



**Tauranga City Council**

**Mount Maunganui Motor  
Campground Upgrading  
Project**

**Geotechnical  
Assessment Report**

**Date:** 29 April 2009

**File Ref:** 3471

**Revision:** 1

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**TAURANGA CITY COUNCIL**  
**PROPOSED MOUNT MAUNGANUI MOTORCAMP UPGRADING**  
**GEOTECHNICAL ASSESSMENT REPORT**

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- A: Figures
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## 1.0 INTRODUCTION

Terrane Consultants Ltd (Terrane) was engaged by Tauranga City Council (TCC) to undertake a geotechnical assessment for aspects of the proposed upgrading of the Mount Maunganui Motorcamp.

This assessment covers the construction of cabins within the north-western corner of the campground, directly below the eastern slopes of Mauao, as well as minor works for tent sites within the Pilot Bay part of the campground. Both locations are within the broad area considered to be potentially at risk from rockfall.

The results of the risk assessment and an outline of the recommended protection measures are summarised in this report.

In overall summary, the proposed approach is to reduce the level of risk by replacing the existing boundary fences in both locations with a specialist rock catch fence. The unique setting of the campground means that the protection system will need very careful design to ensure that it is consistent with cultural and aesthetic values.

## 2.0 SCOPE OF WORK

The scope of the geotechnical assessment included:

- Review of published geotechnical & geological information;
- Subsurface investigations to assess ground conditions in key locations;
- Quantitative risk analysis of rockfall hazards;
- Comparison with past rockfall assessments for Mauao;
- Assessment of other slope stability hazards; and
- Assessment of options for protecting the proposed cabins.

The author of this report has undertaken inspections of rockfalls and landslips on Mauao for TCC since 2002. This included the assessment and removal of the unstable rock pinnacle on the bluff directly above the campground in late 2003.

## 3.0 SITE DESCRIPTION

The Mount Maunganui Beachside Holiday Park ('the campground') is located on the eastern side of Mauao, adjacent to Adams Avenue, at the western end of Mount Maunganui locality. Mauao comprises an extinct volcanic cone extending to an elevation of 232 metres above sea level. It is a historic reserve and has iconic status.

The layout of the campground and the adjoining part of Mauao are shown on Figures 1 to 4 included in Appendix A of this report.

The top of Mauao on the eastern side is marked by a prominent rock bluff over 30 metres high. The mid-to-upper flanking slopes are mostly vegetated in regenerating native bush, while the lower slopes are in grass and are used to graze sheep. A number of terraces have been formed on parts of the lower slopes during Maori occupation.

Slope gradients generally reduce with lower elevation. Cross-sections through the slopes above the campground are shown in Figure 5 included in Appendix A of this report.

The campground straddles the lowest part of the slope and the gently sloping ground at road level. Cut batters show that some recontouring was undertaken within the campground area. Batters of up to approximately 3 metres high have been formed along the northwestern boundary of the campsite. The larger batters have a timber facing, while the smaller batters are generally unsupported. The bench along the upslope boundary of the Pilot Bay tent site area has been formed close to the natural ground level, meaning little or no undercutting of the slope.

#### 4.0 PROPOSED DEVELOPMENT

The proposed redevelopment of the campground includes the construction of a row of cabins along the north-western boundary, within an area that is currently used for semi-permanent caravan sites (refer Figure 3 in Appendix A).

Seven or eight cabins will be included. The proposed layout is shown on Drawing 02: Proposed Cabin Layout by Boffa Miskell, dated 29 January 2009, Ref. T07166 (Rev. A). We understand the cabins will be approximately 6m by 8m in size and are expected to be single storey, lightweight structures.

The other area considered as part of this assessment is the upper part of the Pilot Bay tent sites located behind the Hot Pools, as shown on Figure 4. We understand works within this area will be limited to small scale measures to improve functionality, such as stabilising the outside edge of the existing cut bench and upgrading stormwater control.

#### 5.0 SITE INVESTIGATIONS

Site investigations undertaken as part of this geotechnical assessment included:

- A detailed walkover inspection;
- Mapping of boulders and other geomorphological features on the Mauao slopes; and
- Four dynamic (Scala) penetrometer tests (SC1 to SC4 inclusive).

The investigation locations are shown on the Figure 3 included in Appendix A, while factual results are included in Appendix B of this report.

Recommendations and opinions in this report are based on data from outcrops and penetrometer tests at discrete locations. The nature and continuity of subsoil away from the investigation locations are inferred, but it must be appreciated that actual conditions could vary from the assumed model.

## 6.0 SUBSURFACE CONDITIONS

### 6.1 Geological Setting

The overall geological setting of Mauao can be summarised in three main stratigraphic units;

- An eroded central dome of rhyolite rock approximately 2.3 million years old;
- Remnants of once-extensive terrace deposits deposited during sea level cycles over the last approximately 750,000 years. Only discontinuous remnants have been preserved; and
- Colluvial deposits originating from the upper slopes of Mauao, including slope wash, rockfall and soil slide/flow deposits.

The terrace deposits are not exposed within the area of the proposed cabins and so are not considered in detail in this report.

### 6.2 Subsurface Units

#### 6.2.1 Rhyolite Rock

The rhyolite rock comprises weak to moderately strong grey to pinkish grey material. Flow banding is common. The overall rockmass is dominated by subvertical cooling joints, as exposed within the bluffs below summit level, although the presence of other essentially random orientations mean it is not possible to define a reliable anisotropy to the rockmass in terms of rockfall potential. Defects within the intact rockmass tend to be clean, curved and rough. Within outcrop the joints can open to well over a metre wide, infilling with slopewash soils and vegetation.

#### 6.2.2 Colluvium

As would be expected, the colluvial fan and other deposits on the flanks of Mauao are variable in composition. It includes loose rock scree directly below the bluffs, gap-graded silt and boulder deposits within the mid-slope area, and brown clayey silt with occasional sand lenses and “floating” boulders within the lower slopes.

A series of dynamic penetrometer tests were completed along the toe of the main slope to assess insitu strengths and the frequency of buried boulders. The tests were located along the boundary with the campground, as shown on Figure 1.

The results indicate the colluvium is generally quite competent, with results generally between 2 to 3 blows per 50mm and some parts giving 4 to 5 blows per 50mm.

Boulders were encountered in four of the seven tests. In three of these a boulder was encountered within the first metre, and a second (or third) attempt was made in the same area. Considering the penetrometer has a diameter of 20mm (area = 314 mm<sup>2</sup>) and the cumulative depth of testing was 18.7m, this frequency indicates a boulder concentration reasonably similar to what is exposed on the ground surface.

#### 6.2.3 Boulders

While individual boulders are of colluvial origin, they have been considered separately for the purposes of the rockfall risk assessment. The boulders are generally slab to disc shaped, with the length and width approximately equal and the thickness being smaller (generally approximately half).

Boulders typically range between approximately 0.01m<sup>3</sup> and 3m<sup>3</sup>. Larger boulders are present, as best seen on the southern slopes (above the hot pools), where individual boulders are up to approximately 13 to 14m<sup>3</sup>.

The boulders above the campground include material generated by the removal operation undertaken in 2003. It is inferred that some boulders are associated with maori activity, including warfare and also terracing of the slope for the purposes of horticulture and occupation.

### 6.3 Groundwater

There is no sign of permanent groundwater seepage within the vicinity of the proposed cabins. Some groundwater seepage has been observed within cut slopes at campground and base track level following periods of prolonged rainfall, however these tend to disappear within a few days.

Groundwater conditions for the purposes of this assessment have been assumed as saturated under design conditions, with a normal groundwater table at least 1.0m below the ground surface.

## 7.0 SLOPE STABILITY HAZARDS

Three main slope stability hazards have been identified;

### Rockfalls

This is where boulders fall, bounce and roll down the flanks of Mauao, particularly from the summit bluffs but also from the lower to middle slope areas. Rockfall dominates the overall risk profile and is discussed in detail in Section 8 of this report.

### Soil-and-debris slide/flow failures

In addition to the rockfall hazard there is a potential for mass movement (landslippage) within the middle and lower slopes on Mauao. The potential mechanisms include similar size and scale to previous slips on Mauao such as shallow-seated slide/flow failures within the near surface colluvium and other slopewash soils, as well as batter failures along the cut batters at campground level.

Some smaller, more recent gully features are also present, related to recent scour and slope instability.

Tauranga has been affected by a number of extreme rainfall episodes over the past 10 years or so<sup>1</sup>. These resulted in a number of soil or regolith failures around Mauao, mainly within the cut batters and gullies adjacent to the base track but including others scattered elsewhere. There have been relatively few failures within the grassed mid-slope areas such as that directly upslope of the proposed cabins.

The exiting cut batters in the vicinity of the proposed cabins are either unsupported or faced with old retaining walls which clearly have limited ground retention capacity.

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<sup>1</sup> Major rainfalls include April 2004 (which coincided with an earthquake swarm), the extreme storm on 18th May 2005, the wet winter in 2008, and the weather bombs of 18th Feb and 6th March 2009.

In terms of the risk of soil slide/flow failures to the occupants of the proposed cabins:

- The velocity of a soil slip is fundamentally lower than a rockfall event. This contributes to significantly lower vulnerability of the occupants;
- Based on the size of past slip events, a rockfall fence can be expected to intercept most, if not all, of the debris; and
- In the event of an extreme event that overtopped a rockfall fence, the material would flow through the gap in the line of the cabins.

It is concluded that the soil slide hazard is covered by the proposed mitigation measures for rockfall protection. This should be checked during the detailed design phase.

#### “Deep-seated” instability

There are two, possibly three, large scallop-shaped indentations within the lower slopes on the northeastern and eastern sides of Mauao. These have the appearance of ancient “deep-seated” landslide scarps.

While the features are of reasonable size, factors such as the well developed soil profiles within the scarps and the lack of debris lobes indicate they probably occurred at some time in the geological past, most likely due to toe erosion during times of higher sea level (and within more adverse climatic conditions than present).

The risk of this type of failure is judged to be extremely low. Notwithstanding this, it would be appropriate that this be confirmed during the detailed design stage.

## 8.0 ROCKFALL RISK ASSESSMENT

### 8.1 Existing Conditions

Rockfall events have taken place on Mauao over geological time - that is, many thousands of years. Triggers for an event can include earthquake shaking, thermal expansion/contraction, general weathering and erosion. In all likelihood, rolling rocks were used in defence of the fortified pa on Mauao in pre-European times. Even now, human activity can result in rockfall events, either accidentally or deliberately.

TCC has undertaken a significant programme to manage the risk of rockfall at Mauao. Assessments of rockfall risk were undertaken in 1999 and 2003 by Dr Laurie Richards. Since 2003, Avalon Industrial Services Ltd (Avalon) has undertaken rockfall risk assessments, inspections and scaling operations. The author of this report has undertaken both peer review and assessment work for TCC since 2003, for both rockfall and soil slip events and for risk assessments.

A number of unstable boulders have been stabilised. In November 2003 a controlled blasting operation removed approximately 150m<sup>3</sup> of unstable rock from a bluff just below the summit, above the campground. Parameters such as rock size, shape and trajectory information were collected during the blast. This has been useful in calibrating numerical rockfall simulation analysis.

The middle slopes and upper bluffs contain potentially unstable boulders that could theoretically reach the campground. These areas are subject to regular inspection (nominally annually) by Avalon.

Within the bush-covered upper to middle slopes there are a number of boulders dating from the removal operation in 2003. The follow-up work at that time included rolling and stabilising the largest boulders that were hanging in trees or sitting somewhat precariously.

Engineering geological mapping of the lower, grassed slopes above the proposed cabins area identified between twenty and thirty boulders which would be classified as being potentially unstable. Most appear to have a low to very low risk of movement, with an even lower risk of being able to reach the campground. No evidence was seen for boulders having become more unstable since the 2003 operations.

The location of the gullies and main boulders on the slopes above the proposed cabins is shown in Figure 3.

In the 2003 blasting operation a total of seven boulders reached campground level, by which time they were rolling rather than bouncing. There are some differences between this operation and what may occur in a future “natural” rockfall event, such as there having been an initial velocity component.

We are not aware of any other historical incidents that have resulted in boulders reaching the proposed cabins area.

## 8.2 Risk and Risk Analysis

In this report the following definitions have been adopted:

Hazard = a physical phenomenon that may produce adverse effects on human activities

Risk = the probability of a specified loss or harm

The risk of a serious injury or death from a rockfall event needs to be considered in the context of what would be considered to be an acceptable level of risk for this situation. There are a number of published international guidelines<sup>2</sup> as well as some NZ guidelines<sup>3</sup>, however there is no value which has been universally accepted. The criteria may vary depending on factors such as:

- If the event results in a single or multiple fatality;
- If the risk is knowingly taken on by an individual (a voluntary risk) or whether it is an unbeknown risk (involuntary risk); and
- If an individual is exposed for only a limited time (such as at the proposed cabins) or for an extended period (eg at a workplace).

A generally accepted threshold is that the mean annual exceedance probability of a fatality should not exceed  $1 \times 10^{-6}$  (roughly analogous to a one-in-a-million chance) and preferably be distinctly lower than this. This has been used for previous risk assessments for Mauao and has been adopted for this report.

For comparison purposes, some indicative risk levels given in the literature for a single fatality include:

Car travel : 50 to 100 x  $10^{-6}$

<sup>2</sup> eg Fell & Hatford (1997): “Landslide Risk Management”

IUGS: “Quantitative risk assessment for slopes and landslides - the state of the art”

<sup>3</sup> eg the building collapse mode as given in AS/NZS 1170:2005 Structural Design Loadings

Airline flight	:	7 to 10 x 10 <sup>-6</sup>	
Natural hazards	:	3 x 10 <sup>-6</sup>	(flood, earthquake, tsunami, etc)

It is important to appreciate that any activity involves some level of risk. It is not appropriate to consider a “zero risk” approach as this would be simply unrealistic.

### 8.3 Rockfall Analysis

Quantitative Risk Assessment (QRA) is a mathematical method used to calculate the risk of a certain event occurring, which can then be compared to acceptable and tolerable levels of risk. For this project, the analysis considered the probability of a fatality as a result of rockfall of a person staying in one of the proposed cabins for one day per year.

It is important to appreciate that QRA is not an exact science and should be considered as only one part of the overall decision making process.

Parameters used in the analysis were based on the field investigations, parameters used previously for rockfall analysis at Mauao, and the precedent from the 2003 removal operation.

The following input was used for the assessment:

- Source area: the area upslope of the cabins, extending up to the summit bluffs. Area of lower slopes = 500 m<sup>2</sup>
- Rockfall events: from >3m<sup>3</sup> to 0.1m<sup>3</sup> size (particles less than <0.1m<sup>3</sup> will clearly not reach the campground and therefore can be ignored); frequency ranges 0.01, 0.1 and 1 particle/yr per m<sup>2</sup> of source area
- Percentage of rocks reaching campground: 10% to 0.1%
- Cabin occupancy: each containing 3 people, occupied 75% of the year
- Exposure time: 12 hours/day
- Target area per person: 1 m<sup>2</sup>
- Vulnerability: 0.5 to 1.0.

The rockfall grouping and frequency was based on field observations. Some of the input values vary from those used in previous assessments for rockfall risk at Mauao. For example, a higher occupation rate has been used because cabins are more suited for off-season useage than tents.

The slope profiles used are shown on Figure 2 (refer Appendix A). The numerical analysis was undertaken using Rocfall software<sup>4</sup> and spreadsheet calculations. An overview of the input parameters and results of the analysis is included in Appendix C.

It has been assumed that the TCC programme for active mitigation of rockfall risk on Mauao will continue.

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<sup>4</sup> ROCFALL software version 4.00, by Rocscience Inc., Canada

## 8.4 Analysis Results

In the situation where the cabins were constructed without protection measures, the calculated mean annual probability of a fatality is in the order of  $1$  to  $5 \times 10^{-6}$  per year (for a person staying in one of the cabins one day per year). This level of risk is above guidelines for involuntary risk.

A follow-up analysis was undertaken to determine the reduction in risk with a barrier system along the upslope side of the line of cabins (rockfall fence or other measure). For a 2.0 metre high barrier the probability of a fatality reduces to less than approximately  $1 \times 10^{-6}$ . A higher fence (say to 2.5m) would decrease the risk even further.

The analysis results are considered to be conservative, as there is no specific allowance for mitigating factors such as:

- The channelling effect of the gully;
- The proactive monitoring and stabilisation programme run by TCC; and
- The positive benefit of vegetation.

As a comparison, more than several hundred thousand people walk the Mauao tracks every year. Calculations by Avalon undertaken in 2006 indicated the high level of visitor numbers gave a calculated rockfall fatality return period in the order of ten years. While occasional near-misses have been reported, there have been no injuries or fatalities.

It is noted that a 2.0m high barrier would have intercepted all of the boulders that reached the base of the slope in the 2003 removal operation, as the boulders were rolling with little or no bounce.

## 9.0 THE CABINS

### 9.1 Development Options

A number of alternatives have been considered to reduce the level of rockfall risk to the proposed cabins to within normally accepted levels. A quick summary of some options is as follows:

- A. Remove the risk altogether. This would require stabilisation of the rock bluffs at summit level, using rock bolting, meshing and other techniques, with possibly some stabilisation works on the mid-to-lower slopes. Clearly this would be inconceivable for Mauao;
- B. Diversion measures on the upper slopes, to divert boulders and soil debris away from the campground. This could involve diversion bunds, ditches, fences, etc. Again, this would be inconceivable on Mauao;
- C. Move the cabins. While commonly used elsewhere, it usually means buildings are located on higher ground, away from potential run-out paths. However, in this instance it conflicts with the requirement to minimise the visibility of the cabins by tucking them back into the hillside. We have concluded that this is not an option;

- D. Include some protection measures and then allow users to choose to take on the residual risk via signing a waiver. It is expected that the level of risk could be reduced to below the elemental requirement within the Building Act 2004 for buildings to be “safe and sanitary”. Having observed firsthand just how much risk some members of the public will take on when visiting Mauao (ignoring warning signs, avoiding security officers, etc) we would expect this may be acceptable to some persons, however this approach would be impractical from an administrative point of view;
- E. Strengthening the cabins to withstand rock impact. However , on its own it would most likely result in a “bunker” design, nor would it protect the utility areas around the cabins. It can be considered in conjunction with other options to control overall levels of risk;
- F. Protection measures directly behind the cabins. Considering requirements such as minimisation of visual impact and soil disturbance, the optimum approach here would be to install a specialist rockfall fence along the upslope fence line of the campground. This is the preferred option.

Given the iconic status of Mauao it is essential that any protection system be discrete, have no irreversible impact, yet be sufficient to reduce the level of risk to within normally accepted levels.

Structural strengthening of the rear walls of the cabins can be used to provide additional protection, if deemed necessary. It is noted that a rockfall fence will also reduce the risk to the nearby tent area.

## 9.2 Proposed Approach

The proposed rockfall fence would comprise a proprietary system with special energy-absorbing mechanisms (eg Geobrugge, Maccaferri or similar). Preliminary sizings indicate the fence would be 2.0 metres high, possibly increasing to 2.5 metres high within the corridor with the highest risk (that is, within the main gully).

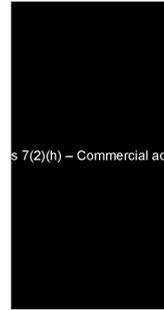
The fence would replace the existing boundary fence on the upslope side of the campground. The increase in footprint would be limited to steel wire tiebacks to each pole.

It is expected that only minor contouring would be required to construct the new fence. Ground disturbance should be limited to the drilling of the tieback anchors and pads to support the poles.

The fence would be painted matt green or similar (that is, not the standard stainless steel colour), to reduce visual impact.

A preliminary cost estimate for a rockfall fence behind the cabins is as follows:

Preparatory works	
Rockfall fence - 75m long at [REDACTED] per metre length	
Engineering design and certification	
SUBTOTAL	
Contingency - [REDACTED]	
TOTAL (exclusive of GST)	



Notes to estimate:

- Preliminary costing, based on indicative rates
- Allow max energy range = 250kJ to 500 kJ
- Includes some allowance for boulder obstructions, based on the penetrometer results
- Excludes landscaping

### 9.3 Building Platform Development

A subsurface investigation for the purposes of foundation design has not been undertaken at the time of this report. Based on cut batter exposures and the penetrometer test results it is expected that the ground conditions at foundation level within the proposed building platforms will be generally favourable.

Bearing capacities should be such that foundations can be designed in accordance with NZS3609:2004 *Timber Framed Buildings*. It would be prudent to allow for localised soft zones, as there may be some soft natural ground and/or non-engineered filling present.

Further subsurface investigations will be required during the detailed design stage. Ground conditions will need to be verified during construction.

Assessment of ground retention requirements (retaining walls, etc) is outside the scope of this report.

## 10.0 PILOT BAY TENT SITES

### 10.1 General

As described previously, the proposed works within this area will be limited to small scale measures to improve functionality, such as stabilising the outside edge of the existing cut bench and upgrading stormwater control.

The uncertainties in predicting future rockfall events were reflected in an event in June 2005, when a large boulder near the base of the terraced mid-slope area became dislodged and rolled into the gully. The boulder had not previously been identified as being at particularly high risk and, although it occurred a relatively short time after the extreme storm of May 2005, the storm that actually triggered the movement was not particularly severe.

Investigations showed the boulder had been sitting on disturbed topsoil, indicating it had become emplaced since maori occupation<sup>5</sup>. The boulder was stabilised by rolling it into a pre-dug hole.

A detailed mapping exercise was undertaken on the slopes overlooking this side of Mauao by Avalon in mid-2005. A total of fifteen boulders were identified as being unstable. These were dislodged and made secure. Most only rolled a few metres and none of the boulders got anywhere near the base of the slope.

The assessed level of risk to the southern part of the campground is consistent with previous assessments undertaken by TCC, being somewhat lower than the northern sector. While a detailed rockfall analysis has not been undertaken at this time, aspects such as the 2006 event indicate some form of protection measures should be installed across the highest area of risk.

## 10.2 Proposed Approach

The proposed approach is to replace the existing post-and-wire fence across the gully feature with a rockfall fence. The new fence would be essentially the same as that behind the cabins area, 2.0m high, painted matt green, etc. It would be located along the existing boundary fence and within an established grove of trees (refer Figure 4 in Appendix A), and so should be indistinguishable beyond the site.

A preliminary cost estimate for a rockfall fence within this area is as follows:

Preparatory works

Rockfall fence - 65m long at s 7(2)(h) - Com per metre - say

Engineering design and certification

SUBTOTAL

Contingency - s 7(2)(h) - Commercial activ

TOTAL (exclusive of GST)

Notes:

- Extend across the gully
- Preliminary costing, based on indicative rates. Appears somewhat conservative
- Retention capacity up to 250 kJ
- Excludes landscaping and other works

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<sup>5</sup> The location suggests the boulder was moved to allow terracing for gardens, although it could alternatively have been a man-induced or natural rockfall.

## 11.0 SUMMARY OF KEY RECOMMENDATIONS

A summary of the key geotechnical recommendations for the proposed upgrading project at the Mount Motorcamp is as follows:

- (a) A specialist rockfall interception fence system should be installed along the existing upslope boundary fence behind the proposed cabins towards the northern end of the campground. Preliminary analysis indicates a fence height of 2.0m is satisfactory, although this could be increased if a higher level of protection was desired.
- (b) The cabin buildings should be spaced to allow for an overland flowpath down the central part of the gully, for stormwater runoff and soil/debris not captured by the rockfall fence.
- (c) A similar rockfall fence should be constructed across the gully on the upslope side of the tent sites in the southern part of the campground. This fence would be up to 2.0 m high.
- (d) The rockfall protection systems will need to be subject to specific design and supervision of construction.
- (e) Other aspects of the proposed development such as earthworks, building foundations and retaining walls will also need to be subject to specific geotechnical design.
- (f) The subgrade soils for the building foundations and retaining wall(s) should be inspected and approved by a suitably experienced Chartered Professional Engineer familiar with the contents of this report. Any variation from the inferred subsurface model described herein should be referred back to Terrane Consultants to allow assessment of its significance.

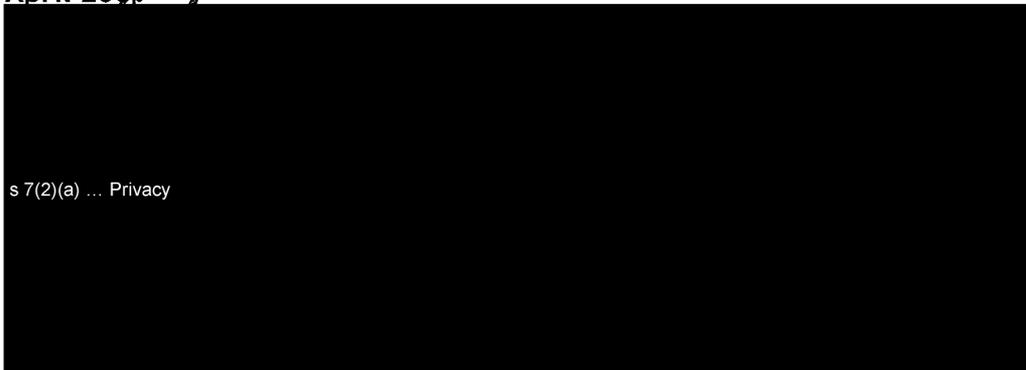
## 12.0 APPLICABILITY

This report has been prepared for Tauranga City Council with respect to the specific brief given to us. It shall not be used in any other context without our prior review and written agreement.

Comments and recommendations given in this report relate to the specific development proposal described to us. Any change to the scope of development should be checked for any geotechnical issues arising.

Terrane Consultants Ltd

April 2009



s 7(2)(a) ... Privacy