REPORT

TO
HUNTINGDON NURSING HOME
C/- TRINITY MANAGEMENT SERVICES PTY LTD

ON
GEOTECHNICAL INVESTIGATION

FOR
PROPOSED NURSING HOME DEVELOPMENT

AT
181 FOREST WAY, BELROSE, NSW

3 September 2018
Ref: 30222SMrpt

JK Geotechnics
GEOTECHNICAL & ENVIRONMENTAL ENGINEERS

PO Box 976, North Ryde BC NSW 1670
Tel: 02 9888 5000 Fax: 02 9888 5001
www.jkgeotechnics.com.au

Jeffery & Katauskas Pty Ltd, trading as
JK Geotechnics ABN 17 003 550 801

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Report prepared by:

Matthew Pearce
Associate I Geotechnical Engineer

Report reviewed by:

Paul Stubbs
Principal I Geotechnical Engineer

For and on behalf of
JK GEOTECHNICS
PO Box 976
NORTH RYDE BC NSW 1670

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1 INTRODUCTION

This report presents the results of a geotechnical investigation for a proposed nursing home at 181 Forest Way, Belrose. The investigation was commissioned by return of an acceptance of proposal form dated 16 February 2017, and was completed generally in accordance with our proposal P43456SM dated 27 September 2017.

Based on the supplied Morrison Design Partnership architectural drawings (Pro No 2951 DA050, 101 to 105, 200, 201 and 300 all Rev B dated 31 August 2018), we understand the development includes the following:

- A two to four level nursing home development
- The development is limited to the western (upper) portion of the site,
- The Lower Ground Floor (LGF) of RL163.1m and Ground Floor Level (GFL) of RL167.2m will be partially cut into the hillside requiring maximum cuts of 7.3m from existing surface levels but typically in the order of 2.5m to 4.5m.
- Conversely, the lower ground floor level will be up to 4.8m above existing surface levels requiring either fill and/or a retaining wall or to be structurally suspended above grade.
- Required excavation would have set backs of
  - 20m from the front (western) boundary with Forest Way,
  - 10m from the southern side boundary,
  - 20m to 30m from the northern boundary and
  - about 100m from the rear (eastern), and
- A driveway and a small parking area at RL167.05m toward the southern end of the property frontage with Forest Way, providing access to a ramp to a GFL car park.
- A deceleration lane off Forest Way

The purpose of the investigation was to obtain geotechnical information on the subsurface conditions, and to complete a geotechnical slope stability assessment to identify the hazards and assess the risk to property and the risk to the person most at risk. This assessment is in accordance with the Australian Geomechanics Society Landslide Risk Assessment methodology of 2007. The investigation, together with the assessment, was used as a basis for providing comments and recommendations on excavation, batters, retaining walls, footings floor slabs and pavements.

With reference to Warringah LEP 2011 Landslip Map Sheet LSR_007 and Northern Beaches Council requirements for DA application for 'Development on Sloping Land', we consider the property would be classified as in “Area B- Flanking Slopes 5° to 25°” and this report covers the necessary criteria.

No contamination testing of the soils was completed as part of this investigation.

2 INVESTIGATION PROCEDURE

The fieldwork for the investigation was carried out on 3 March 2017, and comprised the drilling of seven boreholes (BH1 to BH7) using spiral auger techniques with our track mounted JK308 drilling rig. The boreholes were drilled to refusal to further penetration of the tungsten carbide bit at depths ranging from 1.4m to 5.8m below existing surface levels.

The site location is shown on Figure 1. The borehole locations, as shown on the attached Figure 2, were set out by taped measurements from existing surface features. The approximate surface reduced levels shown on the attached borehole logs were estimated by interpolation between spot levels and contours shown on the supplied survey plan (Ref. $19442^{\text{Rev 00}}$ Sheets 2, 3 and 5 dated 14 April 2017). The datum is the Australian Height Datum (AHD).

The strength and relative density of the soils were assessed from the Standard Penetration Test (SPT) ‘N’ values. The strength of the rock in the boreholes was assessed by observation of auger penetration resistance whilst using a tungsten carbide (TC) bit, together with examination of recovered rock cuttings. We note that rock strengths assessed in this way are approximate and variations of about one order of strength should not be unexpected.

Groundwater observations were made during and on completion of drilling each borehole. Heavy rainfall occurred during the day of fieldwork infiltrating the open boreholes preventing further groundwater observations. No long term groundwater monitoring was carried out.

Our Senior Geotechnical Engineer, Mr Matthew Pearce, was present on a full-time basis during the fieldwork to set out the investigation locations, nominate the sampling and testing, and prepare the borehole logs. The borehole logs are attached, together with a glossary of the terms and symbols used in the logs.

Mr Pearce also completed a detailed inspection of the topographic, surface drainage and geological conditions of the site and its immediate environs. The strength of rock outcrops was assessed by sounding with a geological pick. The principal geotechnical features and slope stability hazards are presented on Figures 3a and 3b using the survey base plans. Figure 4A shows an overview of the site and the location of two cross sections which have been prepared. A typical long section and a section showing the steepest surface profile are presented as Figures 4B and 4C which also show some of the geotechnical features and slope stability hazards. These features were compared to those of other similar lots in neighbouring locations to provide a comparative basis for assessing the risk of instability affecting the proposed development. The attached Appendix A defines the terminology adopted for the risk assessment together with a flow chart illustrating the Risk Management Process based on the guidelines given in the Australian Geomechanics Vol 42, No 1, (AGS) 2007c (Reference 1).

Selected samples of the soil were returned to Soil Test Services (STS), a NATA registered laboratory, for standard compaction and four day soaked CBR testing. The results of the testing are presented in the attached STS Tables A. Additional samples of the augered soil and rock were sent to Envirolab Services Pty Ltd, also a NATA registered analytical laboratory, to determine pH, sulphate content, chloride content and soil resistivity. The results of these tests are summarised in the Envirolab Services Certificate of Analysis No.163255.

For further details of the investigation techniques adopted, and their limitations, reference should be made to the attached Report Explanation Notes.

3 RESULTS OF INVESTIGATION

3.1 Site Description

The site at 181 Forest Way is located on the eastern side of a broad ridgeline along which Forest Way runs. The site is approximately 190m long (east-west) by about 95m to 127m wide (north-south). It typically has gentle and moderate falls eastwards from about RL167m to 170m at the western street frontage, to about RL145m at the eastern end of the site. Beyond the site to the east is the heavily vegetated natural gully of Snake Creek.

There is a localised hill peak about mid-length of the northern side boundary, beyond which is laneway which becomes a fire trail as it traverses the peak and descends towards the creek. From the peak there are a series of rounded sandstone bedrock outcrops typically about 1.5m in height although as tall as 3m at the summit. The outcrops and rock shelves have an overall slope down to the south-east of about 15° to 30°. The outcrops become less distinct in the landscape towards the middle of the site.

Except for the influence of the hill peak, the relatively flat ridge line of Forest Way extends for about 50m into the site, after which there are moderate slopes (10 to 25°) for a further 50m to 70m and then flatter slopes (5° to 10°) over the lower reaches of the site.

The site contains two semi-detached single-storey brick and masonry houses with car ports, decks and an above ground pool located towards the front of the site. There is an unsurfaced driveway off the northern side lane, also linking to a separated large car port to the north-east of the houses. There are lawns around the houses with a few large trees. To the rear of the house is a large water tank in a small cutting into the hillside. There is exposed sandstone bedrock in this cutting and several exposures of sandstone rock in the lawn. From the large carport there is a gravel surfaced track winding down and across the hillslope to the lower portion of the site. The middle and lower slopes comprise recently cleared and back burned bushland with numerous exposures of sandstone bedrock at the surface, as well as small outcrops and rock shelves.

Most of the rock was assessed as medium or high strength, although to the north of the internal track (about 20m downslope from the water tank) was a large exposed batter slope of low strength sandstone. There was some onion skin weathering of rock shelves observed. On some of the rock shelves there are also boulders of (1m to 2m diameter) most of which are flat and elongated, resting on outcrops. Some boulders however have clearly been repositioned at the toe of an embankment to support a short section of the internal track, as shown on Figure 3a.

A drainage channel had been cut into bedrock adjacent to the upslope side of the internal track. Stormwater (from intense rain during the fieldwork) dispersed onto the lower slopes and then drained down a natural rock channel in the south-eastern corner of site.

To the south of the site is a another large residential property, the house of which is also on the broad ridge line set back about 10m from the common boundary. This property has similar slopes and levels across the common boundary except where there has been a 1.5m to 3m deep cutting into the bedrock to accommodate a tennis court located about mid-length along the boundary. The cut rock face was assessed as being of medium strength and free of adversely inclined defects.

The western street frontage with Forest Way is marked by a strip of dense vegetation with medium and tall trees located within the subject site. Forest Way has a concrete footpath, grass verge and overhead services. It is relatively flat.

The northern, southern and eastern boundaries are marked by wire chain link fencing. Site slopes of about 5° extend beyond the rear (eastern) boundary for about 5m to 10m, after which are steep vegetated slopes in the order of 25° to 35° with rock outcrops extending down towards a gravel fire trail/walking track. The track traverses the lower shallower slopes of Snake Creek.

3.2 <u>Geology and Subsurface Conditions</u>

Reference to the 1:100,000 Sydney Geological Series Sheet indicates that the site is underlain by Hawksbury Sandstone. Generally, the boreholes encountered a shallow layer of fill, and at a few locations sandy soil, over sandstone bedrock at depths ranging from 0.2m to 1.0m below existing ground surface levels. Some of the more pertinent details of the encountered subsurface profile are discussed below but for more specific details reference should be made to the attached borehole logs.

Fill

Silty sandy topsoil fill or sandy gravel fill was encountered in all boreholes to depths ranging from 0.2m (BH1 to BH3) to 0.65m (BH5).

Natural Sand

Natural clayey sand was encountered in BH3 while in BH4 and BH5 there was silty sand beneath the fill. The natural sands were assessed to be of very loose to loose, or loose relative density and extended to depths ranging from 0.85m to 1.0m.

Sandstone Bedrock

Sandstone bedrock was encountered in all the boreholes from depths ranging from 0.2m to 1.0m below existing ground surface levels.

The upper metre of rock was typically low to medium strength in BH1, BH2 and BH4. High strength rock was encountered within 0.6m to 1.9m from the top of rock in these boreholes. However high strength rock was encountered within the top metre at all other boreholes and as a result caused TC bit refusal in all but BH6. In BH6, the rock became of medium and very low strength to 5.5m depth where refusal occurred.

As described in Section 3.1, the exposed sandstone was assessed as medium or high strength, except in one area where it was low strength.

Groundwater

No groundwater was noted during the augering of the boreholes, and the infiltration of surface stormwater precluded further useful measurements on the day of the fieldwork. No long term groundwater monitoring was carried out.

3.3 Laboratory Test Results

Table A contains the result of soaked CBR test completed on a sample of the natural sandy. The result was 18%, indicating a potentially good subgrade is present at the site.

The results of the pH tests indicated the rock and sandy soils to be moderately acidic with the pH ranging from 4.7 to 5.8. The sulphate and chloride contents were all very low with all results being less than 36 ppm (mg/kg). The resistivity was ranged from 310 to 470 ohm m (31,000 to 47,000 ohm cm) which is high.

4 GEOTECHNICAL ASSESSMENT

4.1 Summary of Assessment

The overall ground surface of the site slopes are of a shallow to moderate gradient, falling across the site from west to east with numerous and extensive exposures of sandstone bedrock. Where surface slopes are locally steeper (20° to 30°) they comprise a series of rounded rock outcrops so we would expect all slopes to be relatively stable under existing site conditions. There are a few detached boulders on some of the outcrops but due to their slabby shape most are unlikely to be able to roll downslope.

There appears to have been minimal cut and fill on the site and there are no retaining walls, nor are there any rock cuttings greater than about 1.5m. The exception is a short section of track which appears to be a filled soil embankment for an internal track across the site. If either this embankment or any more rounded boulders did slide or rotate there are ample flatter gradients within the lower portion of the site such that there is minimal risk to any persons or structures beyond the site. Nor are there existing or proposed structures in the lower portion of the site.

The landslide hazards and risk assessment process are described in more detail in the following subsections.

The assessment of site slope stability has been made using the guidelines presented in the Landslide Risk Management Concepts and Guidelines prepared by the Australian Geomechanics Society, Sub-Committee on Landslide Risk Management[1]. In this regard an acceptable risk for loss of life for the person most at risk of $1x10^{-5}$ has been adopted for existing slopes/structures and $1x10^{-6}$ for new developments. For loss to property the acceptable risk should be determined by the owner, provided loss to property only affects the owners' property and does not impact on the property of others. As a guide, some council's Interim Landslide Risk Management Plan adopts an acceptable risk to property posed by existing slopes as 'Low'. Where risks posed by slope instability are considered unacceptable, remedial measures should be adopted to reduce the risk posed to an acceptable level.

The risk to life assessment has been made on a semi-quantitative basis with quantitative values assigned to qualitative assessments. The risk to property assessment has been carried out in qualitative terms. The range of annual probabilities assigned to the likelihood of events occurring, the recommended vulnerability values and the qualitative risk analysis matrix are presented in Appendix A.

The qualitative assessments are based on judgements made in the field by the geotechnical engineer and in this regard are subjective and formed in part by the engineers' previous experiences. For example, if the area below Hazard B is used regularly the overall risk would increase accordingly.

4.2 Potential Landslide Hazards

We consider that the potential landslide hazards associated with the site to be the following:

A Failure of 20° soil embankment with boulders along the toe

B Failure of Rock Outcrops

C Rotation of Boulders

These potential hazards are indicated in schematic form on the attached Figures 3A and 3B, and some on Figure 4B and 4C.

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[1] Australian Geomechanics Society (2007c) *'Practice Note Guidelines for Landslide Risk Management'*, Australian Geomechanics, Vol 42, No 1, March 2007, pp63-114

4.3 Risk Analysis

The attached Table A summarises our qualitative assessment of each potential landslide hazard and of the consequences to property should the landslide hazard occur. Based on the above, the qualitative risks to property have been determined. The terminology adopted for this qualitative assessment is in accordance with Table A1 given in Appendix A.

Table A indicates that the assessed risk to property varies between Very Low, which would be considered acceptable in accordance with the criteria given in Reference 1.

We have also used the indicative probabilities associated with the assessed likelihood of instability to calculate the risk to life. The temporal and vulnerability factors that have been adopted are given in the attached Table B together with the resulting risk calculation. Our assessed risk to life for the person most at risk is [4.5×10^{-9}]. This would be considered to be acceptable in relation to the criteria given in Reference 1.

4.4 Risk Assessment Conclusion

Based on the assessment presented in Tables A and B above, the site in its present state poses an acceptable risk to life and a low risk to property.

Provided our comments and recommendations are followed, the risk to both property and the person most a risk following the construction of the proposed development will be not greater than the risk posed by the site in its current condition. We assume that good design and construction practices will be adopted during this development.

5 COMMENTS AND RECOMMENDATIONS

5.1 Excavation

The construction of the proposed development will require excavations to maximum depths of 7.3m in the north-western corner, and about 5m in the south-western and north-eastern building corners. These excavations will extend through the fill and natural sands which are of limited depth, and into sandstone bedrock of high strength. The south-eastern portion of the proposed building is the exception where fill is likely to be required to achieve the finished subgrade levels, unless the slab is to be fully suspended.

The sandy soils should be readily excavated using conventional earthmoving equipment such as tracked excavators. The excavation of sandstone bedrock to very low to low strength should be achievable using ripping tynes on large excavators of say 30-40 tonne size but such low strength rock should be expected to be in the minority.

Sandstone of medium or higher strength will likely be effectively unrippable to conventional excavators, however, the site is large enough to make use of a bulldozer (such as a D10) with a tyning hook, which we expect will be the most effective technique for the bulk works. This should be used in combination with rock breaker attachments fitted to large hydraulic excavators for excavation closer to the edges of the building outline and also to assist with high strength bands which are known to be present, although the thickness of high strength rock has not been determined from investigations to date. Further investigation comprising cored boreholes and strength index testing could be carried out to assist with obtaining tenders based on detailed expectation of rock conditions. On site trials/demonstrations could also be suggested to prospective earthworks contractors.

Where rock breakers are used for excavation, there is the risk of potentially damaging vibrations to be generated. We consider the risks to be relatively low at this site where the neighbouring buildings are set back about 30m or so from the proposed excavation, however, some quantitative vibration monitoring should be completed at the commencement of the use of rock breakers. Provided the initial monitoring confirms the vibrations at these distances are well below threshold levels, as would be expected, then the remainder of the excavation should continue with just tactile monitoring by the site foreman/supervisor provided the excavation is undertaken with similar excavation and techniques, and there is no significant change in strata. Reference should be made to the attached Vibration Emission Design Goals (Group 2 limits).

For detailed footing excavations we recommend the outlines are initially cut with a rock saw and then hammered with small to medium sized excavators to prevent over-break.

5.2 Batter Slopes and Retention

Temporary batters in the sandy soils should be no steeper than 1 Vertical (V) in 1.5 Horizontal (H), and surcharge loads must be kept well clear of the crests of these batters. Even at these slopes there could be some minor slumping of the soils, especially when subjected to vibration such as from rock breaking activities. Therefore we recommend that the toes of such batters be kept at least 0.5m back from the crest of cuts in the sandstone bedrock. Any permanent cuts in the sandy soils should be battered at no steeper than 1V in 2.5H and should be protected such as by a dense vegetative cover.

Where sandstone is of at least low to medium strength, it could be cut vertically subject to geotechnical inspection of the faces following each 1.5m lift of excavation. The purpose of the inspection is to assess whether there are any defects which form potentially unstable blocks of sandstone, and if such features are encountered, the geotechnical engineer must provide advice on appropriate stabilisation measures. These stabilisation measures must then be implemented prior to undertaking further excavation in that area.

Where the sandstone is of low strength or lower, it should be battered at no steeper than 1V in 0.5H, and again these cuts should be inspected by a geotechnical engineer following each 1.5m lift of excavation.

In the lower south-eastern portion of the proposed building, one option would be to place fill to reach the proposed LGF. Assuming this fill comprises sandstone won from the other building excavations, batters in the fill should not exceed 1V in 1H in the short term and 1V in 2H in the long term. However, due to the moderately steep slope, long term batters downslope of the proposed LGF would extend a significant distance making this option unlikely to be adopted.

Construction of a retaining structure first and backfilling behind it would be another option. Fill for the purpose of permanently supporting a slab on grade should be compacted as engineered fill. Reference should be made to Section 5.6 for details on material and compaction specifications, however, with a variable and significant depth of new fill there would be differential settlement (in terms of magnitude and time). For design of retaining structures reference should be made to Section 5.4. Our preference would instead be to use the fill in lieu of formwork to support the concrete slab pour and for the slab to be structurally suspended. For this purpose we still recommend the fill be nominally compacted such as by track rolling. The cost difference between provision of a retaining wall and suspending the slab over a void will have to be evaluated.

For temporary fill batters greater than 3m height, the lower 3m should comprise carefully stacked boulder sized pieces of excavated sandstone thus in effect forming a stable, non-erodible gravity wall for the base.

5.3 Long Term Rock Face Protection

Where the sandstone cut faces are of medium strength or stronger, they would be considered to be suitable to stand vertically in the long term provided:

- The faces are not exposed to the weather;
- Any stabilisation measures recommended during the inspection are carried out; and
- Any weathered or clay seams are raked out and replaced with dry packed cementitious mortar. The thickness of the mortar should be at least equal to the seam height. Weep holes must be drilled through the mortar at 0.5m centres to allow the dissipation of seepage from behind the mortar.

Where the sandstone is of low strength or weaker, it would be expected to continue to weather and fret over time. Therefore such rock faces should be supported by either spraying the batters with reinforced shotcrete held in place by steel rock bolts, or by constructing and backfilling a retaining wall adjacent to the rock excavation.

5.4 Retaining Wall Design

As the proposed excavations are set well back from the boundary, and the sandy soils are shallow, we assume the basement would be constructed with temporary batters in the soils and weaker rock, and vertical cuts in the stronger rock. The permanent case would probably require low height retaining walls above low to medium strength rock cuts, or full-height retaining walls where cuts are in rock of less than low to medium strength. We note the investigation results will give some guidance as to where full height retention will be required in the long term, but the final decision must be made following the completion of excavation when the entire rock faces can be inspected.

Retaining walls constructed where some minor movements of the walls is tolerable may be designed for an active lateral earth pressure coefficient (Ka) of 0.33 for the sandy soils, engineered fill and extremely low strength sandstone bedrock, and 0.25 for sandstone bedrock of very low and low strength. Sandstone bedrock of at least medium strength should be assumed to be self-supporting in the long term provided any stabilisation recommended during the geotechnical inspections is carried out. Where a retaining wall is offset from the cut face and the void backfilled, the pressure coefficient will be dependent upon the backfill used, though we recommend a Ka of 0.33 assuming granular backfill will be used.

Where the retaining walls will be braced, such as where they are integrated with the proposed structure, they should be designed for at-rest lateral earth pressure coefficients (K_o) of 0.5 for the sandy soils, engineered fill and extremely low strength sandstone bedrock, and 0.4 for sandstone bedrock of very low and low strength.

The active and at-rest lateral earth parameters above are for near horizontal back-slopes only, and must be appropriately increased for sloping backfill.

Retaining walls must also be designed for appropriate surcharge loads and hydrostatic pressures, and drainage should be installed behind the walls to remove hydrostatic pressures from immediately behind the walls.
Compaction stresses must also be considered in the retaining wall design. To avoid the need for detailed compaction of the backfill, consideration should be given to using a free-draining, hard and durable backfill such as crushed uniform sized igneous rock gravel or concrete, which could be tamped into place in nominal 0.5m thick layers. The upper 0.5m of fill should comprise a more clayey soil to prevent surface water flowing into the retaining wall backfill, with a non-woven filter geotextile between the free draining backfill and overlying soil.

5.5 Subgrade Preparation

The following subgrade preparation should be undertaken in all areas where fill will be placed to support buildings, or where pavements will be constructed.

All existing fill, topsoil, and soil containing deleterious substances such as significant organic matter should be stripped from these areas and disposed of or reused for soft landscaping purposes. Any excavation to achieve the required subgrade level should then be undertaken. The exposed subgrade soils should be proof rolled using at least eight passes of a five-tonne smooth drum roller without vibration. If the proof rolling is causing shearing of the sandy soils, the rolling should be terminated, and a layer of 150mm thickness of material such as crushed sandstone or DGS40 placed and compacted; this will require some minor additional excavation below the subgrade level. The purpose of the select layer is to form a layer which will bind and prevent the shearing of the underlying sands during rolling. Following the compaction of this layer, the last compaction pass of this layer should be witnessed by a geotechnical engineer or experienced earthworks superintendent to confirm the subgrade is not exhibiting any further heaving. If there is any further heaving, localised excavation to a sound base and replacement with engineered fill will be required.

Proof rolling is not required where sandstone bedrock of at least very low strength is present.

5.6 Engineered Fill

Any fill required to replace heaving subgrade, or to raise site levels to support buildings or pavements, should be placed as engineered fill. Engineered fill should preferably comprise a well graded select granular material such as crushed or ripped sandstone, containing no organics or other deleterious substances, and with a maximum particle size not exceeding 75mm. The sandstone won from the building excavations would be expected to produce suitable fill, provided it is appropriately crushed to remove oversize particles, and to provide a reasonably well graded material. These materials should be compacted in layers not exceeding 200mm loose thickness to a density of at least 98% of Standard Maximum Dry Density (SMDD).

While it would be theoretically possible to reuse the sandy soils, our observations suggest that in much of the site the sands contain a high proportion of silt, and hence will be quite difficult to work with, as they would be moisture content sensitive and they will tend to shear on compaction which causes a reduction in compaction. We therefore recommend the sandstone from the excavation be used for engineered fill.

In-situ density tests must be completed on each layer of engineered fill to confirm the target density is being achieved. The rate of testing must comply with at least the minimum frequency specified in AS3798-2007. Where the fill will support floor slabs or small free standing structures, the earthworks should be completed under Level 1 testing as defined in AS3798, while Level 2 testing would be considered suitable below paved areas.

5.7 Footing Design

Sandstone bedrock will be exposed at bulk excavation level for the entire building. Where the LGF is above existing levels, sandstone bedrock will be at shallow depth below surficial vegetation and fill. All footings should be uniformly founded on sandstone bedrock using pad and/or strip footings to support the proposed structures.

Few of the boreholes penetrated the high strength rock to reach the proposed footing level. Furthermore, there is some variability of the assessed rock strength between borehole locations with some very low strength sandstone in BH6, albeit well below the likely footing level. Unless further investigation or proving of the footing material is undertaken, the footings founded with a nominal 0.3m socket into the sandstone bedrock of at least very low strength should be designed for an allowable bearing pressure of 1,000kPa. The settlement of footings designed for these bearing pressures would be expected to be less than 1% of the footing width. Representative footing excavations should be inspected to confirm the strata being exposed in the footings is suitable for these pressures.

Following additional investigation, it may be possible to increase the design allowable bearing pressures used in parts of the site, possibly to 3,500kPa or so, but it must be noted that bands of weathered shale (for example) can occur and an increase in rock quality with depth cannot be assumed.

Investigation could comprise a number of cored boreholes drilled prior to bulk excavation works. Alternatively, the rock should be inspected by a geotechnical engineer upon completion of bulk excavation and ‘spoon tests’ be completed at 1/3 of the footing locations with every footing excavation also inspected by a geotechnical engineer. To facilitate spoon tests which would be completed by a geotechnical engineer, 50mm diameter cored holes drilled from the base of the footing excavation, to 1.5 x the breadth of the footing, are required.

5.8 Earthquake Loading

Table 3.2 of 1170.4-2007 shows the hazard factor (Z) for Sydney to be 0.08, while the sub-soil class is B_e (Rock) as there is less than 3m of soil on the site.

5.9 Pavements

Where proposed pavements will be constructed over the natural sandy soils such as may be the case in the south-western corner of the site (for the entry courtyard), we recommend they should be designed for a CBR value of 10%. However, it may well be that the soil is completely removed to achieve the design depth of pavement exposing sandstone bedrock at subgrade level across this pavement area. Care is required with rock subgrades as undulations in the rock surface can result in water ponding which can cause rapid break up of pavement layers due to pumping.

Most of the trafficable LGF slab (basement carpark) will be over sandstone bedrock of at least low strength. The basement will typically be excavated into at low strength sandstone bedrock. Some seepage will likely occur at the soil/rock interface and this will be able to be controlled by conventional sump and pump methods or gravity drainage during construction. In the long term we recommend that subsoil drainage be provided below the basement slab around the perimeter and we expect that the subsoil drains will likely be able to be dispersed by gravity drainage to the east.

The basement slab should also be underlain by a good quality durable igneous gravel sub-base (such as DGB20) to provide a uniform bearing layer for the basement slab and also to provide a separation layer from the sandstone bedrock subgrade. Sand should not be used below trafficable slabs. Rigid/concrete pavements should have keyed or doweled joints to transfer shear forces and prevent stepping at joints.

We expect the deceleration lane, being part of an RMS maintained road, will require specific additional boreholes to be drilled and additional CBR samples obtained, following DA, prior to CC.

5.10 Groundwater Issues

Minor seepage through defects in the rock mass should be expected. There could also be minor ponds of groundwater in surface undulations of the rock, particularly following heavy or prolonged rainfall. Where seepage is through defects within sandstone bedrock, these defects are generally of quite low permeability. Therefore while seepage should be expected during the excavation and in the long term, we expect that it would be adequately controlled using gravity drainage methods. The collected water could be piped downhill of the proposed development and disposed of by release as diffused surface flows along a contour in such a manner as to prevent erosion in the shallow surface soils. The site is not considered suitable for the use of infiltration trenches due to the lack of soil depth over the rock.

5.11 Soil Aggression

Based on the pH test results, the soil and rock has a 'Mild' exposure classification in accordance with Table 6.4.2(C) of AS2159-2009. The sulfate chloride and resistivity were below levels which influence the classification. The minimum concrete strength and reinforcement cover provisions of AS2159 must be taken into account in the design of concrete elements in contact with the soil.

5.12 Summary of Additional Geotechnical Works

As discussed in more detail above, the following additional geotechnical works investigations and or inspections:

- Drilling of boreholes for the RMS deceleration lane and sampling and testing for specific CBR. We can also assist with pavement thickness design
- Inspection of subgrade for pavements
- Possible coring for more detailed information for excavation tenders, and for early confirmation of the suitability for higher footing bearing pressures

- Vibration monitoring at commencement of excavation
- Inspection of temporary and permanent batters
- Inspection of rock at bulk excavation
- Inspection of all footings and spoon testing of 1/3 of footings where appropriate

6 GENERAL COMMENTS

The recommendations presented in this report include specific issues to be addressed during the construction phase of the project. As an example, special treatment of soft spots may be required as a result of their discovery during proof-rolling, etc. In the event that any of the construction phase recommendations presented in this report are not implemented, the general recommendations may become inapplicable and JK Geotechnics accept no responsibility whatsoever for the performance of the structure where recommendations are not implemented in full and properly tested, inspected and documented.

The long term successful performance of floor slabs and pavements is dependent on the satisfactory completion of the earthworks. In order to achieve this, the quality assurance program should not be limited to routine compaction density testing only. Other critical factors associated with the earthworks may include subgrade preparation, selection of fill materials, control of moisture content and drainage, etc. The satisfactory control and assessment of these items may require judgment from an experienced engineer. Such judgment often cannot be made by a technician who may not have formal engineering qualifications and experience. In order to identify potential problems, we recommend that a pre-construction meeting be held so that all parties involved understand the earthworks requirements and potential difficulties. This meeting should clearly define the lines of communication and responsibility.

Occasionally, the subsurface conditions between the completed boreholes may be found to be different (or may be interpreted to be different) from those expected. Variation can also occur with groundwater conditions, especially after climatic changes. If such differences appear to exist, we recommend that you immediately contact this office.

This report provides advice on geotechnical aspects for the proposed civil and structural design. As part of the documentation stage of this project, Contract Documents and Specifications may be prepared based on our report. However, there may be design features we are not aware of or have not commented on for a variety of reasons. The designers should satisfy themselves that all the necessary advice has been obtained. If required, we could be commissioned to review the geotechnical aspects of contract documents to confirm the intent of our recommendations has been correctly implemented.

This report has been prepared for the particular project described and no responsibility is accepted for the use of any part of this report in any other context or for any other purpose. If there is any change in the proposed development described in this report then all recommendations should be reviewed. Copyright in this report is the property of JK Geotechnics. We have used a degree of care, skill and diligence normally exercised by consulting engineers in similar circumstances and locality. No other warranty expressed or implied is made or intended. Subject to payment of all fees due for the investigation, the client alone shall have a licence to use this report. The report shall not be reproduced except in full.

TABLE A: SUMMARY OF RISK ASSESSMENT TO PROPERTY

	POTENTIAL STABILITY HAZARD		
	A	**B**	**C**
	Soil Embankment Failure	**Rock Outcrops**	**Boulders**
Assessed Likelihood	Possible	Rare	Unlikely
Assessed Consequences	Insignificant	Insignificant	Insignificant
Risk	Very Low	Very Low	Very Low
Comments	**Assumes fill is granular as would be expected from site won material.** **No existing or proposed structures above or below.**	Assumes rock is free of adverse defects. No such defects observed during walkover for this assessment.	Only a few boulders were rounded and would require a highly unlikely trigger to activate movement. Most boulders were too elongate to rotate.

Assumed property price: $3,500,000

TABLE B: SUMMARY OF RISK ASSESSMENT TO LIFE

	POTENTIAL STABILITY HAZARD		
	A	**B**	**C**
Assessed Likelihood	Possible	Rare	Unlikely
Indicative Annual Probability	1×10^{-3}	1×10^{-5}	1×10^{-4}
Duration of Use of Area Affected (Temporal Probability)	Walking along track to access lower section of site: 1 min / week	Leisure walking amongst rock outcrops: ½ hour/ week	Leisure walking amongst rock outcrops: ½ hour/ week
	9.9×10^{-5}	1.7×10^{-6}	1.7×10^{-6}
Probability of Not Evacuating Area Affected	1	1	0.5
Spatial Probability	1	1	1×10^{-2}
Vulnerability to Life if Failure Occurs Whilst Person Present	Possibly buried 0.5	Likely to be crushed 1	Likely to be crushed 1
Risk for Person Most at Risk	4.5×10^{-9}	1.7×10^{-11}	1.7×10^{-12}
Total Risk for Person Most at Risk	**4.5×10^{-9}**		

115 Wicks Road
Macquarie Park, NSW 2113
PO Box 976
North Ryde, BC 1670
Telephone: 02 9888 5000
Facsimile: 02 9888 5001

SOIL TEST SERVICES
ABN 43 002 145 173

TABLE A
FOUR DAY SOAKED CALIFORNIA BEARING RATIO TEST REPORT

Client:	JK Geotechnics	**Ref No:**	30222SM
Project:	Proposed Nursing Home	**Report:**	A
Location:	181 Forest Way, Belrose, NSW	**Report Date:**	15/03/2017
		Page 1 of 1	

BOREHOLE NUMBER	5
DEPTH (m)	0.65 - 1.00
Surcharge (kg)	4.5
Maximum Dry Density (t/m^3)	1.92 STD
Optimum Moisture Content (%)	12.8
Moulded Dry Density (t/m^3)	1.87
Sample Density Ratio (%)	98
Sample Moisture Ratio (%)	104
Moisture Contents	
Insitu (%)	18.9
Moulded (%)	13.3
After soaking and	
After Test, Top 30mm(%)	13.8
Remaining Depth (%)	12.5
Material Retained on 19mm Sieve (%)	8*
Swell (%)	0.0
@2.5mm penetration	
C.B.R. value: @5.0mm penetration	18

NOTES:

- Refer to appropriate Borehole logs for soil descriptions
- Test Methods :
  - (a) Soaked C.B.R. : AS 1289 6.1.1
  - (b) Standard Compaction : AS 1289 5.1.1
  - (c) Moisture Content : AS 1289 2.1.1
- Date of receipt of sample: 7/03/2017
- * Denoes not used in test sample

NATA
NATA Accredited Laboratory Number:1327

Accredited for compliance with ISO/IEC 17025 - Testing.
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Authorised Signature / Date
(A. Tatikonda) 15/3/17

12 Ashley Street, Chatswood, NSW 2067
tel: +61 2 9910 6200

email: sydney@envirolab.com.au
envirolab.com.au

Envirolab Services Pty Ltd - Sydney | ABN 37 112 535 645

CERTIFICATE OF ANALYSIS 163255

Client:
JK Geotechnics
PO Box 976
North Ryde BC
NSW 1670

Attention: P Stubbs

Sample log in details:

Your Reference:	**30222SM, Belrose**	
No. of samples:	3 soils	
Date samples received / completed instructions received	09/03/17	/ 09/03/17

Analysis Details:
Please refer to the following pages for results, methodology summary and quality control data.
Samples were analysed as received from the client. Results relate specifically to the samples as received.
Results are reported on a dry weight basis for solids and on an as received basis for other matrices.
Please refer to the last page of this report for any comments relating to the results.

Report Details:

Date results requested by: / Issue Date:	16/03/17	/ 15/03/17
Date of Preliminary Report:	Not Issued	

NATA accreditation number 2901. This document shall not be reproduced except in full.
Accredited for compliance with ISO/IEC 17025 - Testing **Tests not covered by NATA are denoted with *.**

Results Approved By:

David Springer
General Manager

Misc Inorg - Soil				
Our Reference:	UNITS	163255-1	163255-2	163255-3
Your Reference	-------------	1	3	4
Depth	------------	1.7-2.0	0.5-0.85	0.5-0.8
Date Sampled		3/03/2017	3/03/2017	3/03/2017
Type of sample		Soil	Soil	Soil
Date prepared	-	14/03/2017	14/03/2017	14/03/2017
Date analysed	-	14/03/2017	14/03/2017	14/03/2017
pH 1:5 soil:water	pH Units	5.8	4.7	5.0
Chloride, Cl 1:5 soil:water	mg/kg	<10	<10	<10
Sulphate, SO4 1:5 soil:water	mg/kg	36	32	10
Resistivity in soil*	ohm m	390	310	470

Method ID	Methodology Summary
Inorg-001	pH - Measured using pH meter and electrode in accordance with APHA latest edition, 4500-H+. Please note that the results for water analyses are indicative only, as analysis outside of the APHA storage times.
Inorg-081	Anions - a range of Anions are determined by Ion Chromatography, in accordance with APHA latest edition, 4110-B. Alternatively determined by colourimetry/turbidity using Discrete Analyer.
Inorg-002	Conductivity and Salinity - measured using a conductivity cell at 25oC in accordance with APHA 22nd ED 2510 and Rayment & Lyons. Resistivity is calculated from Conductivity.

QUALITY CONTROL Misc Inorg - Soil	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base II Duplicate II %RPD	Spike Sm#	Spike % Recovery
Date prepared	-			14/03/2017	[NT]	[NT]	LCS-1	14/03/2017
Date analysed	-			14/03/2017	[NT]	[NT]	LCS-1	14/03/2017
pH 1:5 soil:water	pH Units		Inorg-001	[NT]	[NT]	[NT]	LCS-1	102%
Chloride, Cl 1:5 soil:water	mg/kg	10	Inorg-081	<10	[NT]	[NT]	LCS-1	82%
Sulphate, SO4 1:5 soil:water	mg/kg	10	Inorg-081	<10	[NT]	[NT]	LCS-1	91%
Resistivity in soil*	ohm m	1	Inorg-002	<1.0	[NT]	[NT]	[NR]	[NR]

Report Comments:

Asbestos ID was analysed by Approved Identifier:	Not applicable for this job
Asbestos ID was authorised by Approved Signatory:	Not applicable for this job

INS: Insufficient sample for this test	PQL: Practical Quantitation Limit	NT: Not tested
NR: Test not required	RPD: Relative Percent Difference	NA: Test not required
<: Less than	>: Greater than	LCS: Laboratory Control Sample

Quality Control Definitions

Blank: This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.

Duplicate: This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.

Matrix Spike : A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.

LCS (Laboratory Control Sample) : This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.

Surrogate Spike: Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.

Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction.

Spikes for Physical and Aggregate Tests are not applicable.

For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: <5xPQL - any RPD is acceptable; >5xPQL - 0-50% RPD is acceptable.

Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals; 60-140% for organics (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

Where sampling dates are not provided, Envirolab are not in a position to comment on the validity of the analysis where recommended technical holding times may have been breached.

Measurement Uncertainty estimates are available for most tests upon request.

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BOREHOLE LOG

Borehole No.
1
1/1

Client: HUNTINGDON NURSING HOME C/- TRINITY MANAGEMENT SERVICES PTY LTD
Project: PROPOSED NURSING HOME
Location: 181 FOREST WAY, BELROSE, NSW

Job No. 30222SM
Date: 3-3-17
Method: SPIRAL AUGER JK308
Logged/Checked by: M.P./P.S.
R.L. Surface: ≈ 169.4m
Datum: AHD

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0			FILL: Sandy gravel, fine to coarse grained igneous and sandstone, brown and dark grey, trace of clay fines.	M			GRAVEL DRIVEWAY
					N = SPT 3/50mm REFUSAL			-	SANDSTONE: fine to medium grained, light grey and orange brown.	DW-SW	L		LOW 'TC' BIT RESISTANCE
											M		MODERATE RESISTANCE
						1							MODERATE TO HIGH RESISTANCE
										SW	H		HIGH RESISTANCE
						2							
									END OF BOREHOLE AT 2.3m				PRACTICABLE REFUSAL ON HIGH STRENGTH ROCK
						3							
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No. **2**

1/1

Client: HUNTINGDON NURSING HOME C/- TRINITY MANAGEMENT SERVICES PTY LTD

Project: PROPOSED NURSING HOME

Location: 181 FOREST WAY, BELROSE, NSW

Job No. 30222SM **Method:** SPIRAL AUGER JK308 **R.L. Surface:** ≈ 170.5m

Date: 3-3-17 **Datum:** AHD

Logged/Checked by: M.P./P.S.

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0			FILL: Sandy gravel, fine to coarse grained ironstone and sandstone, brown, with sandstone cobbles.	M			GRAVEL DRIVEWAY
								-	SANDSTONE: fine to medium grained, light grey.	DW-SW	L		LOW 'TC' BIT RESISTANCE
						1							
									as above, but red brown.		M		MODERATE RESISTANCE
						2			as above, but light grey.		L-M		LOW TO MODERATE RESISTANCE
									as above, but red brown.		H		HIGH RESISTANCE
									END OF BOREHOLE AT 2.2m				'TC' BIT REFUSAL ON HIGH STRENGTH SANDSTONE
						3							
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
3
1/1

Client: HUNTINGDON NURSING HOME C/- TRINITY MANAGEMENT SERVICES PTY LTD
Project: PROPOSED NURSING HOME
Location: 181 FOREST WAY, BELROSE, NSW

Job No. 30222SM
Date: 3-3-17
Method: SPIRAL AUGER JK308
R.L. Surface: ≈ 169.0m
Datum: AHD
Logged/Checked by: M.P./P.S.

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0			FILL: Silty sand topsoil, fine to medium grained, brown.	M			GRASS COVER
								SC	CLAYEY SAND: fine to medium grained, red brown, yellow brown and light grey, trace of ironstone gravel.	M	VL-L		RESIDUAL
				■	N > 4 2,2,2/50mm REFUSAL								
						1		-	SANDSTONE: fine to medium grained, light grey and red brown.	DW	M-H		MODERATE TO HIGH 'TC' BIT RESISTANCE
											H		HIGH RESISTANCE
						2			END OF BOREHOLE AT 1.5m				'TC' BIT REFUSAL ON HIGH STRENGTH SANDSTONE
						3							
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
4
1/1

Client: HUNTINGDON NURSING HOME C/- TRINITY MANAGEMENT SERVICES PTY LTD
Project: PROPOSED NURSING HOME
Location: 181 FOREST WAY, BELROSE, NSW

Job No. 30222SM
Date: 3-3-17
Method: SPIRAL AUGER JK308
R.L. Surface: ≈ 167.7m
Datum: AHD
Logged/Checked by: M.P./P.S.

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0			FILL: Silty sand, fine to medium grained, brown, trace of ash.	M			GRASS COVER APPEARS POORLY COMPACTED
			■	■	N > 10 4,2,8/ 100mm REFUSAL			SM	SILTY SAND: fine grained, light brown.	M	L		RESIDUAL
						1		-	SANDSTONE: fine to medium grained, light grey and orange brown.	DW-SW	L-M		LOW TO MODERATE 'TC' BIT RESISTANCE
											H		HIGH RESISTANCE
						2			END OF BOREHOLE AT 1.65m				'TC' BIT REFUSAL ON HIGH STRENGTH SANDSTONE
						3							
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
5
1/1

Client: HUNTINGDON NURSING HOME C/- TRINITY MANAGEMENT SERVICES PTY LTD
Project: PROPOSED NURSING HOME
Location: 181 FOREST WAY, BELROSE, NSW

Job No. 30222SM **Method:** SPIRAL AUGER JK308 **R.L. Surface:** ≈ 167.7m
Date: 3-3-17 **Datum:** AHD
Logged/Checked by: M.P./P.S.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0			FILL: Silty sand, fine to medium grained, dark brown, trace of root fibres and organic material.	M			GRASS COVER
									FILL: Silty sand, fine to medium grained, light brown, trace of igneous gravel.				APPEARS POORLY COMPACTED
			■		N = 5 3,3,2			SM	SILTY SAND: fine grained, orange brown, trace of clay fines.	M	L		RESIDUAL
						1		-	SANDSTONE: fine to medium grained, orange brown and red brown.	DW	VL		VERY LOW 'TC' BIT RESISTANCE
											H		HIGH RESISTANCE
									END OF BOREHOLE AT 1.4m				'TC' BIT REFUSAL ON HIGH STRENGTH SANDSTONE
						2							
						3							
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No. 6
1/1

Client: HUNTINGDON NURSING HOME C/- TRINITY MANAGEMENT SERVICES PTY LTD
Project: PROPOSED NURSING HOME
Location: 181 FOREST WAY, BELROSE, NSW

Job No. 30222SM
Date: 3-3-17
Method: SPIRAL AUGER JK308
R.L. Surface: ≈ 165.5m
Datum: AHD
Logged/Checked by: M.P./P.S.

Groundwater Record	Samples (ES, U50, DB, DS)	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION			0			FILL: Silty sand, fine to medium grained, brown and red brown, trace of fine to medium grained sandstone and ironstone gravel.	M			GRASS COVER APPEARS POORLY COMPACTED
		N = SPT 3/0mm REFUSAL			-	SANDSTONE: fine to medium grained, light grey.	DW	M-H		MODERATE TO HIGH 'TC' BIT RESISTANCE
			1					H		HIGH RESISTANCE
								M		MODERATE RESISTANCE
										MODERATE RESISTANCE WITH VERY LOW BANDS
			2							
	DS (3.0–4.5)		3					VL-L		VERY LOW TO LOW RESISTANCE
			4							
			5					H		HIGH RESISTANCE
						END OF BOREHOLE AT 5.6m				'TC' BIT REFUSAL ON HIGH STRENGTH SANDSTONE
			6							
			7							

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BOREHOLE LOG

Borehole No.
7
1/1

Client: HUNTINGDON NURSING HOME C/- TRINITY MANAGEMENT SERVICES PTY LTD

Project: PROPOSED NURSING HOME

Location: 181 FOREST WAY, BELROSE, NSW

Job No. 30222SM **Method:** SPIRAL AUGER JK308 **R.L. Surface:** ≈ 158.0m

Date: 3-3-17 **Datum:** AHD

Logged/Checked by: M.P./P.S.

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION						0			FILL: Silty sand, fine to coarse grained.	M			GRAVEL TRACK
				■				-	SANDSTONE: fine to medium grained, light grey and orange brown.	SW	H		HIGH 'TC' BIT RESISTANCE
						1			END OF BOREHOLE AT 0.8m				'TC' BIT REFUSAL ON HIGH STRENGTH SANDSTONE
						2							
						3							
						4							
						5							
						6							
						7							

AERIAL IMAGE SOURCE: GOOGLE EARTH PRO 7.1.5.1557
AERIAL IMAGE ©: 2015 GOOGLE INC.

This plan should be read in conjunction with the JK Geotechnics report.

Title:	**SITE LOCATION PLAN**
Location:	181 FOREST WAY BELROSE, NSW
Report No: 30222SM	Figure No: 1

JK Geotechnics

PLOT DATE: 13/03/2017 11:00:19 AM DWG FILE: S:\6 GEOTECHNICAL\6F GEOTECHNICAL JOBS\30000'S\30222SM BELROSE\CAD\30222SM.DWG

0 5 10 15 20 25

SCALE 1:500 @A3 METRES

This plan should be read in conjunction with the JK Geotechnics report.

Title: **BOREHOLE LOCATION PLAN SHOWING PROPOSED DEVELOPMENT OUTLINE**

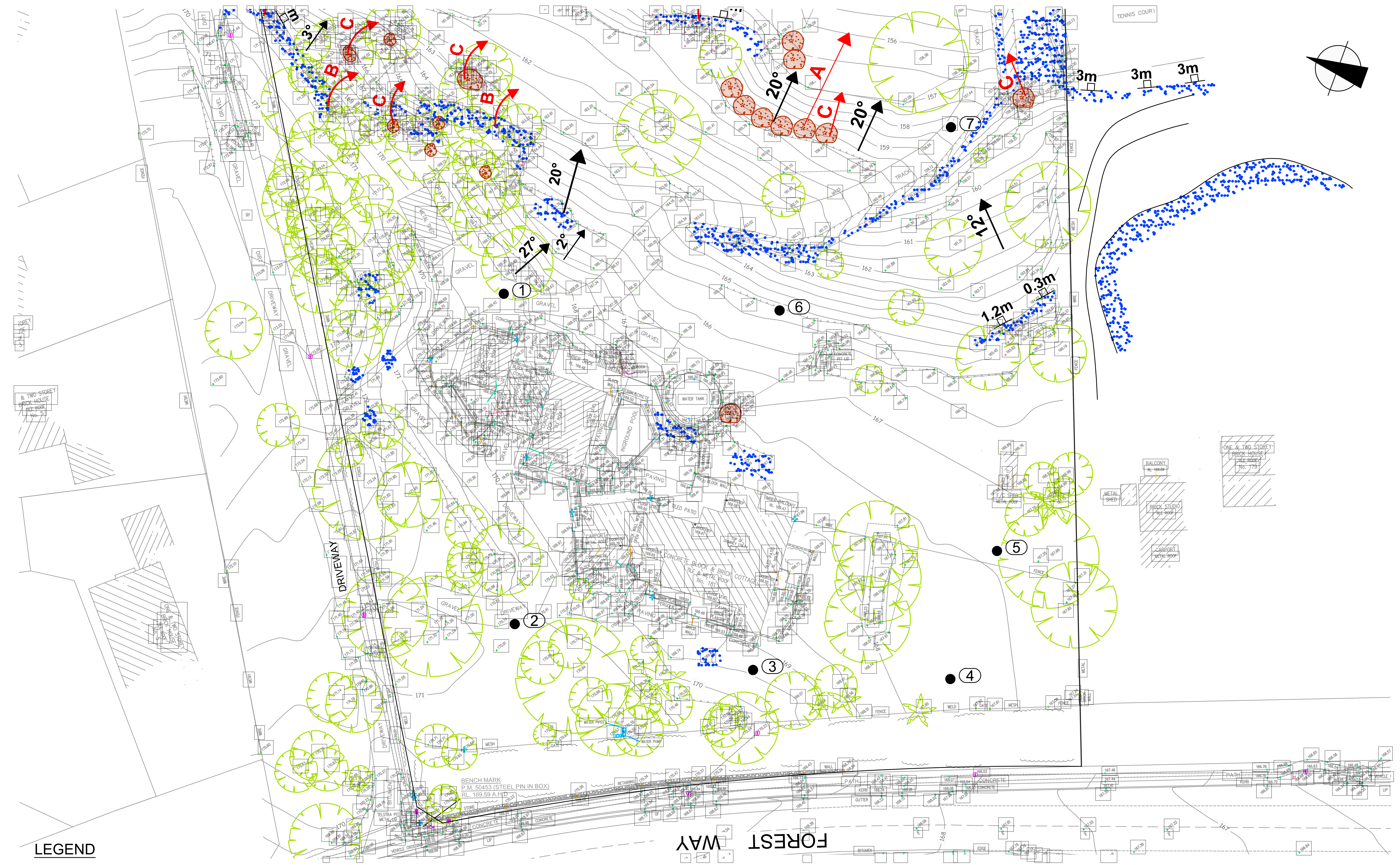
Location: 181 FOREST WAY BELROSE, NSW

Report No: 30222SM

Figure No: 2

JK Geotechnics

PLOT DATE: 4/09/2018 12:57:38 PM DWG FILE: S:\6 GEOTECHNICAL\6F GEOTECHNICAL JOBS\30000'S\30222SM BELROSE\CAD\30222SM.DWG



LEGEND

2.0m	SANDSTONE OUTCROP OR EXPOSURE
0.7m	RETAINING WALL HEIGHT (m)
	SANDSTONE BOULDER
14°	SLOPE INCLINATION AND DIRECTION
E	SLOPE STABILITY HAZARD

0 5 10 15 20 25
SCALE 1:500 @A3 METRES

This plan should be read in conjunction with the JK Geotechnics report.

Title: **SITE PLAN SHOWING GEOTECHNICAL HAZARDS**

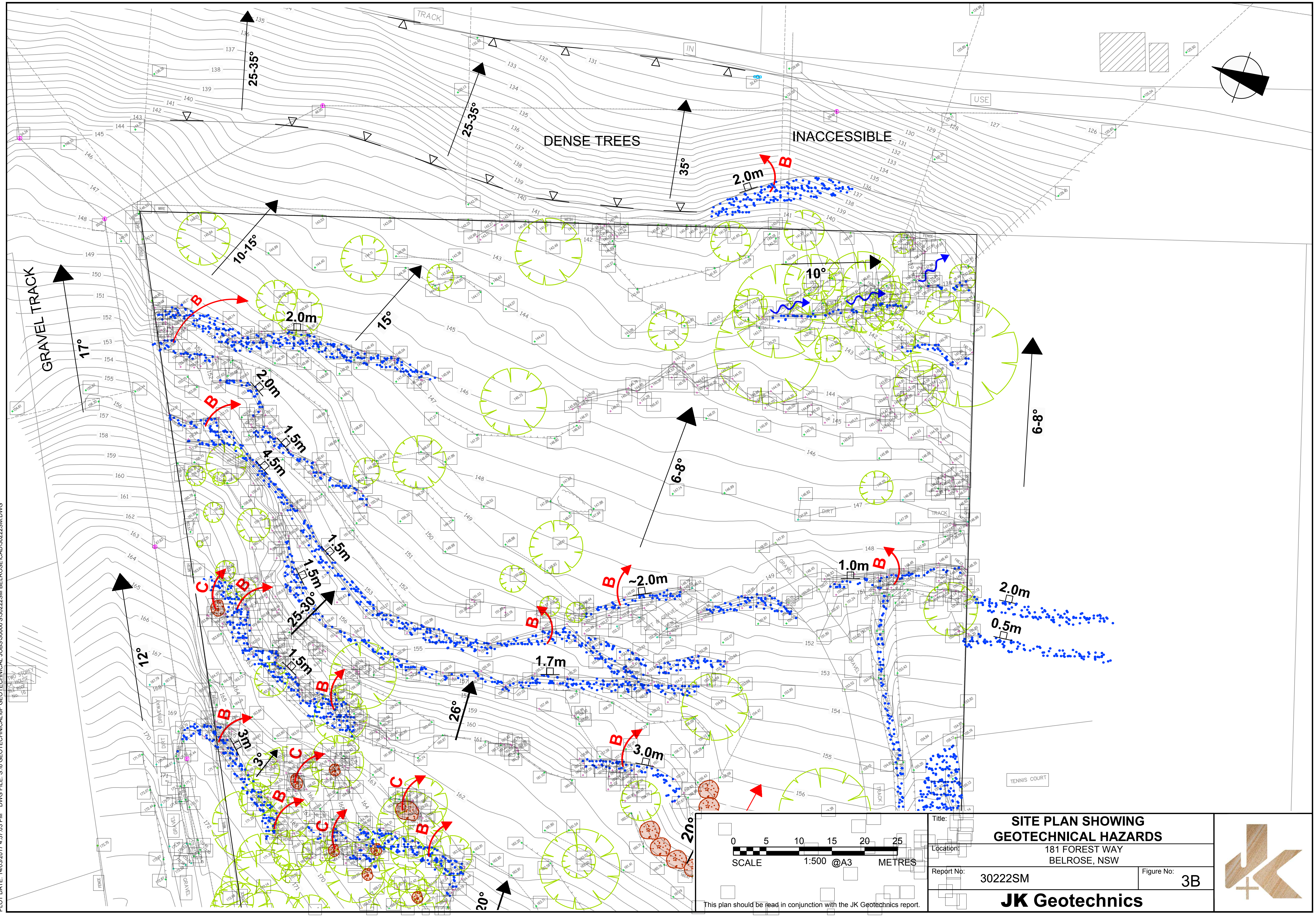
Location: 181 FOREST WAY BELROSE, NSW

Report No: 30222SM

Figure No: 3A

JK Geotechnics

PLOT DATE: 14/03/2017 4:52:11 PM DWG FILE: S:\6 GEOTECHNICAL\6F GEOTECHNICAL JOBS\30000'S\30222SM BELROSE\CAD\30222SM.DWG



Title: **SITE PLAN SHOWING GEOTECHNICAL HAZARDS**

Location: 181 FOREST WAY BELROSE, NSW

Report No: 30222SM

Figure No: 3B

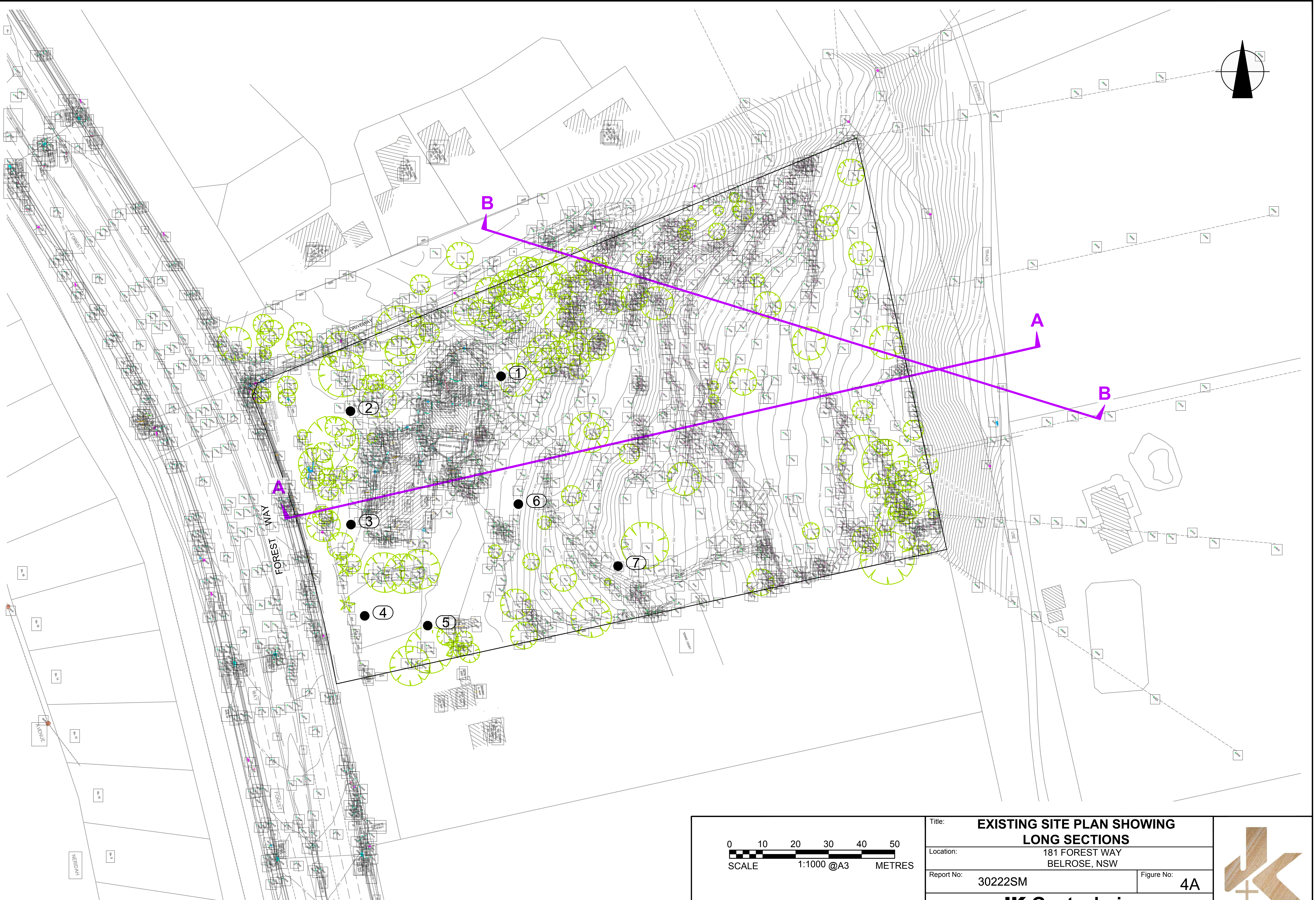
JK Geotechnics

0 5 10 15 20 25

SCALE 1:500 @A3 METRES

This plan should be read in conjunction with the JK Geotechnics report.

PLOT DATE: 14/03/2017 4:57:03 PM DWG FILE: S:\16 GEOTECHNICAL\6F GEOTECHNICAL JOBS\30000'S\30222SM BELROSE\CAD\30222SM.DWG



0 10 20 30 40 50
SCALE 1:1000 @A3 METRES

This plan should be read in conjunction with the JK Geotechnics report.

Title: **EXISTING SITE PLAN SHOWING LONG SECTIONS**

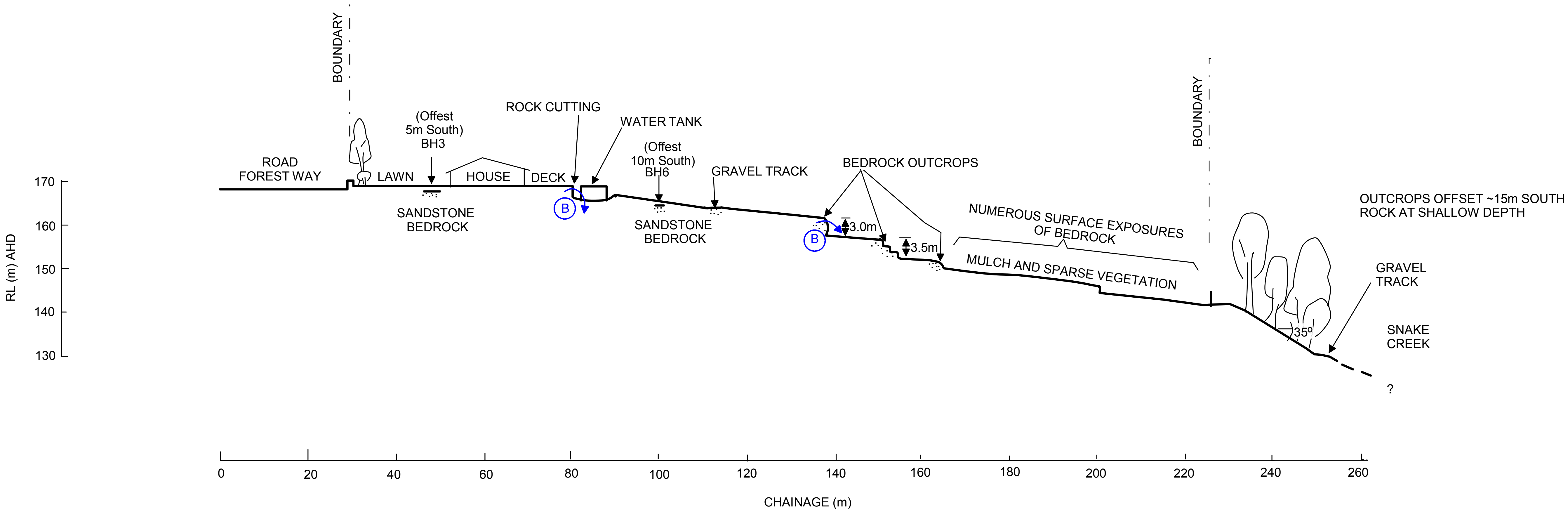
Location: 181 FOREST WAY BELROSE, NSW

Report No: 30222SM

Figure No: 4A

JK Geotechnics

PLOT DATE: 14/03/2017 11:32:44 AM DWG FILE: S:\6 GEOTECHNICAL\6F GEOTECHNICAL JOBS\30000'S\30222SM BELROSE\CAD\30222SM.DWG

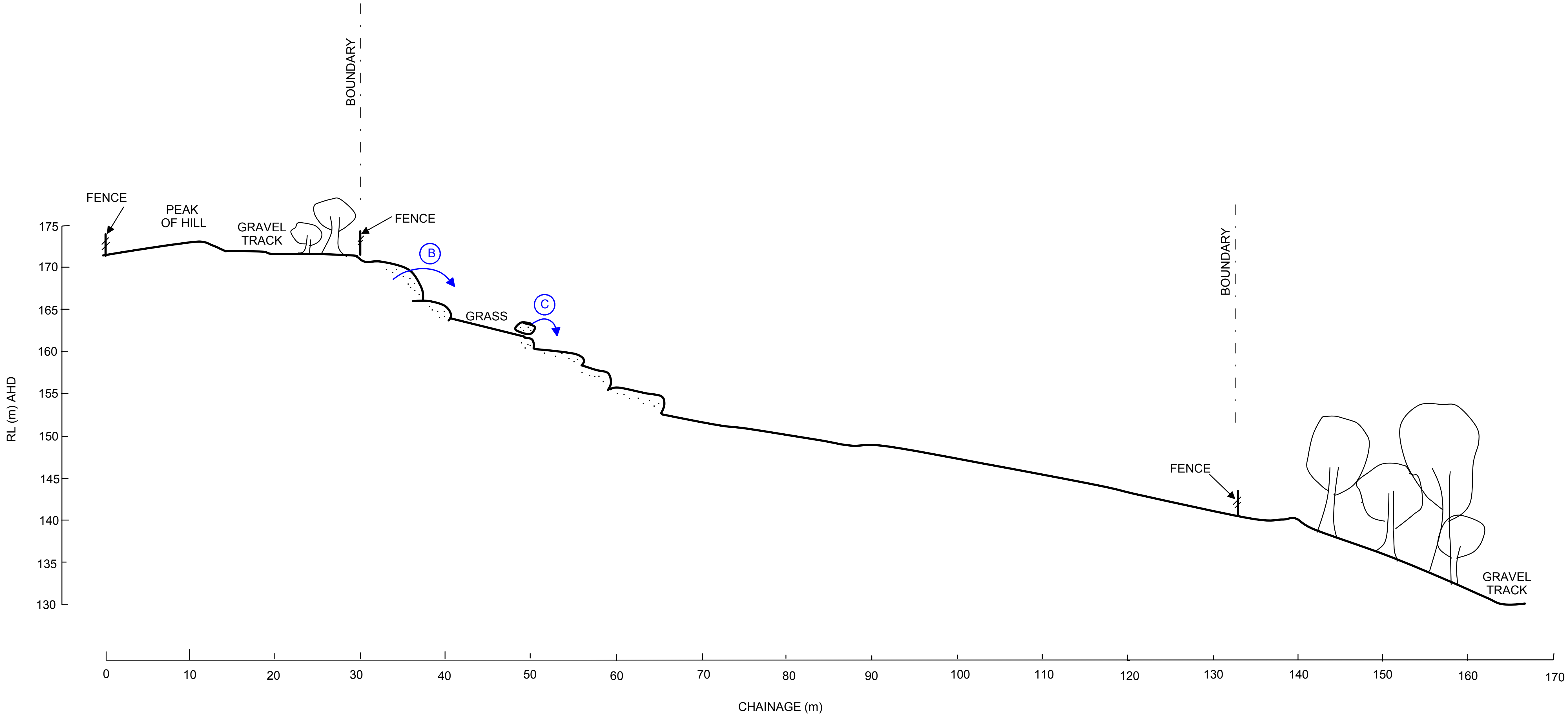


LONG SECTION A-A
SHOWING GEOTECHNICAL HAZARDS

0 50
Scale 1:1000 @A3 Metres

JK Geotechnics
GEOTECHNICAL & ENVIRONMENTAL ENGINEERS

Report No. 30222SM
Figure No. 4b



LONG SECTION B-B
SHOWING GEOTECHNICAL HAZARDS

0 25
Scale 1:500 @A3 Metres

JK Geotechnics
GEOTECHNICAL & ENVIRONMENTAL ENGINEERS
Report No. 30222SM Figure No. 4c

APPENDIX A

LANDSLIDE RISK

MANAGEMENT

TERMINOLOGY

APPENDIX A
LANDSLIDE RISK MANAGEMENT

Definition of Terms and Landslide Risk

Risk Terminology	Description
Acceptable Risk	A risk for which, for the purposes of life or work, we are prepared to accept as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable.
Annual Exceedance Probability (AEP)	The estimated probability that an event of specified magnitude will be exceeded in any year.
Consequence	The outcomes or potential outcomes arising from the occurrence of a landslide expressed qualitatively or quantitatively, in terms of loss, disadvantage or gain, damage, injury or loss of life.
Elements at Risk	The population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by landslides.
Frequency	A measure of likelihood expressed as the number of occurrences of an event in a given time. See also 'Likelihood' and 'Probability'.
Hazard	A condition with the potential for causing an undesirable consequence (the landslide). The description of landslide hazard should include the location, volume (or area), classification and velocity of the potential landslides and any resultant detached material, and the likelihood of their occurrence within a given period of time.
Individual Risk to Life	The risk of fatality or injury to any identifiable (named) individual who lives within the zone impacted by the landslide; or who follows a particular pattern of life that might subject him or her to the consequences of the landslide.
Landslide Activity	The stage of development of a landslide; pre failure when the slope is strained throughout but is essentially intact; failure characterised by the formation of a continuous surface of rupture; post failure which includes movement from just after failure to when it essentially stops; and reactivation when the slope slides along one or several pre-existing surfaces of rupture. Reactivation may be occasional (eg. seasonal) or continuous (in which case the slide is 'active').
Landslide Intensity	A set of spatially distributed parameters related to the destructive power of a landslide. The parameters may be described quantitatively or qualitatively and may include maximum movement velocity, total displacement, differential displacement, depth of the moving mass, peak discharge per unit width, or kinetic energy per unit area.
Landslide Risk	The AGS Australian GeoGuide LR7 (AGS, 2007e) should be referred to for an explanation of Landslide Risk.
Landslide Susceptibility	The classification, and volume (or area) of landslides which exist or potentially may occur in an area or may travel or retrogress onto it. Susceptibility may also include a description of the velocity and intensity of the existing or potential landsliding.
Likelihood	Used as a qualitative description of probability or frequency.
Probability	A measure of the degree of certainty. This measure has a value between zero (impossibility) and 1.0 (certainty). It is an estimate of the likelihood of the magnitude of the uncertain quantity, or the likelihood of the occurrence of the uncertain future event. These are two main interpretations: (i) Statistical – frequency or fraction – The outcome of a repetitive experiment of some kind like flipping coins. It includes also the idea of population variability. Such a number is called an 'objective' or relative frequentist probability because it exists in the real world and is in principle measurable by doing the experiment.

Risk Terminology	Description
Probability ***(continued)***	(ii) Subjective probability (degree of belief) – Quantified measure of belief, judgment, or confidence in the likelihood of an outcome, obtained by considering all available information honestly, fairly, and with a minimum of bias. Subjective probability is affected by the state of understanding of a process, judgment regarding an evaluation, or the quality and quantity of information. It may change over time as the state of knowledge changes.
Qualitative Risk Analysis	An analysis which uses word form, descriptive or numeric rating scales to describe the magnitude of potential consequences and the likelihood that those consequences will occur.
Quantitative Risk Analysis	An analysis based on numerical values of the probability, vulnerability and consequences and resulting in a numerical value of the risk.
Risk	A measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated by the product of probability x consequences. However, a more general interpretation of risk involves a comparison of the probability and consequences in a non-product form.
Risk Analysis	The use of available information to estimate the risk to individual, population, property, or the environment, from hazards. Risk analyses generally contain the following steps: scope definition, hazard identification and risk estimation.
Risk Assessment	The process of risk analysis and risk evaluation.
Risk Control or Risk Treatment	The process of decision-making for managing risk and the implementation or enforcement of risk mitigation measures and the re-evaluation of its effectiveness from time to time, using the results of risk assessment as one input.
Risk Estimation	The process used to produce a measure of the level of health, property or environmental risks being analysed. Risk estimation contains the following steps: frequency analysis, consequence analysis and their integration.
Risk Evaluation	The stage at which values and judgments enter the decision process, explicitly or implicitly, by including consideration of the importance of the estimated risks and the associated social, environmental and economic consequences, in order to identify a range of alternatives for managing the risks.
Risk Management	The complete process of risk assessment and risk control (or risk treatment).
Societal Risk	The risk of multiple fatalities or injuries in society as a whole: one where society would have to carry the burden of a landslide causing a number of deaths, injuries, financial, environmental and other losses.
Susceptibility	See 'Landslide Susceptibility'.
Temporal Spatial Probability	The probability that the element at risk is in the area affected by the landsliding, at the time of the landslide.
Tolerable Risk	A risk within a range that society can live with so as to secure certain net benefits. It is a range of risk regarded as non-negligible and needing to be kept under review and reduced further if possible.
Vulnerability	The degree of loss to a given element or set of elements within the area affected by the landslide hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the damage relative to the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is affected by the landslide.

NOTE: Reference should be made to Figure A1 which shows the inter-relationship of many of these terms and the relevant portion of Landslide Risk Management.

Reference should also be made to the paper referenced below for Landslide Terminology and more detailed discussion of the above terminology.

This appendix is an extract from PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT as presented in Australian Geomechanics, Vol 42, No 1, March 2007, which discusses the matter more fully.

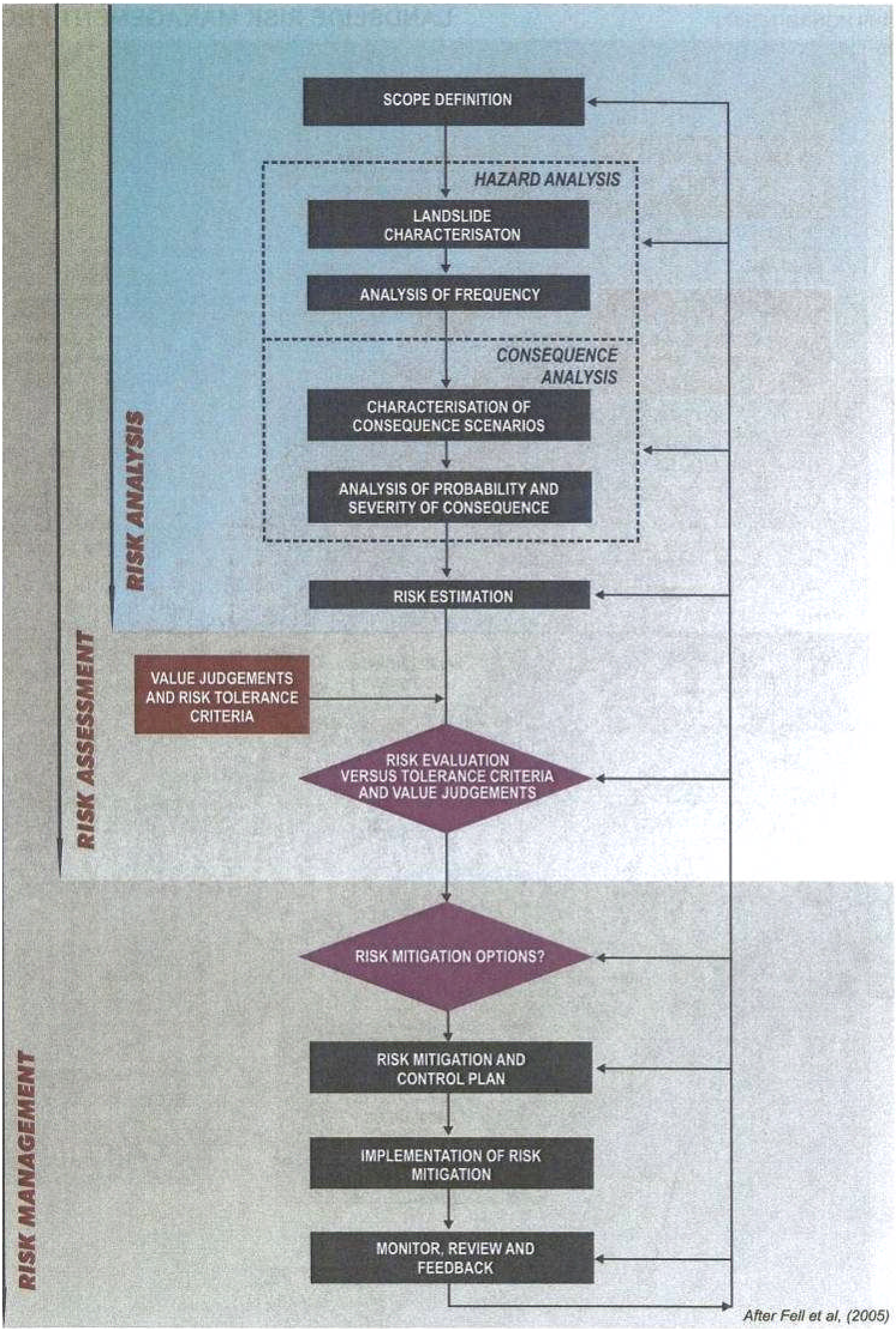


FIGURE A1: Flowchart for Landslide Risk Management.

This figure is an extract from GUIDELINE FOR LANDSLIDE SUSCEPTIBILITY, HAZARD AND RISK ZONING FOR LAND USE PLANNING, as presented in Australian Geomechanics Vol 42, No 1, March 2007, which discusses the matter more fully.

TABLE A1: LANDSLIDE RISK ASSESSMENT
QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

Approximate Annual Probability		Implied Indicative Landslide Recurrence Interval		Description	Descriptor	Level
Indicative Value	Notional Boundary					
10^{-1}	$5x10^{-2}$	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	$5x10^{-3}$	100 years	200 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	$5x10^{-4}$	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	$5x10^{-5}$	10,000 years	20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	$5x10^{-6}$	100,000 years	200,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}		1,000,000 years		The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

Note: (1) The table should be used from left to right; use Approximate Annual Probability or Description to assign Descriptor, not *vice versa*.

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

Approximate Cost of Damage		Description	Descriptor	Level
Indicative Value	Notional Boundary			
200%	100%	Structure(s) completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.	CATASTROPHIC	1
60%	40%	Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	MAJOR	2
20%	10%	Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	MEDIUM	3
5%	1%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%		Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%. See Risk Matrix.)	INSIGNIFICANT	5

Notes: (2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.

(3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional design fees, and consequential costs such as legal fees, temporary accommodation. It does not include additional stabilisation works to address other landslides which may affect the property.

(4) The table should be used from left to right; use Approximate Cost of Damage or Description to assign Descriptor, not vice versa.

Extract from PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT as presented in Australian Geomechanics, Vol 42, No 1, March 2007, which discusses the matter more fully.

TABLE A1: LANDSLIDE RISK ASSESSMENT
QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (continued)

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

LIKELIHOOD		CONSEQUENCES TO PROPERTY (With Indicative Approximate Cost of Damage)				
	Indicative Value of Approximate Annual Probability	**1: CATASTROPHIC 200%**	**2: MAJOR 60%**	**3: MEDIUM 20%**	**4: MINOR 5%**	**5: INSIGNIFICANT 0.5%**
A – ALMOST CERTAIN	10^{-1}	VH	VH	VH	H	M or **L** (5)
B - LIKELY	10^{-2}	VH	VH	H	M	**L**
C - POSSIBLE	10^{-3}	VH	H	M	M	**VL**
D - UNLIKELY	10^{-4}	H	M	**L**	**L**	**VL**
E - RARE	10^{-5}	M	**L**	**L**	**VL**	**VL**
F - BARELY CREDIBLE	10^{-6}	**L**	**VL**	**VL**	**VL**	**VL**

Notes: (5) Cell A5 may be subdivided such that a consequence of less than 0.1% is Low Risk.
(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

RISK LEVEL IMPLICATIONS

Risk Level		**Example Implications** (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
H	HIGH RISK	Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to Low. Work would cost a substantial sum in relation to the value of the property.
M	MODERATE RISK	May be tolerated in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as practicable.
L	LOW RISK	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.
VL	VERY LOW RISK	Acceptable. Manage by normal slope maintenance procedures.

Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

Extract from PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT as presented in Australian Geomechanics, Vol 42, No 1, March 2007, which discusses the matter more fully.

AUSTRALIAN GEOGUIDE LR2 (LANDSLIDES)

What is a Landslide?

Any movement of a mass of rock, debris, or earth, down a slope, constitutes a "landslide". Landslides take many forms, some of which are illustrated. More information can be obtained from Geoscience Australia, or by visiting its Australian landslide Database at www.ga.gov.au/urban/factsheets/landslide.jsp. Aspects of the impact of landslides on buildings are dealt with in the book "Guideline Document Landslide Hazards" published by the Australian Building Codes Board and referenced in the Building Code of Australia. This document can be purchased over the internet at the Australian Building Codes Board's website www.abcb.gov.au.

Landslides vary in size. They can be small and localised or very large, sometimes extending for kilometres and involving millions of tonnes of soil or rock. It is important to realise that even a 1 cubic metre boulder of soil, or rock, weighs at least 2 tonnes. If it falls, or slides, it is large enough to kill a person, crush a car, or cause serious structural damage to a house. The material in a landslide may travel downhill well beyond the point where the failure first occurred, leaving destruction in its wake. It may also leave an unstable slope in the ground behind it, which has the potential to fall again, causing the landslide to extend (regress) uphill, or expand sideways. For all these reasons, both "potential" and "actual" landslides must be taken very seriously. The present a real threat to life and property and require proper management.

Identification of landslide risk is a complex task and must be undertaken by a geotechnical practitioner (GeoGuide LR1) with specialist experience in slope stability assessment and slope stabilisation.

What Causes a Landslide?

Landslides occur as a result of local geological and groundwater conditions, but can be exacerbated by inappropriate development (GeoGuide LR8), exceptional weather, earthquakes and other factors. Some slopes and cliffs never seem to change, but are actually on the verge of failing. Others, often moderate slopes (Table 1), move continuously, but so slowly that it is not apparent to a casual observer. In both cases, small changes in conditions can trigger a landslide with series consequences. Wetting up of the ground (which may involve a rise in groundwater table) is the single most important cause of landslides (GeoGuide LR5). This is why they often occur during, or soon after, heavy rain. Inappropriate development often results in small scale landslides which are very expensive in human terms because of the proximity of housing and people.

Does a Landslide Affect You?

Any slope, cliff, cutting, or fill embankment may be a hazard which has the potential to impact on people, property, roads and services. Some tell-tale signs that might indicate that a landslide is occurring are listed below:

- Open cracks, or steps, along contours
- Groundwater seepage, or springs
- Bulging in the lower part of the slope
- Hummocky ground
- trees leaning down slope, or with exposed roots
- debris/fallen rocks at the foot of a cliff
- tilted power poles, or fences
- cracked or distorted structures

These indications of instability may be seen on almost any slope and are not necessarily confined to the steeper ones (Table 1). Advice should be sought from a geotechnical practitioner if any of them are observed. Landslides do not respect property boundaries. As mentioned above they can "run-out" from above, "regress" from below, or expand sideways, so a landslide hazard affecting your property may actually exist on someone else's land.

Local councils are usually aware of slope instability problems within their jurisdiction and often have specific development and maintenance requirements. **Your local council is the first place to make enquiries if you are responsible for any sort of development or own or occupy property on or near sloping land or a cliff.**

TABLE 1 – Slope Descriptions

Appearance	Slope Angle	Maximum Gradient	Slope Characteristics
Gentle	0° - 10°	1 on 6	Easy walking.
Moderate	10° - 18°	1 on 3	Walkable. Can drive and manoeuvre a car on driveway.
Steep	18° - 27°	1 on 2	Walkable with effort. Possible to drive straight up or down roughened concrete driveway, but cannot practically manoeuvre a car.
Very Steep	27° - 45°	1 on 1	Can only climb slope by clutching at vegetation, rocks, etc.
Extreme	45° - 64°	1 on 0.5	Need rope access to climb slope.
Cliff	64° - 84°	1 on 0.1	Appears vertical. Can abseil down.
Vertical or Overhang	84° - 90±°	Infinite	Appears to overhang. Abseiler likely to lose contact with the face.

Some typical landslides which could affect residential housing are illustrated below:

Rotational or circular slip failures (Figure 1) - can occur on moderate to very steep soil and weathered rock slopes (Table 1). The sliding surface of the moving mass tends to be deep seated. Tension cracks may open at the top of the slope and bulging may occur at the toe. The ground may move in discrete "steps" separated by long periods without movement. More rapid movement may occur after heavy rain.

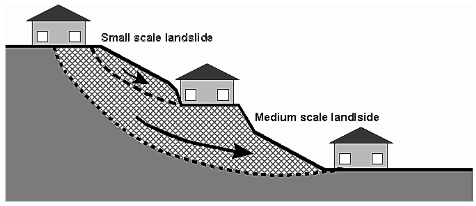


Figure 1

Translational slip failures (Figure 2) - tend to occur on moderate to very steep slopes (Table 1) where soil, or weak rock, overlies stronger strata. The sliding mass is often relatively shallow. It can move, or deform slowly (creep) over long periods of time. Extensive linear cracks and hummocks sometimes form along the contours. The sliding mass may accelerate after heavy rain.

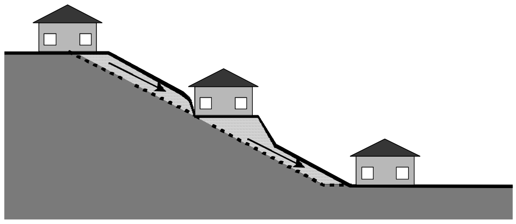


Figure 2

Wedge failures (Figure 3) - normally only occur on extreme slopes, or cliffs (Table 1), where discontinuities in the rock are inclined steeply downwards out of the face.

Rock falls (Figure 3) - tend to occur from cliffs and overhangs (Table 1).

Cliffs may remain, apparently unchanged, for hundreds of years. Collections of boulders at the foot of a cliff may indicate that rock falls are ongoing. Wedge failures and rock falls do not "creep". Familiarity with a particular local situation can instil a false sense of security since failure, when it occurs, is usually sudden and catastrophic.

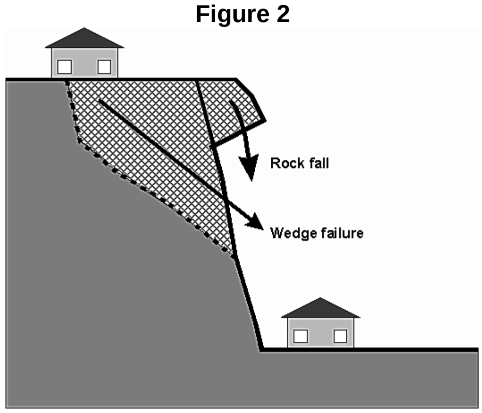


Figure 3

Debris flows and mud slides (Figure 4) - may occur in the foothills of ranges, where erosion has formed valleys which slope down to the plains below. The valley bottoms are often lined with loose eroded material (debris) which can "flow" if it becomes saturated during and after heavy rain. Debris flows are likely to occur with little warning; they travel a long way and often involve large volumes of soil. The consequences can be devastating.

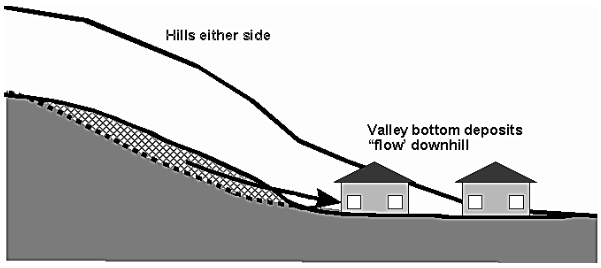


Figure 4

More information relevant to your particular situation may be found in other Australian GeoGuides:

- GeoGuide LR1 - Introduction
- GeoGuide LR3 - Soil Slopes
- GeoGuide LR4 - Rock Slopes
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- GeoGuide LR8 - Hillside Construction
- GeoGuide LR9 - Effluent & Surface Water Disposal
- GeoGuide LR10 - Coastal Landslides
- GeoGuide LR11 - Record Keeping

The Australian GeoGuides (LR series) are a set of publications intended for property owners; local councils; planning authorities; developers; insurers; lawyers and, in fact, anyone who lives with, or has an interest in, a natural or engineered slope, a cutting, or an excavation. They are intended to help you understand why slopes and retaining structures can be a hazard and what can be done with appropriate professional advice and local council approval (if required) to remove, reduce, or minimise the risk they represent. The GeoGuides have been prepared by the Australian Geomechanics Society, a specialist technical society within Engineers Australia, the national peak body for all engineering disciplines in Australia, whose members are professional geotechnical engineers and engineering geologists with a particular interest in ground engineering. The GeoGuides have been funded under the Australian governments' National Disaster Mitigation Program.

AUSTRALIAN GEOGUIDE LR7 (LANDSLIDE RISK)

Concept of Risk

Risk is a familiar term, but what does it really mean? It can be defined as *"a measure of the probability and severity of an adverse effect to health, property, or the environment."* This definition may seem a bit complicated. In relation to landslides, geotechnical practitioners (see GeoGuide LR1) are required to assess risk in terms of the likelihood that a particular landslide will occur and the possible consequences. This is called landslide risk assessment. The consequences of a landslide are many and varied, but our concerns normally focus on loss of, or damage to, property and loss of life.

Landslide Risk Assessment

Some local councils in Australia are aware of the potential for landslides within their jurisdiction and have responded by designating specific "landslide hazard zones". Development in these areas is normally covered by special regulations. If you are contemplating building, or buying an existing house, particularly in a hilly area, or near cliffs, then go first for information to your local council. If you have any concern that you could be dealing with a landslide hazard that your local council is not aware of you should seek advice from a geotechnical practitioner.

Landslide risk assessment must be undertaken by a geotechnical practitioner. It may involve visual inspection, geological mapping, geotechnical investigation and monitoring to identify:

- potential landslides (there may be more than one that could impact on your site);
- the likelihood that they will occur;
- the damage that could result;
- the cost of disruption and repairs; and
- the extent to which lives could be lost.

Risk assessment is a predictive exercise, but since the ground and the processes involved are complex, prediction inevitably lacks precision. If you commission a landslide risk assessment for a particular site you should expect to receive a report prepared in accordance with current professional guidelines and in a form that is acceptable to your local council, or planning authority.

Risk to Property

Table 1 indicates the terms used to describe risk to property. Each risk level depends on an assessment of how likely a landslide is to occur and its consequences in dollar terms. Likelihood is the chance of it happening in any one year, as indicated in Table 2. Consequences are related to the cost of the repairs and perhaps temporary loss of use. These two factors are combined by the geotechnical practitioner to determine the Qualitative Risk.

TABLE 1 – RISK TO PROPERTY

Qualitative Risk		Significance - Geotechnical engineering requirements
Very high	VH	**Unacceptable** without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low. May be too expensive and not practical. Work likely to cost more than the value of the property.
High	H	**Unacceptable** without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to acceptable level. Work would cost a substantial sum in relation to the value of the property.
Moderate	M	**May be tolerated** in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as possible.
Low	L	**Usually acceptable** to regulators. Where treatment has been needed to reduce the risk to this level, ongoing maintenance is required.
Very Low	VL	**Acceptable**. Manage by normal slope maintenance procedures.

TABLE 2 – LIKELIHOOD

Likelihood	Annual Probability
Almost Certain	1:10
Likely	1:100
Possible	1:1,000
Unlikely	1:10,000
Rare	1:100,000
Barely credible	1:1,000,000

The terms "unacceptable", "tolerable" etc. in Table 1 indicate how most people react to an assessed risk level. However, some people will always be more prepared, or better able, to tolerate a higher risk level than others. Some local councils and planning authorities stipulate a maximum tolerable risk level. This may be lower than you feel is reasonable for your block but it is, nonetheless, a pre-requisite for development. Reasons for this include the fact that a landslide on your block may pose a risk to neighbours and passers-by and that , should you sell, subsequent owners of the block may be more risk averse than you.

Risk to Life

Most of us have some difficulty grappling with the concept of risk and deciding whether, or not, we are prepared to accept it. However, without doing any sort of analysis, or commissioning a report from an "expert", we all take risks every day. One of them is the risk of being killed in an accident. This is worth thinking about, because it tells us a lot about ourselves and can help to put an assessed risk into a meaningful context. By identifying activities that we either are, or are not, prepared to engage in, we can get some indication of the maximum level of risk that we are prepared to take. This knowledge can help us to decide whether we really are able to accept a particular risk, or to tolerate a particular likelihood of loss, or damage, to our property (Table 2).

In Table 3, data from NSW for the years 1998 to 2002, and other sources, is presented. A risk of 1 in 100,000 means that, in any one year, 1 person is killed for every 100,000 people undertaking that particular activity. The NSW data assumes that the whole population undertakes the activity. That is, we are all at risk of being killed in a fire, or of choking on our food, but it is reasonable to assume that only people who go deep sea fishing run a risk of being killed while doing it.

It can be seen that the risks of dying as a result of falling, using a motor vehicle, or engaging in water-related activities (including bathing) are all greater than 1:100,000 and yet few people actively avoid situations where these risks are present. Some people are averse to flying and yet it represents a lower risk than choking to death on food. The data also indicate that, even when the risk of dying as a consequence of a particular event is very small, it could still happen to any one of us today. If this were not so, there would be no risk at all and clearly that is not the case.

In NSW, the planning authorities consider that 1:1,000,000 is the maximum tolerable risk for domestic housing built near an obvious hazard, such as a chemical factory. Although not specifically considered in the NSW guidelines there is little difference between the hazard presented by a neighbouring factory and a landslide: both have the capacity to destroy life and property and both are always present.

TABLE 3 – RISK TO LIFE

Risk (deaths per participant per year)	**Activity/Event Leading to Death** (NSW data unless noted)
1:1,000	Deep sea fishing (UK)
1:1,000 to 1:10,000	Motor cycling, horse riding , ultra-light flying (Canada)
1:23,000	Motor vehicle use
1:30,000	Fall
1:70,000	Drowning
1:180,000	Fire/burn
1:660,000	Choking on food
1:1,000,000	Scheduled airlines (Canada)
1:2,300,000	Train travel
1:32,000,000	Lightning strike

More information relevant to your particular situation may be found in other AUSTRALIAN GEOGUIDES:

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR8 - Hillside Construction
- GeoGuide LR9 - Effluent & Surface Water Disposal
- GeoGuide LR10 - Coastal Landslides
- GeoGuide LR11 - Record Keeping

The Australian GeoGuides (LR series) are a set of publications intended for property owners; local councils; planning authorities; developers; insurers; lawyers and, in fact, anyone who lives with, or has an interest in, a natural or engineered slope, a cutting, or an excavation. They are intended to help you understand why slopes and retaining structures can be a hazard and what can be done with appropriate professional advice and local council approval (if required) to remove, reduce, or minimise the risk they represent. The GeoGuides have been prepared by the Australian Geomechanics Society, a specialist technical society within Engineers Australia, the national peak body for all engineering disciplines in Australia, whose members are professional geotechnical engineers and engineering geologists with a particular interest in ground engineering. The GeoGuides have been funded under the Australian governments' National Disaster Mitigation Program.

APPENDIX B

SOME GUIDELINES

FOR

HILLSIDE CONSTRUCTION

APPENDIX B – SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	POOR ENGINEERING PRACTICE
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical consultant at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminant bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements.
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance (including onto properties below). Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc. in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on bedrock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within bedrock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide generous falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge of roof run-off into absorption trenches.
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use of absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by a geotechnical consultant.	
SITE VISITS	Site visits by consultant may be appropriate during construction.	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident seek advice. If seepage observed, determine cause or seek advice on consequences.	

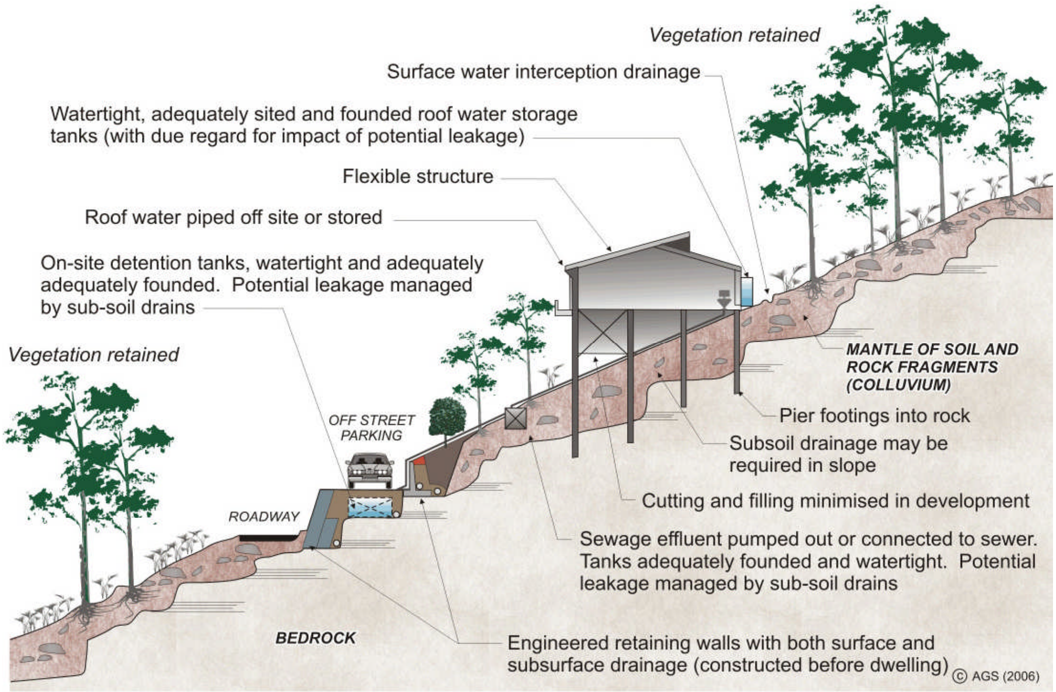
This table is an extract from PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT as presented in *Australian Geomechanics*, Vol 42, No 1, March 2007 which discusses the matter more fully.

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

HILLSIDE CONSTRUCTION PRACTICE

Sensible development practices are required when building on hillsides, particularly if the hillside has more than a low risk of instability (GeoGuide LR7). Only building techniques intended to maintain, or reduce, the overall level of landslide risk should be considered. Examples of good hillside construction practice are illustrated below.

EXAMPLES FOR GOOD HILLSIDE CONSTRUCTION PRACTICE



WHY ARE THESE PRACTICES GOOD?

Roadways and parking areas - are paved and incorporate kerbs which prevent water discharging straight into the hillside (GeoGuide LR5).

Cuttings - are supported by retaining walls (GeoGuide LR6).

Retaining walls - are engineer designed to withstand the lateral earth pressures and surcharges expected, and include drains to prevent water pressures developing in the backfill. Where the ground slopes steeply down towards the high side of a retaining wall, the disturbing force (see GeoGuide LR6) can be two or more times that due to level ground. Retaining walls must be designed taking these forces into account.

Sewage - whether treated or not is either taken away in pipes or contained in properly founded tanks so it cannot soak into the ground.

Surface water - from roofs and other hard surfaces is piped away to a suitable discharge point rather than being allowed to infiltrate into the ground. Preferably, the discharge point will be in a natural creek where ground water exits, rather than enters, the ground. Shallow, lined, drains on the surface can fulfill the same purpose (GeoGuide LR5).

Surface loads - are minimised. No fill embankments have been built. The house is a lightweight structure. Foundation loads have been taken down below the level at which a landslide is likely to occur and, preferably, to rock. This sort of construction is probably not applicable to soil slopes (GeoGuide LR3). If you are uncertain whether your site has rock near the surface, or is essentially a soil slope, you should engage a geotechnical practitioner to find out.

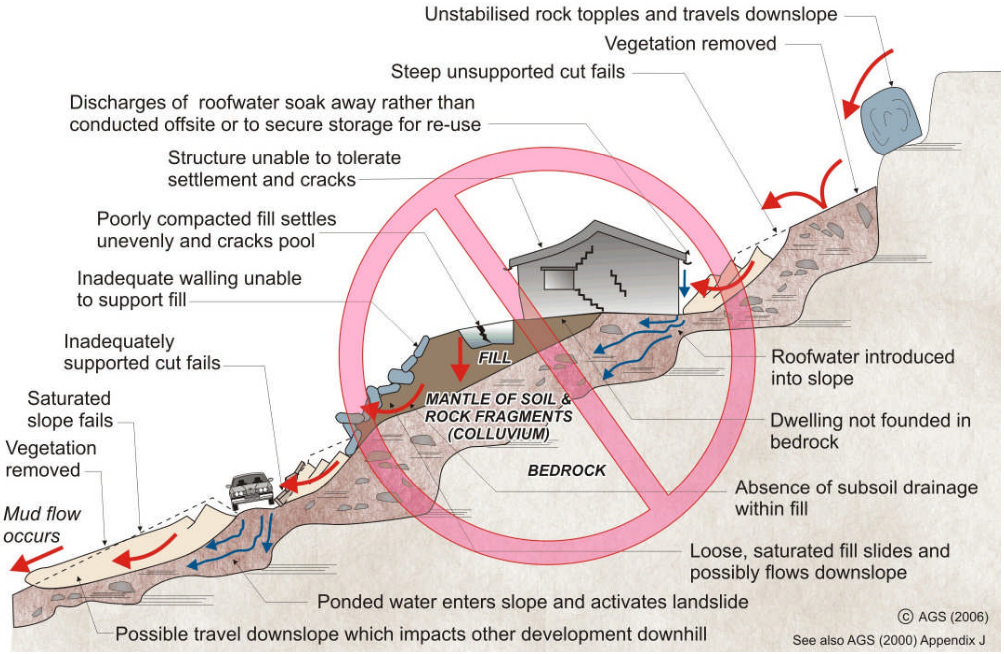
Flexible structures - have been used because they can tolerate a certain amount of movement with minimal signs of distress and maintain their functionality.

Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing can result in a rise in water table with a consequent increase in the likelihood of a landslide (GeoGuide LR5). An exception may have to be made to this rule on steep rock slopes where trees have little effect on the water table, but their roots pose a landslide hazard by dislodging boulders.

Possible effects of ignoring good construction practices are illustrated on page 2. Unfortunately, these poor construction practices are not as unusual as you might think and are often chosen because, on the face of it, they will save the developer, or owner, money. You should not lose sight of the fact that the cost and anguish associated with any one of the disasters illustrated, is likely to more than wipe out any apparent savings at the outset.

ADOPT GOOD PRACTICE ON HILLSIDE SITES
Extract from Geoguide LR8 – Hillside Construction Practice

EXAMPLES FOR **POOR** HILLSIDE CONSTRUCTION PRACTICE



WHY ARE THESE PRACTICES POOR?

Roadways and parking areas - are unsurfaced and lack proper table drains (gutters) causing surface water to pond and soaks into the ground.

Cut and fill - has been used to balance earthworks quantities and level the site leaving unstable cut faces and added large surface loads to the ground. Failure to compact the fill properly has led to settlement, which will probably continue for several years after completion. The house and pool have been built on the fill and have settled with it and cracked. Leakage from the cracked pool and the applied surface loads from the fill have combined to cause landslides.

Retaining walls - have been avoided, to minimise cost, and hand placed rock walls used instead. Without applying engineering design principles, the walls have failed to provide the required support to the ground and have failed, creating a very dangerous situation.

A heavy, rigid, house - has been built on shallow, conventional, footings. Not only has the brickwork cracked because of the resulting ground movements, but it has also become involved in a man-made landslide.

Soak-away drainage - has been used for sewage and surface water run-off from roofs and pavements. This water soaks into the ground and raises the water table (GeoGuide LR5). Subsoil drains that run along the contours should be avoided for the same reason. If felt necessary, subsoil drains should run steeply downhill in a chevron, or herringbone, pattern. This may conflict with the requirements for effluent and surface water disposal (GeoGuide LR9) and if so, you will need to seek professional advice.

Rock debris - from landslides higher up on the slope seems likely to pass through the site. Such locations are often referred to by geotechnical practitioners as "debris flow paths". Rock is normally even denser than ordinary fill, so even quite modest boulders are likely to weigh many tonnes and do a lot of damage once they start to roll. Boulders have been known to travel hundreds of metres downhill leaving behind a trail of destruction.

Vegetation - has been completely cleared, leading to a possible rise in the water table and increased landslide risk (GeoGuide LR5).

DON'T CUT CORNERS ON HILLSIDE SITES - OBTAIN ADVICE FROM A GEOTECHNICAL PRACTITIONER

More information relevant to your particular situation may be found in other Australian GeoGuides:

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- GeoGuide LR9 - Effluent & Surface Water Disposal
- GeoGuide LR10 Coastal Landslides
- GeoGuide LR11 - Record Keeping

The Australian GeoGuides (LR series) are a set of publications intended for property owners; local councils; planning authorities; developers; insurers; lawyers and, in fact, anyone who lives with, or has an interest in, a natural or engineered slope, a cutting, or an excavation. They are intended to help you understand why slopes and retaining structures can be a hazard and what can be done with appropriate professional advice and local council approval (if required) to remove, reduce, or minimise the risk they represent. The GeoGuides have been prepared by the Australian Geomechanics Society, a specialist technical society within Engineers Australia, the national peak body for all engineering disciplines in Australia, whose members are professional geotechnical engineers and engineering geologists with a particular interest in ground engineering. The GeoGuides have been funded under the Australian governments' National Disaster Mitigation Program.

Extract from Geoguide LR8 – Hillside Construction Practice.

REPORT EXPLANATION NOTES

INTRODUCTION

These notes have been provided to amplify the geotechnical report in regard to classification methods, field procedures and certain matters relating to the Comments and Recommendations section. Not all notes are necessarily relevant to all reports.

The ground is a product of continuing natural and man-made processes and therefore exhibits a variety of characteristics and properties which vary from place to place and can change with time. Geotechnical engineering involves gathering and assimilating limited facts about these characteristics and properties in order to understand or predict the behaviour of the ground on a particular site under certain conditions. This report may contain such facts obtained by inspection, excavation, probing, sampling, testing or other means of investigation. If so, they are directly relevant only to the ground at the place where and time when the investigation was carried out.

DESCRIPTION AND CLASSIFICATION METHODS

The methods of description and classification of soils and rocks used in this report are based on Australian Standard 1726, the SAA Site Investigation Code. In general, descriptions cover the following properties – soil or rock type, colour, structure, strength or density, and inclusions. Identification and classification of soil and rock involves judgement and the Company infers accuracy only to the extent that is common in current geotechnical practice.

Soil types are described according to the predominating particle size and behaviour as set out in the attached Unified Soil Classification Table qualified by the grading of other particles present (eg. sandy clay) as set out below:

Soil Classification	Particle Size
Clay	less than 0.002mm
Silt	0.002 to 0.06mm
Sand	0.06 to 2mm
Gravel	2 to 60mm

Non-cohesive soils are classified on the basis of relative density, generally from the results of Standard Penetration Test (SPT) as below:

Relative Density	SPT 'N' Value (blows/300mm)
Very loose	less than 4
Loose	4 – 10
Medium dense	10 – 30
Dense	30 – 50
Very Dense	greater than 50

Cohesive soils are classified on the basis of strength (consistency) either by use of hand penetrometer, laboratory testing or engineering examination. The strength terms are defined as follows.

Classification	Unconfined Compressive Strength kPa
Very Soft	less than 25
Soft	25 – 50
Firm	50 – 100
Stiff	100 – 200
Very Stiff	200 – 400
Hard	Greater than 400
Friable	Strength not attainable – soil crumbles

Rock types are classified by their geological names, together with descriptive terms regarding weathering, strength, defects, etc. Where relevant, further information regarding rock classification is given in the text of the report. In the Sydney Basin, 'Shale' is used to describe thinly bedded to laminated siltstone.

SAMPLING

Sampling is carried out during drilling or from other excavations to allow engineering examination (and laboratory testing where required) of the soil or rock.

Disturbed samples taken during drilling provide information on plasticity, grain size, colour, moisture content, minor constituents and, depending upon the degree of disturbance, some information on strength and structure. Bulk samples are similar but of greater volume required for some test procedures.

Undisturbed samples are taken by pushing a thin-walled sample tube, usually 50mm diameter (known as a U50), into the soil and withdrawing it with a sample of the soil contained in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Details of the type and method of sampling used are given on the attached logs.

INVESTIGATION METHODS

The following is a brief summary of investigation methods currently adopted by the Company and some comments on their use and application. All except test pits, hand auger drilling and portable dynamic cone penetrometers require the use of a mechanical drilling rig which is commonly mounted on a truck chassis.

Test Pits: These are normally excavated with a backhoe or a tracked excavator, allowing close examination of the insitu soils if it is safe to descend into the pit. The depth of penetration is limited to about 3m for a backhoe and up to 6m for an excavator. Limitations of test pits are the problems associated with disturbance and difficulty of reinstatement and the consequent effects on close-by structures. Care must be taken if construction is to be carried out near test pit locations to either properly recompact the backfill during construction or to design and construct the structure so as not to be adversely affected by poorly compacted backfill at the test pit location.

Hand Auger Drilling: A borehole of 50mm to 100mm diameter is advanced by manually operated equipment. Premature refusal of the hand augers can occur on a variety of materials such as hard clay, gravel or ironstone, and does not necessarily indicate rock level.

Continuous Spiral Flight Augers: The borehole is advanced using 75mm to 115mm diameter continuous spiral flight augers, which are withdrawn at intervals to allow sampling and insitu testing. This is a relatively economical means of drilling in clays and in sands above the water table. Samples are returned to the surface by the flights or may be collected after withdrawal of the auger flights, but they can be very disturbed and layers may become mixed. Information from the auger sampling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively lower reliability due to mixing or softening of samples by groundwater, or uncertainties as to the original depth of the samples. Augering below the groundwater table is of even lesser reliability than augering above the water table.

Rock Augering: Use can be made of a Tungsten Carbide (TC) bit for auger drilling into rock to indicate rock quality and continuity by variation in drilling resistance and from examination of recovered rock fragments. This method of investigation is quick and relatively inexpensive but provides only an indication of the likely rock strength and predicted values may be in error by a strength order. Where rock strengths may have a significant impact on construction feasibility or costs, then further investigation by means of cored boreholes may be warranted.

Wash Boring: The borehole is usually advanced by a rotary bit, with water being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from "feel" and rate of penetration.

Mud Stabilised Drilling: Either Wash Boring or Continuous Core Drilling can use drilling mud as a circulating fluid to stabilise the borehole. The term 'mud' encompasses a range of products ranging from bentonite to polymers such as Revert or Biogel. The mud tends to mask the cuttings and reliable identification is only possible from intermittent intact sampling (eg. from SPT and U50 samples) or from rock coring, etc.

Continuous Core Drilling: A continuous core sample is obtained using a diamond tipped core barrel. Provided full core recovery is achieved (which is not always possible in very low strength rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation. In rocks, an NMLC triple tube core barrel, which gives a core of about 50mm diameter, is usually used with water flush. The length of core recovered is compared to the length drilled and any length not recovered is shown as CORE LOSS. The location of losses are determined on site by the supervising engineer; where the location is uncertain, the loss is placed at the top end of the drill run.

Standard Penetration Tests: Standard Penetration Tests (SPT) are used mainly in non-cohesive soils, but can also be used in cohesive soils as a means of indicating density or strength and also of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289, "Methods of Testing Soils for Engineering Purposes" – Test F3.1.

The test is carried out in a borehole by driving a 50mm diameter split sample tube with a tapered shoe, under the impact of a 63kg hammer with a free fall of 760mm. It is normal for the tube to be driven in three successive 150mm increments and the 'N' value is taken as the number of blows for the last 300mm. In dense sands, very hard clays or weak rock, the full 450mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form:

- In the case where full penetration is obtained with successive blow counts for each 150mm of, say, 4, 6 and 7 blows, as

  N = 13
  4, 6, 7

- In a case where the test is discontinued short of full penetration, say after 15 blows for the first 150mm and 30 blows for the next 40mm, as

  N>30
  15, 30/40mm

The results of the test can be related empirically to the engineering properties of the soil.

Occasionally, the drop hammer is used to drive 50mm diameter thin walled sample tubes (U50) in clays. In such circumstances, the test results are shown on the borehole logs in brackets.

A modification to the SPT test is where the same driving system is used with a solid 60° tipped steel cone of the same diameter as the SPT hollow sampler. The solid cone can be continuously driven for some distance in soft clays or loose sands, or may be used where damage would otherwise occur to the SPT. The results of this Solid Cone Penetration Test (SCPT) are shown as 'N_c' on the borehole logs, together with the number of blows per 150mm penetration.

Static Cone Penetrometer Testing and Interpretation: Cone penetrometer testing (sometimes referred to as a Dutch Cone) described in this report has been carried out using a Cone Penetrometer Test (CPT). The test is described in Australian Standard 1289, Test F5.1.

In the tests, a 35mm or 44mm diameter rod with a conical tip is pushed continuously into the soil, the reaction being provided by a specially designed truck or rig which is fitted with a hydraulic ram system. Measurements are made of the end bearing resistance on the cone and the frictional resistance on a separate 134mm or 165mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are electrically connected by wires passing through the centre of the push rods to an amplifier and recorder unit mounted on the control truck.

As penetration occurs (at a rate of approximately 20mm per second) the information is output as incremental digital records every 10mm. The results given in this report have been plotted from the digital data.

The information provided on the charts comprise:

- Cone resistance – the actual end bearing force divided by the cross sectional area of the cone – expressed in MPa.
- Sleeve friction – the frictional force on the sleeve divided by the surface area – expressed in kPa.
- Friction ratio – the ratio of sleeve friction to cone resistance, expressed as a percentage.

  The ratios of the sleeve resistance to cone resistance will vary with the type of soil encountered, with higher relative friction in clays than in sands. Friction ratios of 1% to 2% are commonly encountered in sands and occasionally very soft clays, rising to 4% to 10% in stiff clays and peats. Soil descriptions based on cone resistance and friction ratios are only inferred and must not be considered as exact.

Correlations between CPT and SPT values can be developed for both sands and clays but may be site specific.

Interpretation of CPT values can be made to empirically derive modulus or compressibility values to allow calculation of foundation settlements.

Stratification can be inferred from the cone and friction traces and from experience and information from nearby boreholes etc. Where shown, this information is presented for general guidance, but must be regarded as interpretive. The test method provides a continuous profile of engineering properties but, where precise information on soil classification is required, direct drilling and sampling may be preferable.

Portable Dynamic Cone Penetrometers: Portable Dynamic Cone Penetrometer (DCP) tests are carried out by driving a rod into the ground with a sliding hammer and counting the blows for successive 100mm increments of penetration.

Two relatively similar tests are used:

- Cone penetrometer (commonly known as the Scala Penetrometer) – a 16mm rod with a 20mm diameter cone end is driven with a 9kg hammer dropping 510mm (AS1289, Test F3.2). The test was developed initially for pavement subgrade investigations, and correlations of the test results with California Bearing Ratio have been published by various Road Authorities.
- Perth sand penetrometer – a 16mm diameter flat ended rod is driven with a 9kg hammer, dropping 600mm (AS1289, Test F3.3). This test was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.

LOGS

The borehole or test pit logs presented herein are an engineering and/or geological interpretation of the sub-surface conditions, and their reliability will depend to some extent on the frequency of sampling and the method of drilling or excavation. Ideally, continuous undisturbed sampling or core drilling will enable the most reliable assessment, but is not always practicable or possible to justify on economic grounds. In any case, the boreholes or test pits represent only a very small sample of the total subsurface conditions.

The attached explanatory notes define the terms and symbols used in preparation of the logs.

Interpretation of the information shown on the logs, and its application to design and construction, should therefore take into account the spacing of boreholes or test pits, the method of drilling or excavation, the frequency of sampling and testing and the possibility of other than 'straight line' variations between the boreholes or test pits. Subsurface conditions between boreholes or test pits may vary significantly from conditions encountered at the borehole or test pit locations.

GROUNDWATER

Where groundwater levels are measured in boreholes, there are several potential problems:

- Although groundwater may be present, in low permeability soils it may enter the hole slowly or perhaps not at all during the time it is left open.
- A localised perched water table may lead to an erroneous indication of the true water table.
- Water table levels will vary from time to time with seasons or recent weather changes and may not be the same at the time of construction.
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must be washed out of the hole or 'reverted' chemically if water observations are to be made.

More reliable measurements can be made by installing standpipes which are read after stabilising at intervals ranging from several days to perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from perched water tables or surface water.

FILL

The presence of fill materials can often be determined only by the inclusion of foreign objects (eg. bricks, steel, etc) or by distinctly unusual colour, texture or fabric. Identification of the extent of fill materials will also depend on investigation methods and frequency. Where natural soils similar to those at the site are used for fill, it may be difficult with limited testing and sampling to reliably determine the extent of the fill.

The presence of fill materials is usually regarded with caution as the possible variation in density, strength and material type is much greater than with natural soil deposits. Consequently, there is an increased risk of adverse engineering characteristics or behaviour. If the volume and quality of fill is of importance to a project, then frequent test pit excavations are preferable to boreholes.

LABORATORY TESTING

Laboratory testing is normally carried out in accordance with Australian Standard 1289 *'Methods of Testing Soil for Engineering Purposes'*. Details of the test procedure used are given on the individual report forms.

ENGINEERING REPORTS

Engineering reports are prepared by qualified personnel and are based on the information obtained and on current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal (eg. a three storey building) the information and interpretation may not be relevant if the design proposal is changed (eg. to a twenty storey building). If this happens, the company will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical aspects and recommendations or suggestions for design and construction. However, the Company cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions – the potential for this will be partially dependent on borehole spacing and sampling frequency as well as investigation technique.
- Changes in policy or interpretation of policy by statutory authorities.
- The actions of persons or contractors responding to commercial pressures.

If these occur, the company will be pleased to assist with investigation or advice to resolve any problems occurring.

SITE ANOMALIES

In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, the company requests that it immediately be notified. Most problems are much more readily resolved when conditions are exposed that at some later stage, well after the event.

REPRODUCTION OF INFORMATION FOR CONTRACTUAL PURPOSES

Attention is drawn to the document *'Guidelines for the Provision of Geotechnical Information in Tender Documents'*, published by the Institution of Engineers, Australia. Where information obtained from this investigation is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. The company would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Copyright in all documents (such as drawings, borehole or test pit logs, reports and specifications) provided by the Company shall remain the property of Jeffery and Katauskas Pty Ltd. Subject to the payment of all fees due, the Client alone shall have a licence to use the documents provided for the sole purpose of completing the project to which they relate. License to use the documents may be revoked without notice if the Client is in breach of any objection to make a payment to us.

REVIEW OF DESIGN

Where major civil or structural developments are proposed or where only a limited investigation has been completed or where the geotechnical conditions/ constraints are quite complex, it is prudent to have a joint design review which involves a senior geotechnical engineer.

SITE INSPECTION

The company will always be pleased to provide engineering inspection services for geotechnical aspects of work to which this report is related.

Requirements could range from:

i) a site visit to confirm that conditions exposed are no worse than those interpreted, to

ii) a visit to assist the contractor or other site personnel in identifying various soil/rock types such as appropriate footing or pier founding depths, or

iii) full time engineering presence on site.

GRAPHIC LOG SYMBOLS FOR SOILS AND ROCKS

SOIL

- FILL
- TOPSOIL
- CLAY (CL, CH)
- SILT (ML, MH)
- SAND (SP, SW)
- GRAVEL (GP, GW)
- SANDY CLAY (CL, CH)
- SILTY CLAY (CL, CH)
- CLAYEY SAND (SC)
- SILTY SAND (SM)
- GRAVELLY CLAY (CL, CH)
- CLAYEY GRAVEL (GC)
- SANDY SILT (ML)
- PEAT AND ORGANIC SOILS

ROCK

- CONGLOMERATE
- SANDSTONE
- SHALE
- SILTSTONE, MUDSTONE, CLAYSTONE
- LIMESTONE
- PHYLLITE, SCHIST
- TUFF
- GRANITE, GABBRO
- DOLERITE, DIORITE
- BASALT, ANDESITE
- QUARTZITE

DEFECTS AND INCLUSIONS

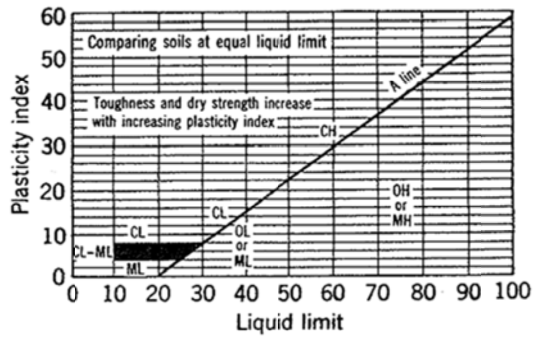
- CLAY SEAM
- SHEARED OR CRUSHED SEAM
- BRECCIATED OR SHATTERED SEAM/ZONE
- IRONSTONE GRAVEL
- ORGANIC MATERIAL

OTHER MATERIALS

- CONCRETE
- BITUMINOUS CONCRETE, COAL
- COLLUVIUM

Field Identification Procedures (Excluding particles larger than 75 μm and basing fractions on estimated weights)				Group Symbols[a]	Typical Names	Information Required for Describing Soils	Laboratory Classification Criteria	
Coarse-grained soils More than half of material is *larger* than 75 μm sieve size[b] (The 75 μm sieve size is about the smallest particle visible to naked eye)	Gravels More than half of coarse fraction is larger than 4 mm sieve size	Clean gravels (little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes	*GW*	Well graded gravels, gravel-sand mixtures, little or no fines	Give typical name; indicate approximate percentages of sand and gravel; maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbols in parentheses For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics Example: *Silty sand*, gravelly; about 20% hard, angular gravel particles 12 mm maximum size; rounded and subangular sand grains coarse to fine, about 15% non-plastic fines with low dry strength; well compacted and moist in place; alluvial sand; (*SM*)	Use grain size curve in identifying the fractions as given under field identification Determine percentages of gravel and sand from grain size curve Depending on percentage of fines (fraction smaller than 75 μm sieve size) coarse grained soils are classified as follows: Less than 5% *GW, GP, SW, SP* More than 12% *GM, GC, SM, SC* 5% to 12% *Borderline* cases requiring use of dual symbols	$C_U = \frac{D_{60}}{D_{10}}$ Greater than 4 $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Predominantly one size or a range of sizes with some intermediate sizes missing	*GP*	Poorly graded gravels, gravel-sand mixtures, little or no fines			Not meeting all gradation requirements for *GW*
		Gravels with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures see *ML* below)	*GM*	Silty gravels, poorly graded gravel-sand-silt mixtures			Atterberg limits below "A" line, or *PI* less than 4 / Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)	*GC*	Clayey gravels, poorly graded gravel-sand-clay mixtures			Atterberg limits above "A" line, with *PI* greater than 7
	Sands More than half of coarse fraction is smaller than 4 mm sieve size	Clean sands (little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes	*SW*	Well graded sands, gravelly sands, little or no fines			$C_U = \frac{D_{60}}{D_{10}}$ Greater than 6 $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Predominantly one size or a range of sizes with some intermediate sizes missing	*SP*	Poorly graded sands, gravelly sands, little or no fines			Not meeting all gradation requirements for *SW*
		Sands with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures, see *ML* below)	*SM*	Silty sands, poorly graded sand-silt mixtures			Atterberg limits below "A" line or *PI* less than 5 / Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)	*SC*	Clayey sands, poorly graded sand-clay mixtures			Atterberg limits below "A" line with *PI* greater than 7

Identification Procedures on Fraction Smaller than 380 μm Sieve Size		Dry Strength (crushing characteristics)	Dilatancy (reaction to shaking)	Toughness (consistency near plastic limit)	Group Symbols	Typical Names	Information Required for Describing Soils
Fine-grained soils More than half of material is *smaller* than 75 μm sieve size	Silts and clays liquid limit less than 50	None to slight	Quick to slow	None	*ML*	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	Give typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition, odour if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions Example: *Clayey silt*, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (*ML*)
		Medium to high	None to very slow	Medium	*CL*	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	
		Slight to medium	Slow	Slight	*OL*	Organic silts and organic silt-clays of low plasticity	
	Silts and clays liquid limit greater than 50	Slight to medium	Slow to none	Slight to medium	*MH*	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	
		High to very high	None	High	*CH*	Inorganic clays of high plasticity, fat clays	
		Medium to high	None to very slow	Slight to medium	*OH*	Organic clays of medium to high plasticity	
Highly Organic Soils		Readily identified by colour, odour, spongy feel and frequently by fibrous texture			*Pt*	Peat and other highly organic soils	



Plasticity chart
for laboratory classification of fine grained soils

Note: 1 Soils possessing characteristics of two groups are designated by combinations of group symbols (eg. GW-GC, well graded gravel-sand mixture with clay fines).
2 Soils with liquid limits of the order of 35 to 50 may be visually classified as being of medium plasticity.

LOG SYMBOLS

LOG COLUMN	SYMBOL	DEFINITION
Groundwater Record	▼	Standing water level. Time delay following completion of drilling may be shown.
	C	Extent of borehole collapse shortly after drilling.
	►	Groundwater seepage into borehole or excavation noted during drilling or excavation.
Samples	ES	Soil sample taken over depth indicated, for environmental analysis.
	U50	Undisturbed 50mm diameter tube sample taken over depth indicated.
	DB	Bulk disturbed sample taken over depth indicated.
	DS	Small disturbed bag sample taken over depth indicated.
	ASB	Soil sample taken over depth indicated, for asbestos screening.
	ASS	Soil sample taken over depth indicated, for acid sulfate soil analysis.
	SAL	Soil sample taken over depth indicated, for salinity analysis.
Field Tests	N = 17 4, 7, 10	Standard Penetration Test (SPT) performed between depths indicated by lines. Individual figures show blows per 150mm penetration. 'R' as noted below.
	N_c = 5 7 3R	Solid Cone Penetration Test (SCPT) performed between depths indicated by lines. Individual figures show blows per 150mm penetration for 60 degree solid cone driven by SPT hammer. 'R' refers to apparent hammer refusal within the corresponding 150mm depth increment.
	VNS = 25	Vane shear reading in kPa of Undrained Shear Strength.
	PID = 100	Photoionisation detector reading in ppm (Soil sample headspace test).
Moisture Condition (Cohesive Soils)	MC>PL	Moisture content estimated to be greater than plastic limit.
	MC≈PL	Moisture content estimated to be approximately equal to plastic limit.
	MC<PL	Moisture content estimated to be less than plastic limit.
(Cohesionless Soils)	D	DRY – Runs freely through fingers.
	M	MOIST – Does not run freely but no free water visible on soil surface.
	W	WET – Free water visible on soil surface.
Strength (Consistency) Cohesive Soils	VS	VERY SOFT – Unconfined compressive strength less than 25kPa
	S	SOFT – Unconfined compressive strength 25-50kPa
	F	FIRM – Unconfined compressive strength 50-100kPa
	St	STIFF – Unconfined compressive strength 100-200kPa
	VSt	VERY STIFF – Unconfined compressive strength 200-400kPa
	H	HARD – Unconfined compressive strength greater than 400kPa
	( )	Bracketed symbol indicates estimated consistency based on tactile examination or other tests.
Density Index/ Relative Density (Cohesionless Soils)		**Density Index (I_D) Range (%)** — **SPT 'N' Value Range (Blows/300mm)**
	VL	Very Loose <15 — 0-4
	L	Loose 15-35 — 4-10
	MD	Medium Dense 35-65 — 10-30
	D	Dense 65-85 — 30-50
	VD	Very Dense >85 — >50
	( )	Bracketed symbol indicates estimated density based on ease of drilling or other tests.
Hand Penetrometer Readings	300 250	Numbers indicate individual test results in kPa on representative undisturbed material unless noted otherwise.
Remarks	'V' bit	Hardened steel 'V' shaped bit.
	'TC' bit	Tungsten carbide wing bit.
	T_{60}	Penetration of auger string in mm under static load of rig applied by drill head hydraulics without rotation of augers.

LOG SYMBOLS continued

ROCK MATERIAL WEATHERING CLASSIFICATION

TERM	SYMBOL	DEFINITION
Residual Soil	RS	Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a large change in volume but the soil has not been significantly transported.
Extremely weathered rock	XW	Rock is weathered to such an extent that it has "soil" properties, ie it either disintegrates or can be remoulded, in water.
Distinctly weathered rock	DW	Rock strength usually changed by weathering. The rock may be highly discoloured, usually by ironstaining. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores.
Slightly weathered rock	SW	Rock is slightly discoloured but shows little or no change of strength from fresh rock.
Fresh rock	FR	Rock shows no sign of decomposition or staining.

ROCK STRENGTH

Rock strength is defined by the Point Load Strength Index (Is 50) and refers to the strength of the rock substance in the direction normal to the bedding. The test procedure is described by the International Journal of Rock Mechanics, Mining, Science and Geomechanics. Abstract Volume 22, No 2, 1985.

TERM	SYMBOL	Is (50) MPa	FIELD GUIDE
Extremely Low:	EL		Easily remoulded by hand to a material with soil properties.
----------------------	-------------	0.03	
Very Low:	VL		May be crumbled in the hand. Sandstone is "sugary" and friable.
----------------------	-------------	0.1	
Low:	L		A piece of core 150mm long x 50mm dia. may be broken by hand and easily scored with a knife. Sharp edges of core may be friable and break during handling.
----------------------	-------------	0.3	
Medium Strength:	M		A piece of core 150mm long x 50mm dia. can be broken by hand with difficulty. Readily scored with knife.
----------------------	-------------	1	
High:	H		A piece of core 150mm long x 50mm dia. core cannot be broken by hand, can be slightly scratched or scored with knife; rock rings under hammer.
----------------------	--------------	3	
Very High:	VH		A piece of core 150mm long x 50mm dia. may be broken with hand-held pick after more than one blow. Cannot be scratched with pen knife; rock rings under hammer.
----------------------	--------------	10	
Extremely High:	EH		A piece of core 150mm long x 50mm dia. is very difficult to break with hand-held hammer. Rings when struck with a hammer.

ABBREVIATIONS USED IN DEFECT DESCRIPTION

ABBREVIATION	DESCRIPTION	NOTES
Be	Bedding Plane Parting	Defect orientations measured relative to the normal to the long core axis (ie relative to horizontal for vertical holes)
CS	Clay Seam	
J	Joint	
P	Planar	
Un	Undulating	
S	Smooth	
R	Rough	
IS	Ironstained	
XWS	Extremely Weathered Seam	
Cr	Crushed Seam	
60t	Thickness of defect in millimetres	

VIBRATION EMISSION DESIGN GOALS

German Standard DIN 4150 – Part 3: 1999 provides guideline levels of vibration velocity for evaluating the effects of vibration in structures. The limits presented in this standard are generally recognised to be conservative.

The DIN 4150 values (maximum levels measured in any direction at the foundation, OR, maximum levels measured in (x) or (y) horizontal directions, in the plane of the uppermost floor), are summarised in Table 1 below.

It should be noted that peak vibration velocities higher than the minimum figures in Table 1 for low frequencies may be quite ‘safe’, depending on the frequency content of the vibration and the actual condition of the structure.

It should also be noted that these levels are ‘safe limits’, up to which no damage due to vibration effects has been observed for the particular class of building. ‘Damage’ is defined by DIN 4150 to include even minor non-structural effects such as superficial cracking in cement render, the enlargement of cracks already present, and the separation of partitions or intermediate walls from load bearing walls. Should damage be observed at vibration levels lower than the ‘safe limits’, then it may be attributed to other causes. DIN 4150 also states that when vibration levels higher than the ‘safe limits’ are present, it does not necessarily follow that damage will occur. Values given are only a broad guide.

Table 1: DIN 4150 – Structural Damage – Safe Limits for Building Vibration

Group	Type of Structure	Peak Vibration Velocity in mm/s			
		At Foundation Level at a Frequency of:			Plane of Floor of Uppermost Storey
		Less than 10Hz	10Hz to 50Hz	50Hz to 100Hz	All Frequencies
1	Buildings used for commercial purposes, industrial buildings and buildings of similar design.	20	20 to 40	40 to 50	40
2	Dwellings and buildings of similar design and/or use.	5	5 to 15	15 to 20	15
3	Structures that because of their particular sensitivity to vibration, do not correspond to those listed in Group 1 and 2 and have intrinsic value (eg. buildings that are under a preservation order).	3	3 to 8	8 to 10	8

Note: For frequencies above 100Hz, the higher values in the 50Hz to 100Hz column should be used.