

Laurie Richards

Rock Engineering Consultant

s 7(2)(a) - Privacy

**TAURANGA LANDSLIDES: 18 MAY 2005
SITE VISIT & REVIEW NOTES**

Report prepared for:

s 7(2)(f)(ii)

Tauranga District Council
Private Bag 12022
Tauranga

Version: 10005.2.1
Date: 13 July 2005



TABLE OF CONTENTS

INTRODUCTION	3
RAINFALL	3
SLIDE MECHANISMS	3
COMMENTS AND OBSERVATIONS	4
RECOMMENDATIONS	4

LIST OF FIGURES

1. 18 May 2005 rainfall compared with 1977 to 1998 at Chapel Street
2. Example of landslide geometry at Vale Street
3. Slide morphology described by Oliver 1997
4. Slide with low groundwater level on ash layer
5. Slide with fully saturated groundwater levels
6. Slide with low groundwater level on ash layer plus tension cracks
7. Slide with fully saturated groundwater levels plus tension crack
8. Piezo locations and slope water pressures

INTRODUCTION

1. The writer visited Tauranga on 22 to 24 June 2005 to view the landslides that occurred during the 18 May 2005 storms. Discussions were held with s 7(2)(f)(ii) (TDC) and visits made with s 7(2)(a) - Privacy (Tonkin & Taylor) and s 7(2)(a) - Privacy (University of Auckland) who had previously inspected the slides and made preliminary reports^{1,2} to TDC.

RAINFALL

2. The triggering event for the landslides was unprecedented rainfall leading to failure of the stormwater drainage system and uncontrolled overland flow. NIWA's Autumn 2005 climate summary indicates unprecedented rainfalls at Tauranga Airport on and prior to 18 May:
 - Total autumn rainfall of 751mm (highest since records began in 1898)
 - Torrential rainfall of 144mm in 24 hours on 3-4 May
 - Unprecedented maximum 24 hour rainfall of 347mm on 18 May
3. Local residents report considerable variation in rainfall and flooding over the city area during the 18 May event. The rainfall has been assessed as a 1 in 150 year event or greater. The effect of rainfall on the stability of slopes can be quantified by considering the total rainfall on the day of the event together with the cumulative rainfall over a previous number of days³. *Figure 1* shows the 18 May 2005 rainfall in comparison with the rainfall data at Chapel St from 1977 to 1998 (as used for the 1999 Mauao stability assessment⁴). The combination of daily and precedent rainfall exceeds any for the period from 1977 to 1998 and probably for the entire period of record in Tauranga.

SLIDE MECHANISMS

4. The slides inspected were notable for a number of features as follows (see *Figure 2*):
 - The heads of the slides are generally close to the slope crest and often controlled by changes in slope cover such as buildings or sealed areas
 - The back faces of the slides are often controlled by near vertical discontinuities or tension cracks
 - High water pressures in these tension cracks have the effect of causing slide "blowouts" which would have initiated regardless of the inherent soil or rock mass strength
 - The slide bases are controlled by less-permeable, low-strength ash horizons. The orientation of these layers (horizontal or dipping out of the slope) affects the size and geometry of the slide
 - Water pressures in the slopes would likely have been high because of the wet autumn but the high joint pressures developed from surface infiltration would have resulted in significant failures even with low groundwater pressures
 - Landslide runout was generally within a 4H:1V line projected from the headscarp. Most of the damage to houses was caused by runout rather than subsidence effects.

The presence of tension cracks is critically important to these slides. Such features have previously been identified by Oliver⁵ (*Figure 3*) who referred to these as *exfoliation defects* rather than the more appropriate terminology of *tension crack* or *stress-relief defect*. These features have a significant effect on slope failures since their orientation precludes any significant frictional resistance along the features, and the water pressure in the open joints can exert high horizontal pressures on the slide mass.

5. Without tension cracks or other structural controls present, the critical failure mode in these types of materials would be fairly deep-seated circular failures (see *Figures 4* and *5*) regardless of the level of the groundwater table. With water-filled tension cracks (*Figures 6* and *7*), the Factor of Safety (FOS) of the slope is significantly reduced and the critical failure surface moves closer to the slope crest for all groundwater conditions. Note that the above analyses are fairly simplistic since the toe of most failures is generally at the ash horizon.

¹ s 7(2)(f)(ii) Tauranga storm event 18 May 2005: Landslide issues. Preliminary report for TDC meeting 8 June 2005. Report to TDC

² s 7(2)(f)(ii) Tauranga landslide event 18 May 2005: Observations and comments. Report to TDC

³ Lumb P. *Slope failures in Hong Kong*. Q Jnl Engng Geol. Vol 8, pp31-65, 1975

⁴ Richards L. *Mauao stability assessment, Mt Maunganui, Tauranga*. Report to TDC, 31 May 1999

⁵ Oliver R. *A geotechnical characterization of volcanic soils in relation to coastal landsliding on the Maungatapu Peninsula, Tauranga, New Zealand*. MSc thesis in Engineering Geology, University of Canterbury, 1997

section properties and cascaded over the escarpment edges. The severity of the surface water flows is indicated by the failure of low garden retaining walls on some of the sections.

7. TDC's consultants have observed that the landslide runout for the May 2005 slides is about 4H:1V. This is consistent with the data collected for the 2001 relic slip review⁶.

COMMENTS AND OBSERVATIONS

8. The 18 May 2005 rainfall event was the highest 24 hour rainfall recorded in Tauranga. Because of the failure of the stormwater drainage system, slope failures would have been significant even if the previous few months had been drier than normal.
9. The subvertical features near the slope crests (*tension cracks*) have a critical effect on the stability of the slopes. Little is known about the extent of such features apart from some incidental descriptions in student theses. Detailed investigation and geological description of these features is required to investigate the extent to which these are located beyond slope crests and whether they are related to specific horizons only.
10. Very little is known about the response of these tension cracks to rainfall events (i.e. crack water pressure versus rainfall relationships). These features are most critical nearest the slope crests. Piezometers placed at some distance from the slope crest (measuring pore pressures within the slope) may give little indication of critical water pressures near the crest. Piezometric monitoring needs to take account of the tension cracks – this is likely to result in piezometers being placed in inclined drillholes to ensure interception of the tension cracks (*Figure 8*). Given the aerial variation of rainfall, automatic rainfall gauges should be located close to all automatic piezometer locations.
11. The slope failure mechanism is essentially a very rapid blowout of a volume of material close to the slope crest. Borehole inclinometers installed at some distance from the slope crest (measuring shear movements normal to the borehole axis) are not likely to provide adequate information for predicting future slope failures. Although horizontal borehole extensometers would be theoretically preferable, these have significant practical problems in this situation.
12. Laboratory testing of the slope materials is currently underway and this program is endorsed. However, the slope material properties are certain to be less critical than the tension crack properties (locations, extent and depth of water). Back analysis of the failed sections of slope will yield important information on slope behaviour.
13. The 2001 relic slip report recommended that specialist geotechnical advice would be required, *inter alia*, where buildings were located within the 4H:1V runout distance from an uphill slope. The May 2005 events and observations indicate that this criterion should be applied to all development in the TDC area. The council GIS database should be used to check for existing buildings with such a hazard zone.
14. TDC's consultants have made recommendations regarding further investigations of geology and groundwater – these are endorsed. Horizontal drains below the slope crest could theoretically provide some useful drainage but this would be dependent on a detailed geological investigation of the vertical fissuring within the ash. Stormwater and surface water control is clearly of paramount importance in the prevention of further slides.

RECOMMENDATIONS

15. Rainfall records should be reviewed to assess the severity of the daily and precedent rainfall for the 18 May 2005 event.
16. Geological cross sections should be established for all failure areas to identify failure mechanisms, allow back analyses and determine runout characteristics of the slides. If slide areas are assessed by different individuals, an overview report to bring all data together would be helpful.
17. Representative areas near the ridge crests should be investigated in detail to provide information on the characteristics of tension cracks near slope crest.

⁶

§ 7(2)(a) - Privacy [REDACTED] *Relic slip verification study*. Report to TDC, March 2001.

18. Piezometric monitoring should be established to identify critical water pressures near the slope crests. Automatic rainfall gauges will be required in the general area of the piezometers.
19. Any further proposals for slope monitoring should be reviewed in relation to the slope failure mechanisms and the instrument capabilities.
20. Conclusions arising from the review of these slides should be used to review TDC land development criteria and made available to all those concerned with development in this area.

s 7(2)(a) - Privacy

Laurie Richards

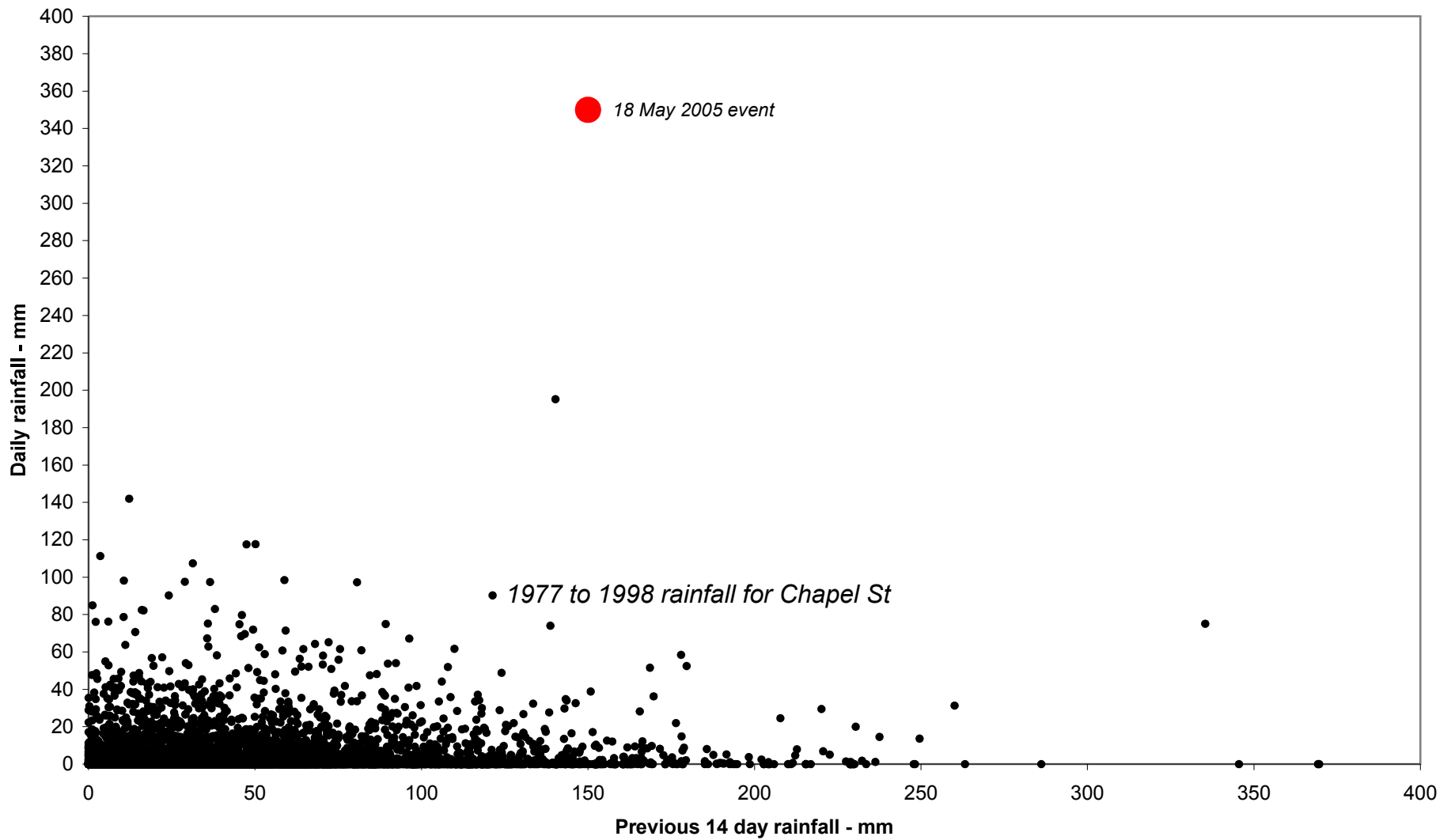


Figure 1: 18 May 2005 rainfall compared with 1977 to 1998 at Chapel St

TAURANGA MAY 2005 LANDSLIDES

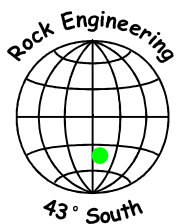
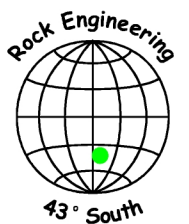
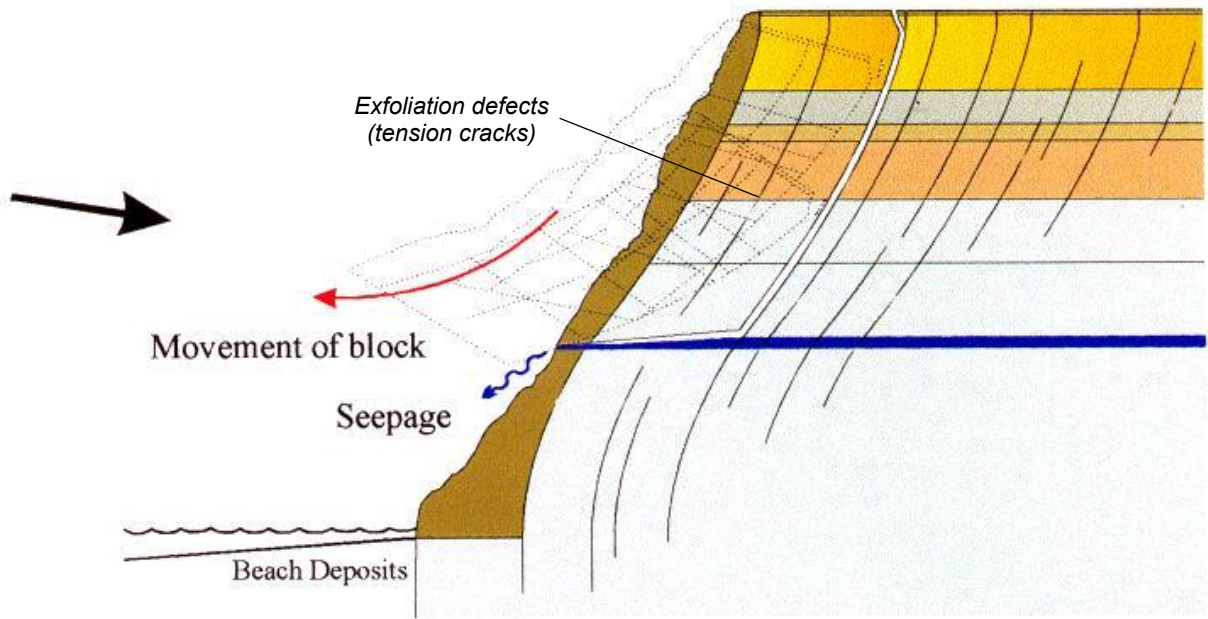


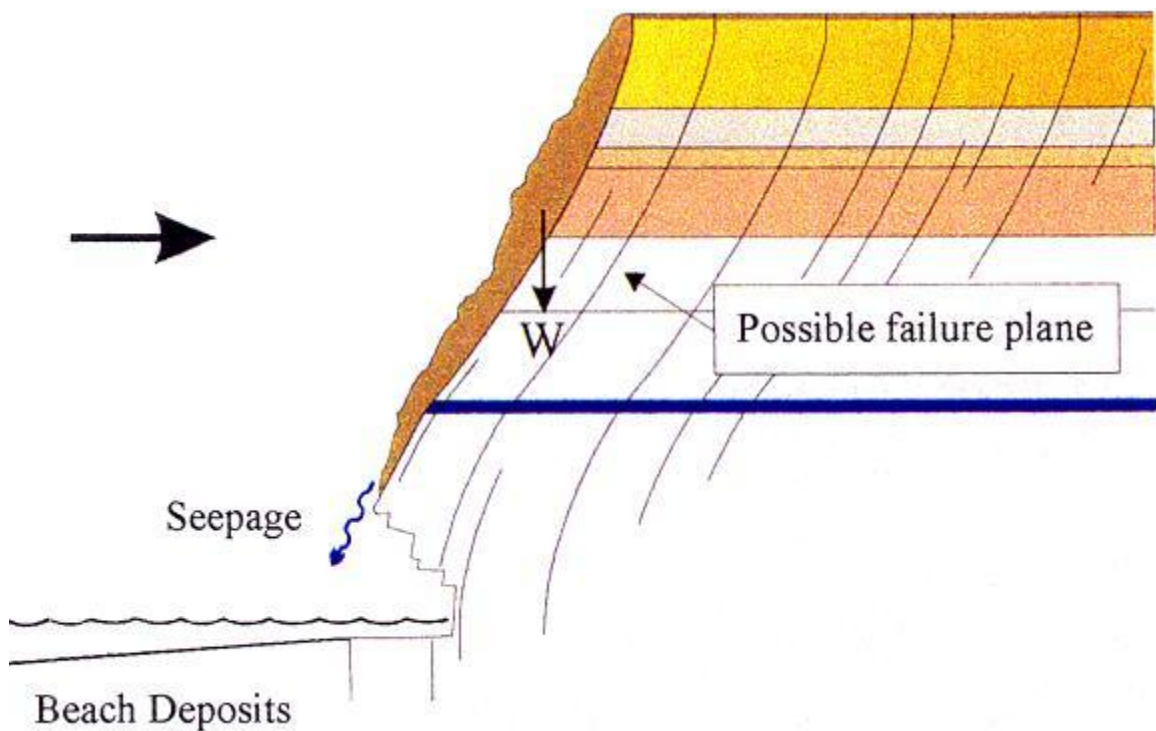


Figure 2: Example of landslide geometry at § 7(2)(a) - Privacy
TAURANGA MAY 2005 LANDSLIDES





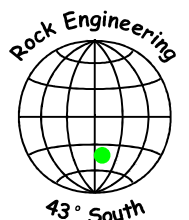
(a) Piping triggered block failure



(b) Wave erosion triggered block failure

Figure 3: Slide morphology described by Oliver 1997

TAURANGA MAY 2005 LANDSLIDES



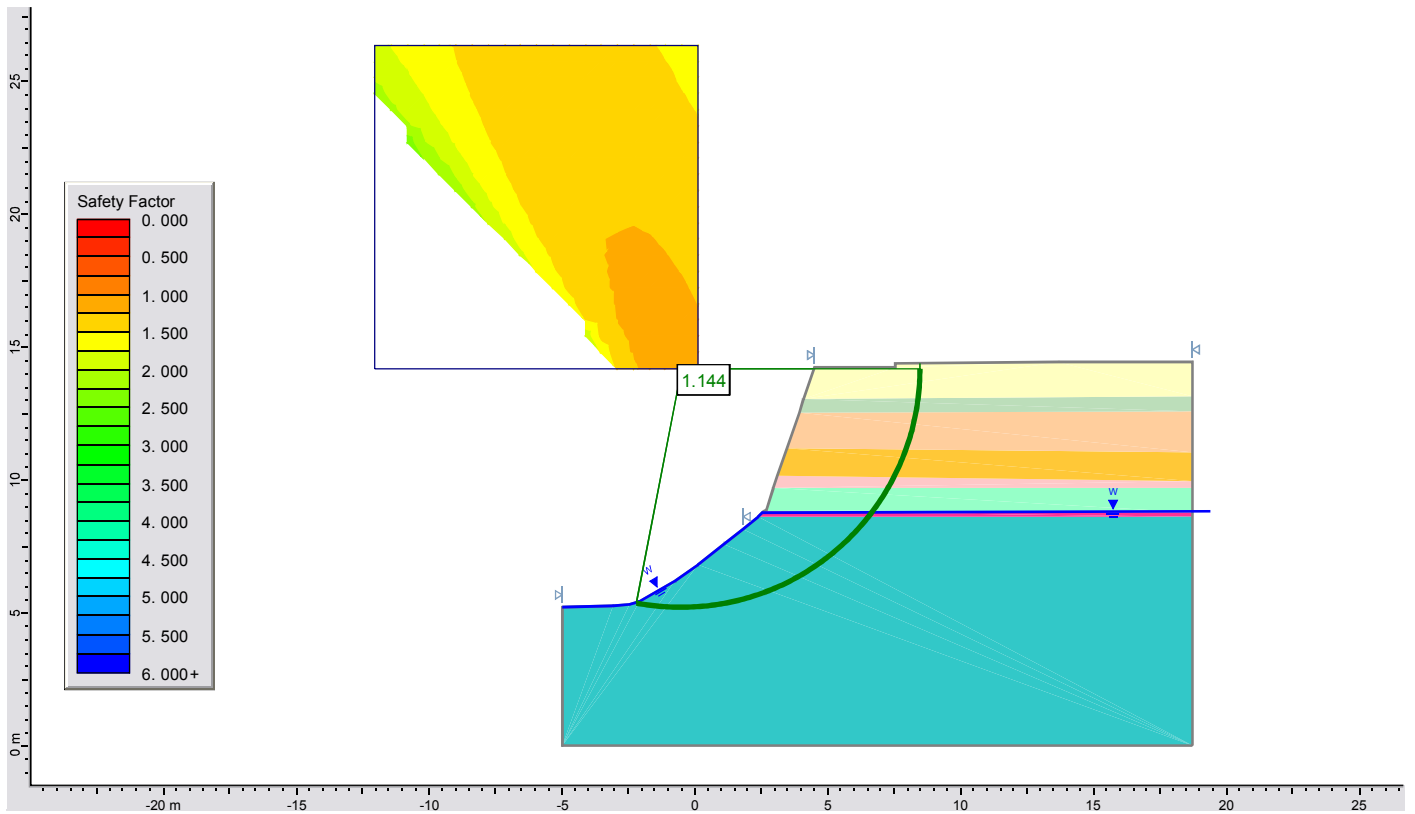


Figure 4: Slide with low groundwater level on ash layer

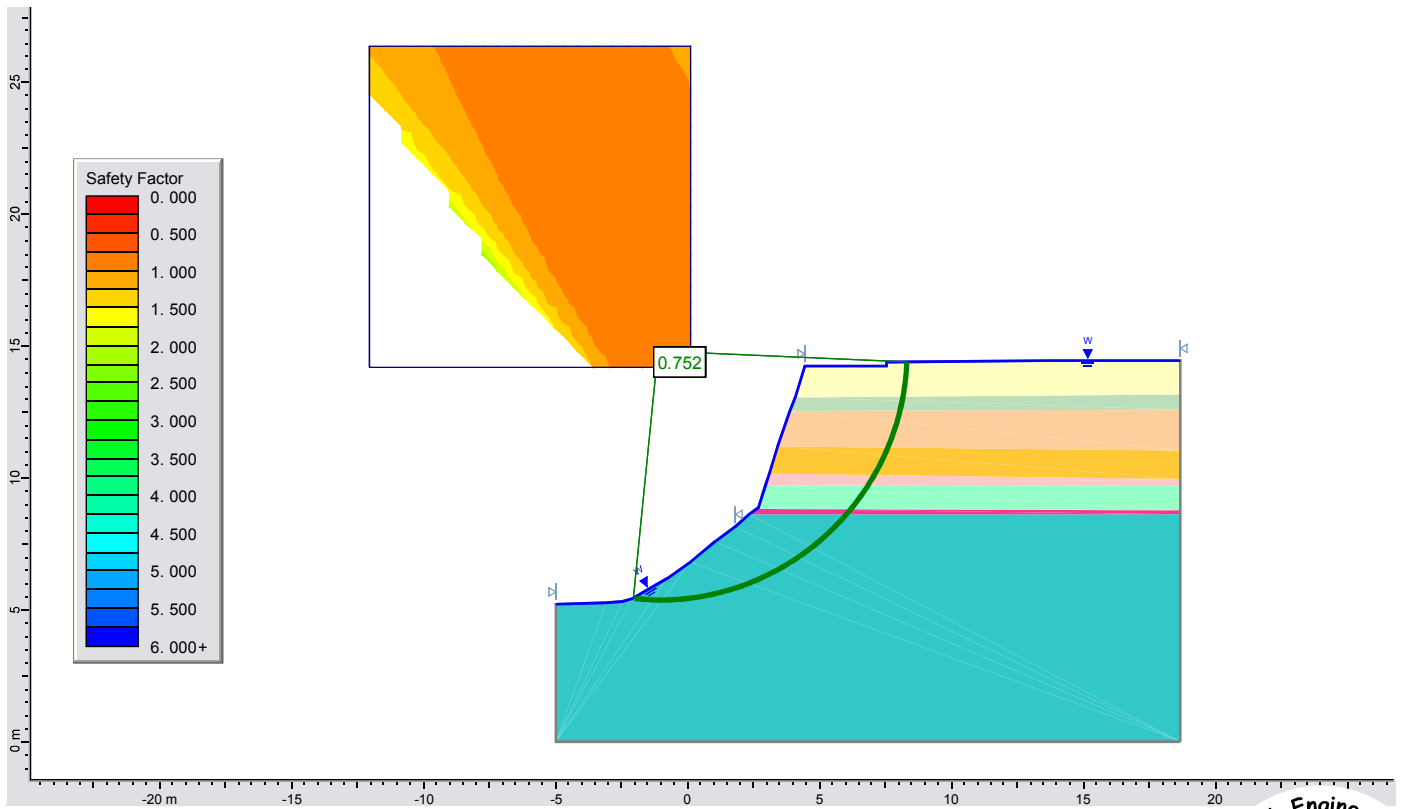
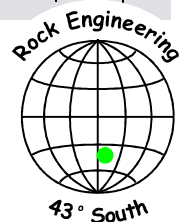


Figure 5: Slide with fully saturated groundwater levels

TAURANGA MAY 2005 LANDSLIDES



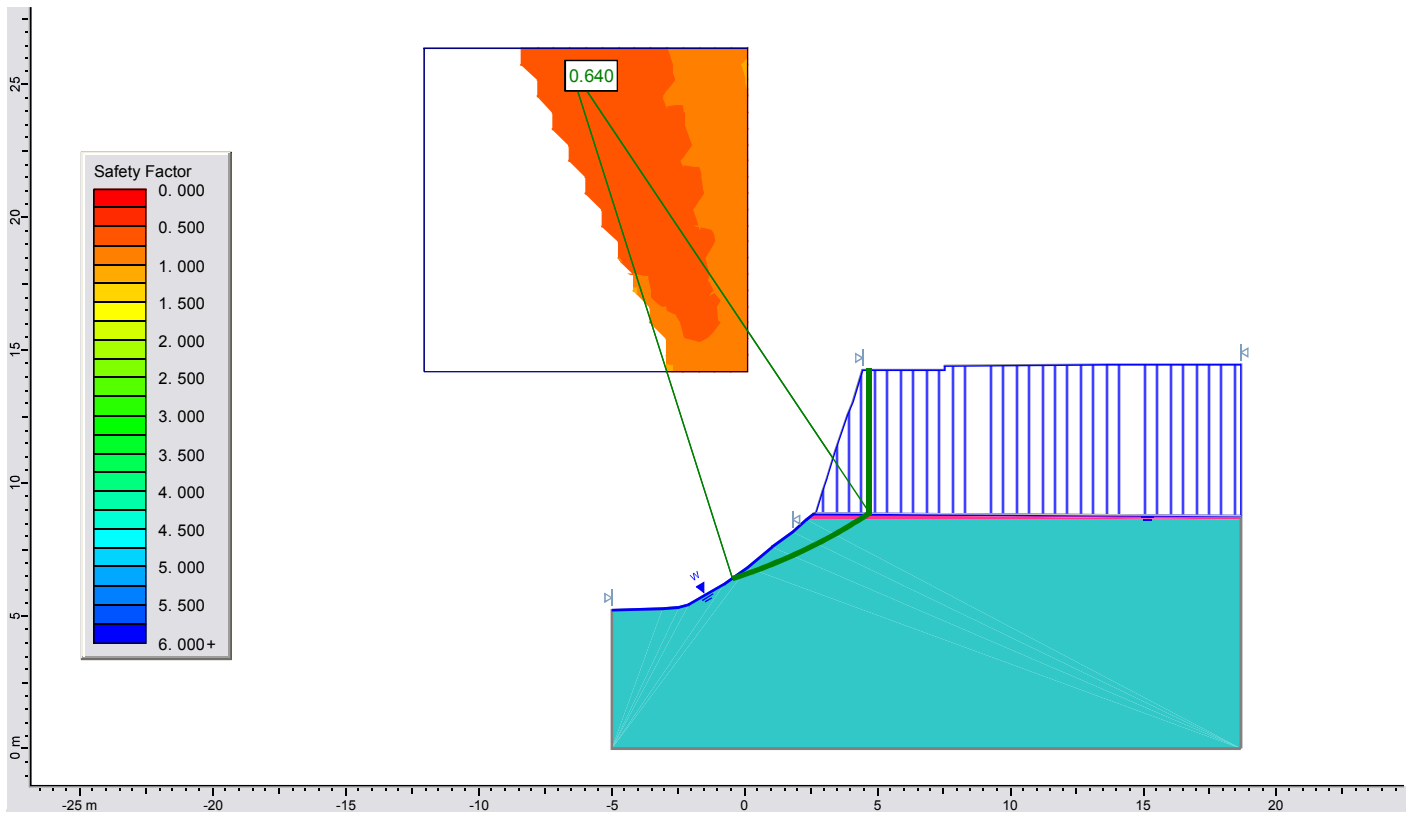


Figure 6: Slide with low groundwater level on ash layer plus tension cracks

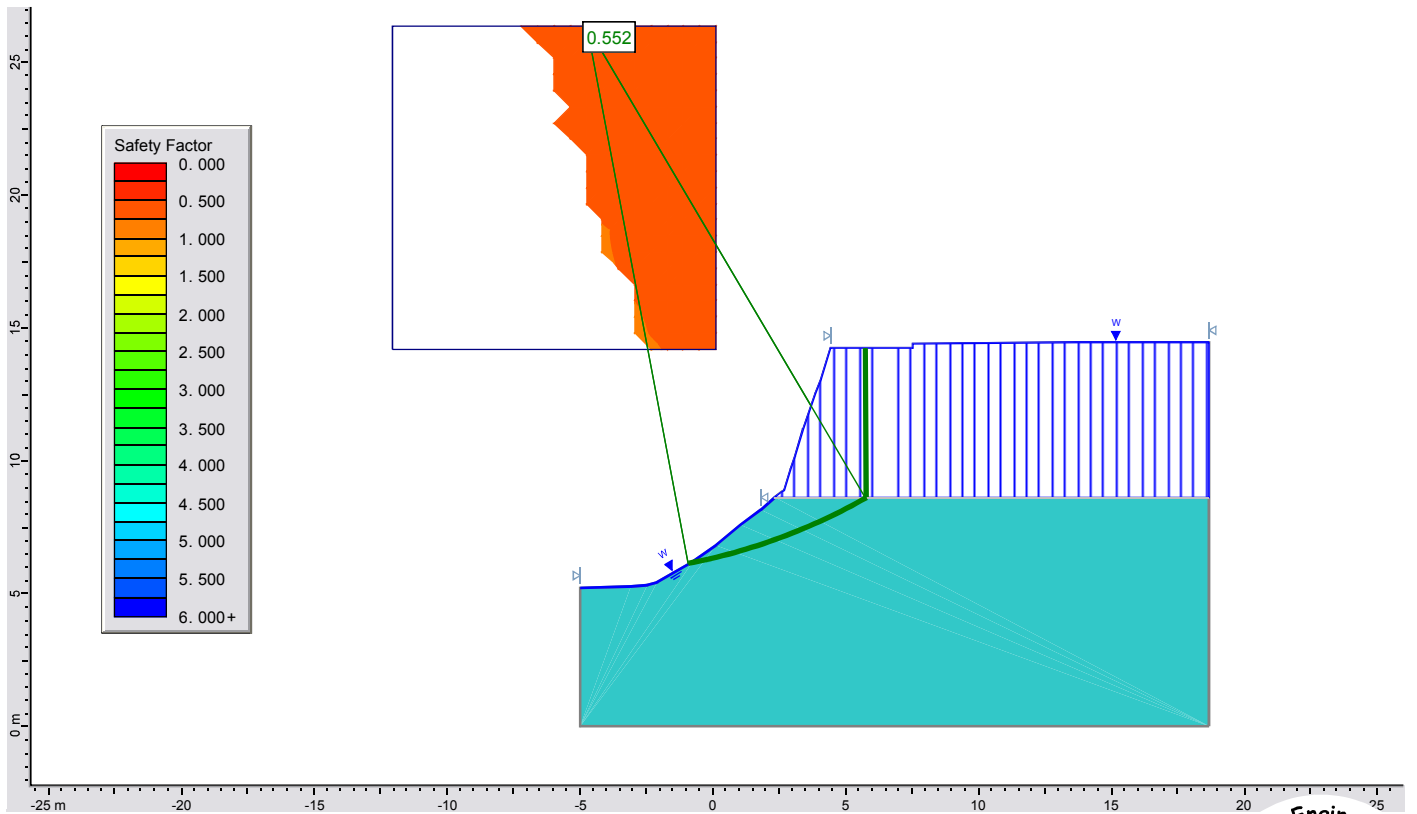
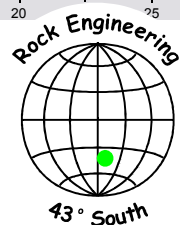


Figure 7: Slide with fully saturated groundwater levels plus tension crack

TAURANGA MAY 2005 LANDSLIDES



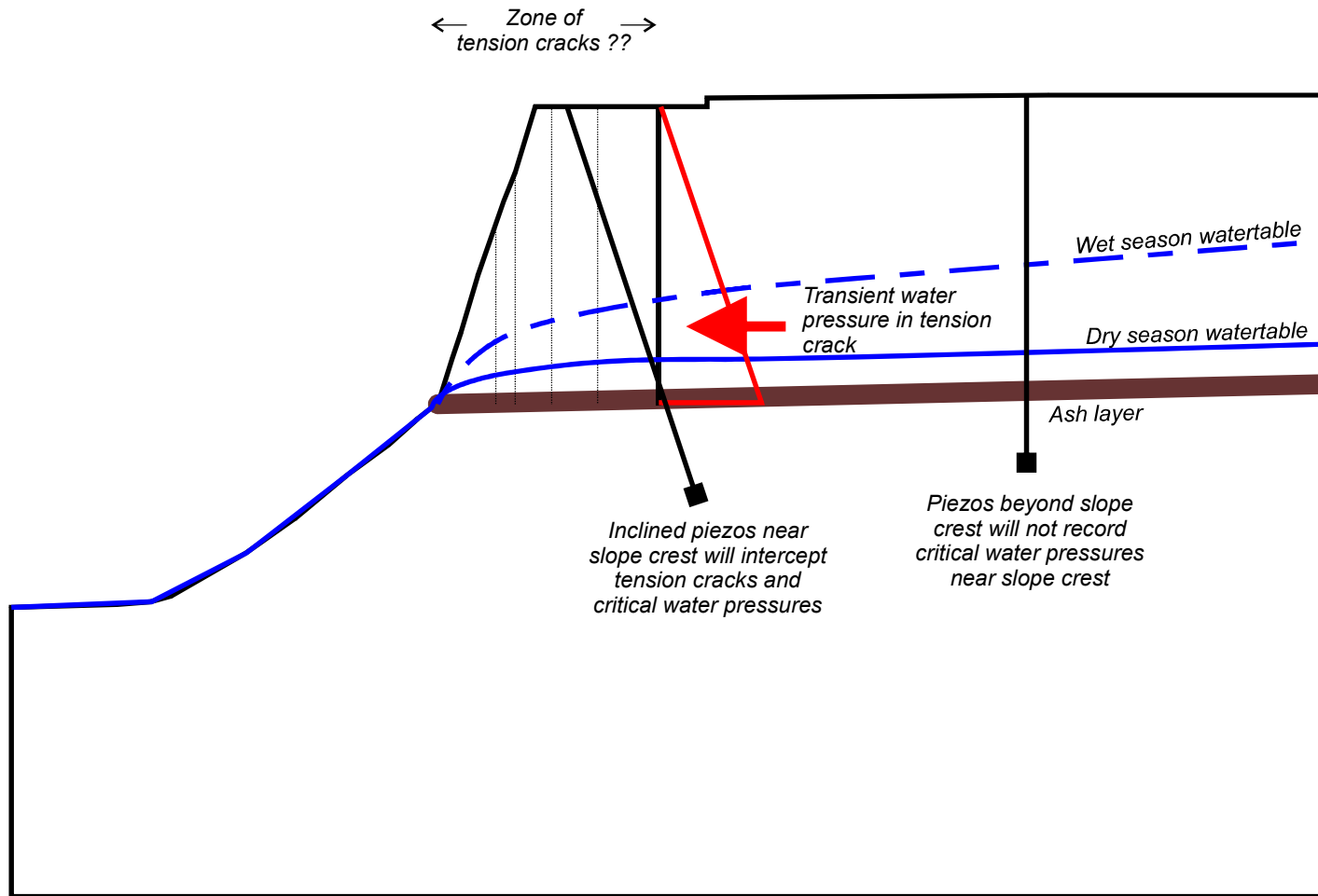


Figure 8: Piezo locations and slope water pressures
TAURANGA MAY 2005 LANDSLIDES

