of installation. These movements occurred following periods of high intensity and/ or prolonged rainfall (up to 89 mm of rain recorded in a two week interval) and periods of elevated groundwater levels. In response to these movements, up to 0.5 mm/day, a network of preliminary horizontal drains were installed (see Section 7 below).

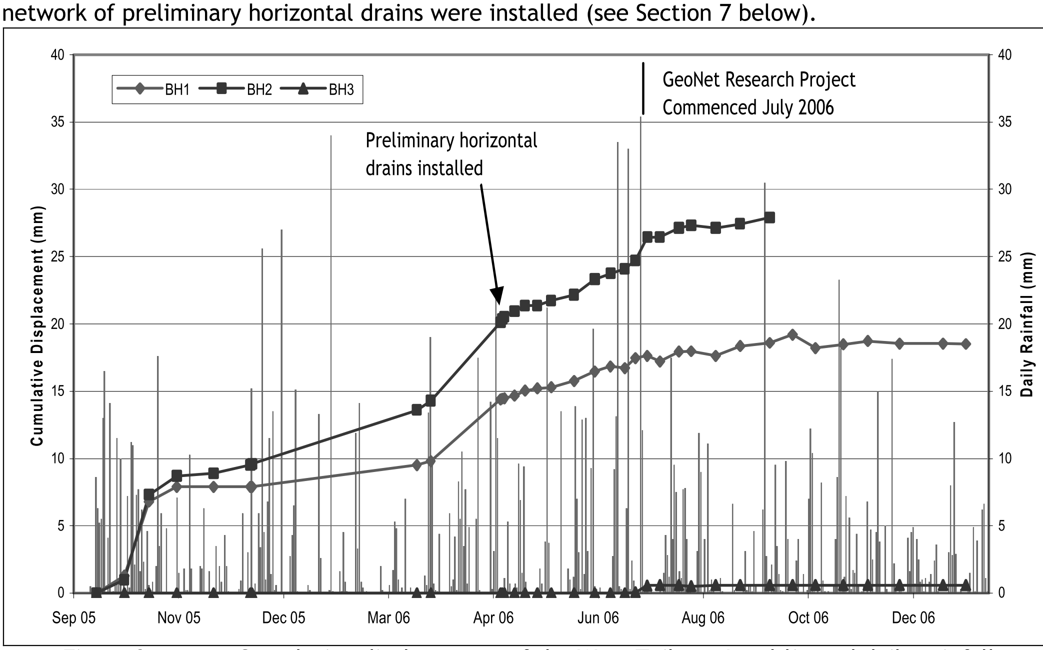

Figure 3: Cumulative displacement of the West Taihape Landslip and daily rainfall

Ongoing monitoring has recorded further discrete movements occurring across the failure surfaces at depth.

- BH1 recorded movement at 22.3 m below ground with up to 19 mm of cumulative displacement in a direction of approximately 160°. This movement has been ongoing since installation.
- BH2 recorded movement at 25.75 m below ground with up to 28 mm of cumulative displacement in a direction of approximately 142°. This movement has been ongoing since installation. Inclinometer monitoring of this installation ceased in early October 2006 due to the amount of shearing the tube had undergone.
- BH3 first observed movement was during the monitoring round in late July 2006. Minor movement (up to 0.6 mm) was recorded around 24 m below ground with a direction of approximately 161° and has remained static since.
- BH4 and BH5 inclinometers have indicated no detectable movement.

5.3 Surface monitoring

With the recent increased movements recorded new risks are now apparent with damage to structures and services about the edges of the reactivated slopes. Ground surface mapping and observations of damage clearly support this as many EQC insurance claims have been received within the last 12 months, with newly reported damage to dwellings and land on private property. This damage in some cases is the result of cumulative movements over a period of time, some with up to 40 years of movement (Figure 4).

Figure 4: Photographs of ongoing damage to land and structures

A near-real time monitoring network of survey prisms located across the landslip has also been established in July 2006 by the GeoNet Research Project (Massey et al., 2007) to monitor surface movements. Preliminary findings (Massey et al., 2007) suggest two types of movement may occur either a slow creep or periodic small surge events.

6 CAUSES OF MOVEMENT

The trigger for the original landslip (1,800 and 11,000 years ago) is not known. However, it is speculated to be earthquake induced. The trigger mechanisms for causing the recent slope movements are considered to be a combined effect of the following:

- Initial erosion and down cutting of the O'Taihape Stream post the February 2004 flood event.
- Elevated groundwater levels due to high intensity and/ or prolonged rainfall events, as set out in Section 5. There is a good correlation between rainfall events and slope movements.

However, small movements due to earthquake shaking, as a result of low magnitude earthquakes recorded in 2004 and 2005, cannot be discounted.

7 REMEDIAL DRAINAGE WORKS

Following the initial investigation and reporting (Tonkin and Taylor Ltd, 2005) it was recommended that drainage should be improved across the wider West Taihape Landslip in particular the toe slope area to reduce and control the groundwater levels. A preliminary trial of drainage measures restricted to the toe was undertaken to assess the practicalities of the drainage works and determine the extent of influence of dewatering.

A series of fanned horizontal bored drains were established during April 2006 along the southern reaches of the lower toe slope area. The works comprised 20 horizontal bored drains drilled up to a maximum of 108 m in length across five locations to target groundwater at the failure surface. Initial water flows from the drains were recorded at 45 cubic metres per day with flows now averaging 20 cubic metres per day. Daily groundwater monitoring has shown a response of groundwater levels in the lower toe slope to drainage works around the school (BH1A Piezometer). Background water levels in BH1 have reduced by up to 5 m for the deep piezometer installation. However, immediately following significant rainfall the vibrating wire piezometer data (Massey et al., 2007) indicates peaks in the groundwater levels are still being recorded with maximum levels similar to those recorded prior to the installation of the horizontal drains. The piezometer installations further up the slope (Kaka Road area, BH2A and BH3A) have shown no response to the installed drainage.

Subsurface movements have continued to be recorded (up to 0.04 mm/day) within the inclinometers (Figure 3) indicating continued creeping of the slope at similar rates to those before the drainage was installed. However, following prolonged rainfall events, post drainage installation, the recorded rates of movement (small surge events) have slowed to 0.2 mm/day in BH2 only and are not evident in BH1 (versus 0.5 mm/day in BH1 and BH2 prior to the drains).

It is concluded from the inclinometer movements that the drains have had a positive effect providing dewatering in the toe area and may have slowed the rate of movement for a small surge event. The drainage has not however removed the peak water levels occurring during significant prolonged rainfall events contributing to these movement events nor affected long term creep rates to date. Further understanding of groundwater movement in the landslip area and drainage options for the wider West Taihape Landslip are currently being developed to increase the influence zone of drainage. These may involve further subsurface drainage and options to reduce seepage zones and improve stormwater control from open drains and the local council services networks.

8 CONCLUSIONS

Ongoing monitoring of the inclinometers has shown that movement, albeit slow, is still occurring within the lower toe slope of the landslip mass following significant prolonged rainfall events. Based on building damage some observable movement upslope is also occurring, although this movement has not yet been detected within the upslope inclinometers. Preliminary remedial drainage works have lowered the localised groundwater profile in the toe slope and appeared to have slowed the rate of movements recorded for small surge events. However, long term creep rates have not been affected. Ongoing monitoring at regular intervals will continue in order to further develop the record of movements so any patterns can be established. Additional work is ongoing to investigate and understand the groundwater regime of the landslip to develop a system of further drainage measures that will likely lower the overall groundwater levels to provide increased stability of the land.

ACKNOWLEDGMENT

The authors wish to thank the Earthquake Commision and Tonkin and Taylor for authorising to use the information to prepare this paper. This work was commissioned by the Earthquake Commission and supported by Rangitikei District Council.

REFERENCES

Brickell Moss Rankine and Hill (1971). *Consultation on Landslide Kaka Rd – Taihape*. Unpublished report prepared for the Earthquake and War Damages Commission.

GNS Science (2007). Active faults database of New Zealand website http://data.gns.cri.nz/af/.

Johnson, R.M. (1983). *Taihape Land Stability Survey Report*. Unpublished report prepared for Rangitikei – Wanganui Catchment Board and Regional Water Board.

Landcare Research New Zealand (2005). *Taihape Urban Slip Zone Report*. Unpublished report for Rangitikei District Council.

Massey, C., Guest, R., Clitheroe, G. (2007). *Monitoring Landslide Movement and Triggering Factors in Near Real-Time – An Example from Taihape, New Zealand.* (In Press) GNS Science.

Thompson, R.C. (1982). *Relationship of Geology to Slope Failures in Soft Rocks of the Taihape-Mangaweka Area, Central North Island, New Zealand.* Unpublished PhD Thesis, University of Auckland.

Tonkin and Taylor Ltd (2005). *West Taihape Landslip – EQC Claim 2005/3768. Site Investigation and Assessment of the Active Toe Slope*. Unpublished report prepared for the Earthquake Commission.

Tonkin and Taylor Ltd (2007). *West Taihape Landslip – EQC Claim 2005/3768. Addendum Report – Site Investigations and Preliminary Remedial Works.* Unpublished report prepared for the Earthquake Commission.