GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1 – To be submitted with Development Application

Development Application for ______________________________

Name of Applicant

Address of site 26a HUDSON PARADE, CLAREVILLE

Declaration made by geotechnical engineer or engineering geologist or coastal engineer (where applicable) as part of a geotechnical report

I, PETER WRIGHT *on behalf of* JK GEOTECHNICS
(Insert Name) (Trading or Company Name)

on this the 6 NOVEMBER 2020 certify that I am a geotechnical engineer or engineering geologist or coastal engineer as defined by the Geotechnical Risk Management Policy for Pittwater - 2009 and I am authorised by the above organisation/company to issue this document and to certify that the organisation/company has a current professional indemnity policy of at least $2million.

We/I:

Please mark appropriate box

- [x] have prepared the detailed Geotechnical Report referenced below in accordance with the Australia Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009
- [ ] Are willing to technically verify that the detailed Geotechnical Report referenced below has been prepared in accordance with the Australian Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009
- [ ] have examined the site and the proposed development in detail and have carried out a risk assessment in accordance with Section 6.0 of the Geotechnical Risk Management Policy for Pittwater - 2009. We/I confirm that the results of the risk assessment for the proposed development are in compliance with the Geotechnical Risk Management Policy for Pittwater - 2009 and further detailed geotechnical reporting is not required for the subject site.
- [ ] have examined the site and the proposed development/alteration in detail and are/am of the opinion that the Development Application only involves Minor Development/Alteration that does not require a Geotechnical Report or Risk Assessment and hence my/our Report is in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009 requirements.
- [ ] have examined the site and the proposed development/alteration is separate from and is not affected by a Geotechnical Hazard and does not require a Geotechnical Report or Risk Assessment and hence my Report is in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009 requirements.
- [ ] have provided the coastal process and coastal forces analysis for inclusion in the Geotechnical Report

Geotechnical Report Details:

Report Title: GEOTECHNICAL ASSESSMENT FOR PROPOSED INCLINATOR

Report Date: 6 NOVEMBER 2020 Report Ref No: 33521PErpt

Author: MICHAEL EGAN / PETER WRIGHT

Author's Company/Organisation: **JK GEOTECHNICS**

Documentation which relate to or are relied upon in report preparation:

PROPOSED INCLINATOR DRAWINGS (PLAN NO. 0720/1A, SHEET NOS. 1, 2 & 3 dated 23 JULY 2020) PREPARED BY P.R. KING AND SONS PTY LTD
SURVEY PLAN (UNREFERENCED, dated 1 APRIL 2020) PREPARED BY YSCO GEOMATICS

We are aware that the above Geotechnical Report, prepared for the abovementioned site is to be submitted in support of a Development Application for this site and will be relied on by Pittwater Council as the basis for confirming that the Geotechnical Risk Management aspects of the proposed development have been adequately addressed to achieve an "Acceptable Risk Management" level for the life of the structure, taken as at least 100 years unless otherwise stated and justified in the Report and that reasonable and practical measures have been identified to remove foreseeable risk, as discussed in the Report.

Signature P. Wright

Name PETER WRIGHT

Chartered Professional Status CPEng

Membership No. 446230

Company **JK GEOTECHNICS**

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1(a) - Checklist of Requirements For Geotechnical Risk Management Report for Development Application

Development Application for PAM WALLIS
Name of Applicant

Address of site 26a HUDSON PARADE, CLAREVILLE

The following checklist covers the minimum requirements to be addressed in a Geotechnical Risk Management Geotechnical Report. This checklist is to accompany the Geotechnical Report and its certification (Form No. 1).

Geotechnical Report Details:

Report Title: GEOTECHNICAL ASSESSMENT FOR PROPOSED INCLINATOR
Report Date: 6 NOVEMBER 2020
Author: MICHAEL EGAN / PETER WRIGHT
Report Ref No: 33521PErpt
Author's Company/Organisation: JK GEOTECHNICS

Please mark appropriate box

- ☑ Comprehensive site mapping conducted 17 SEPTEMBER 2020 (date)
- ☑ Mapping details presented on contoured site plan with geomorphic mapping to a minimum scale of 1:200 (as appropriate)
- ☑ Subsurface investigation required
  - ☑ No Justification LIMITED SUBSURFACE INVESTIGATION COMPLETED ON 17 SEPTEMBER 2020
  - ☐ Yes Date conducted ....
- ☑ Geotechnical model developed and reported as an inferred subsurface type-section
- ☑ Geotechnical hazards identified
  - ☑ Above the site
  - ☑ On the site
  - ☑ Below the site
  - ☑ Beside the site
- ☑ Geotechnical hazards described and reported
- ☑ Risk assessment conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
  - ☑ Consequence analysis
  - ☑ Frequency analysis
- ☑ Risk calculation
- ☑ Risk assessment for property conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
- ☑ Risk assessment for loss of life conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
- ☑ Assessed risks have been compared to "Acceptable Risk Management" criteria as defined in the Geotechnical Risk Management Policy for Pittwater - 2009
- ☑ Opinion has been provided that the design can achieve the "Acceptable Risk Management" criteria provided that the specified recommendations presented in the Report are adopted.
- ☑ Design Life Adopted:
  - ☑ 100 years
  - ☐ Other .... specify
- ☑ Geotechnical Conditions to be applied to all four phases as described in the Geotechnical Risk Management Policy for Pittwater - 2009 have been specified
- ☑ Additional action to remove risk where reasonable and practical have been identified and included in the report.
- ☒ Risk assessment within Bushfire Asset Protection Zone.

We are aware that Pittwater Council will rely on the Geotechnical Report, to which this checklist applies, as the basis for confirming that the geotechnical risk management aspects of the proposal have been adequately addressed to achieve an "Acceptable Risk Management" level for the life of the structure, taken as at least 100 years unless otherwise stated, and justified in the Report and that reasonable and practical measures have been identified to remove foreseeable risk as discussed in the Report.

Signature P. Wright.
Name PETER WRIGHT
Chartered Professional Status CPEng
Membership No. 446230
Company JK GEOTECHNICS

REPORT TO

PAM WALLIS

ON

GEOTECHNICAL ASSESSMENT
(In Accordance with Pittwater Council Risk Management Policy)

FOR

PROPOSED INCLINATOR

AT

26a HUDSON PARADE, CLAREVILLE, NSW

Date: 6 November 2020
Ref: 33521PErpt

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

DOCUMENT REVISION RECORD

Report Reference	Report Status	Report Date
33521PErpt	Final Report	6 November 2020

This report (which includes all attachments and annexures) has been prepared by JK Geotechnics (JKG) for its Client, and is intended for the use only by that Client.

This Report has been prepared pursuant to a contract between JKG and its Client and is therefore subject to:
a) JKG's proposal in respect of the work covered by the Report;
b) The limitations defined in the Client's brief to JKG;
c) The terms of contract between JKG and the Client, including terms limiting the liability of JKG.
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1 INTRODUCTION

This report presents the results of our geotechnical assessment for the proposed inclinator at 26a Hudson Parade, Clareville. The location of the site is shown in Figure 1. The assessment was commissioned by Pam Wallis in an email dated 9 September 2020, and was carried out in general accordance with our fee proposal, Ref. 'P52370P' dated 4 August 2020.

From the supplied 'Design of Proposed Inclinator Within Lot 1 D.P1186229' drawings (Plan No. 0720/1A, Sheet Nos. 1, 2 and 3 dated 23 July 2020) prepared by P. R. King and Sons Pty Ltd (PRKS), we understand that the proposed inclinator will be located along the western portion of the northern site boundary. The inclinator will extend from the timber deck located on the western side of the existing ground floor level down to the timber deck above the Pittwater foreshore. The top and bottom landings will be constructed at approximately RL9.48m and RL2.08m which will be at, or slightly above the adjacent timber decks in these areas. Localised excavation to a maximum depth of approximately 1m will be required to achieve the design levels for the inclinator rail which will be supported on columns at five proposed locations.

We note that Jeffery and Katauskas Pty Ltd (now trading as JK Geotechnics [JKG]) completed a previous geotechnical assessment at the subject site in order to assess the likely causes of cracking to the residence on the property at that time. The results of the assessment were presented in our report (Ref. 10276JD/b) dated 6 April 1994. More recently, a geotechnical assessment report (Ref. P1203455JR01V01) dated 20 July 2012 was completed by Martens Consulting Engineers to support a development application (DA) for a new two storey dwelling. The existing house appears to have been constructed circa 2014 based on a review of available aerial imagery sourced from 'Google Earth'. The previous geotechnical assessment reports have been referred to during preparation of this current report.

This report has been prepared in accordance with the requirements of the Geotechnical Risk Management Policy for Pittwater (2009) as discussed in Section 5 below. Based on reference to the Pittwater Councils (now Northern Beaches Council) Geotechnical Hazard Mapping, the site is located within the Council Geotechnical Hazard Zone H1 requiring a full stability assessment. It is understood that the report will be submitted to Council as part of the DA documentation. Our report is preceded by the completed Council Forms 1 and 1a.

2 ASSESSMENT METHODOLOGY

2.1 Walkover Survey

The walkover assessment was completed by our Senior Geotechnical Engineer, Mr Michael Egan, on 17 September 2020 and comprised a detailed inspection of the topographic, surface drainage and geological conditions of the site and its immediate environs. The identified 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 flowchart illustrating the Risk Management Process based on the guidelines given in Australian Geomechanics Society (2007c) ‘Practice Note Guidelines for Landslide Risk Management’, Australian Geomechanics, Vol 42, No 1, March 2007, pp 63-114, hereafter designated Reference 1.

A summary of our observations is presented in Section 3 below. Our specific recommendations regarding the construction of the proposed inclinator are discussed in Section 6, following our geotechnical risk assessment.

The attached Figure 2 presents a geotechnical site plan showing the principal geotechnical features at the site. Figure 2 is based upon a survey plan (Unreferenced, dated 1 April 2020) prepared by YSCO Geomatics (YSCO). Additional features on Figure 2 have been plotted by hand held clinometer and tape measure techniques and hence are only approximate. Figure 3 presents an inferred geotechnical cross-sectional model through the site which is also based upon an additional survey plan prepared by YSCO, with pertinent surface observations plotted. The terms and symbols used in Figures 2 and 3 are described in Figure 4. Should any of the features on the attached figures be critical to the proposed development, we recommend they be located more accurately using instrument survey techniques.

In addition to the walkover assessment, a limited subsurface investigation was completed by our Senior Geotechnical Engineer using manually operated equipment comprising three Dynamic Cone Penetration (DCP) tests (DCP1 to DCP3). The DCP tests were completed at selected locations in the area of the proposed inclinator rail. The refusal depth of the DCP tests can provide an indicative depth to bedrock, though we note that refusal can also occur on obstructions in fill, ‘floaters’ or bands of weathered bedrock within a residual profile. The DCP tests were extended below ground surface to refusal depths of about 1.5m.

3 SUMMARY OF OBSERVATIONS

3.1 Site Description

We recommend that the summary of observations which follows be read in conjunction with the attached Figures 2 and 3.

The site is situated on a hillside that generally slopes and steps down to the west toward the Pittwater foreshore at between approximately 8° and 27°, with Hudson Parade bounding the site to the south-east. The subject site is a battle-axe property and slopes and steps down with the natural topography. Sandstone bedrock was exposed along the eastern side of Hudson Parade indicating that the road had been partially cut into the hillside. An elevation relief of approximately 25m exists between the street level and foreshore.

At the time of our assessment, a two storey concrete house, double car garage and suspended concrete pool were located in the central portion of the site, with a timber and concrete boat shed situated in the north-western corner above the foreshore. From Hudson Parade, the house was accessed by a concrete surfaced driveway which sloped down to the north-west at an average of approximately 12°. Sandstone block retaining walls up to approximately 1.4m high supported elevated garden areas on the north-eastern and south-western sides of the driveway. The eastern portions of the boat shed and lower ground floor of the two storey house had also been partially excavated into the hillside.

To the east of the lower ground floor level, the hillside and neighbouring property to the south-east were supported by a sandstone block retaining wall up to approximately 3.1m high. The block wall continued approximately 18m to the west along the northern site boundary where it supported (maximum 2.5m height decreasing to the west) the adjacent ground levels both within the neighbouring property and subject site. The block wall also extended a short distance to the west along the southern site boundary supporting the neighbouring grass area to the south-east.

A suspended timber deck extended several metres from the western side of the lower ground floor level where it was supported by a sandstone block wall up to approximately 2.6m high. A partially suspended concrete pool supported on concrete columns was located beyond the southern portion of the deck, with at least one concrete column appearing to be founded on sandstone bedrock, or possibly a large sandstone boulder above bedrock.

From the central portion of the timber deck, a concrete staircase stepped down to the single storey boat shed located immediately above the foreshore in the north-western corner of the site. A timber deck was also located adjacent to the boat shed above the intertidal zone which exposed sandstone bedrock. The sandstone was assessed as distinctly weathered and of medium strength when struck with a geological hammer. Two distinct joint sets were exposed within the bedrock which were orientated either to the north-east (Joint Set 1) or north-west (Joint Set 2).

The hillside to the east of the boat shed was supported by a sandstone block (and possibly concrete block) retaining wall up to approximately 4.3m high. The northern boat shed wall was set back approximately 1.2m from the inferred site boundary which provided up to approximately 3.5m of support to the adjacent ground levels in this area. A steel stormwater grate was located beyond the north-eastern corner of the boat shed with a number of PVC pipes extending through the block wall and down into the drain. Several loosely stacked sandstone boulder and timber retaining walls up to approximately 0.8m high supported the ground levels between the northern site boundary and boat shed. To the south of the boat shed, the concrete stairs and toe of the hillside were further supported by sandstone block walls between approximately 1.1m and 3m high.

Elsewhere within the western rear yard of the site, a sandstone block wall and several loosely stacked sandstone boulder retaining walls between approximately 0.2m and 1.1m high (with inclined faces between 50° and 90°) supported the terraced garden. The boulder walls were in variable condition; voids between adjacent boulders approximately 0.1m wide, erosion of the sandy soil backfill to a maximum horizontal depth of 0.25m, cracked and partially mortared boulders, and local erosion of the sandy soils at the base of the walls were observed.

All block walls mentioned above comprised sandstone blocks typically 2m x 0.5m x 0.5m (length x height x depth) in size.

Vegetation within the garden areas generally comprised small bushes and scattered medium and large sized gum trees up to approximately 15m high. Slight curvature at the base of the larger trees in the order of approximately 5° to 7° were observed.

The neighbouring property to the north (No. 1 Riverview Road) contained a suspended single storey timber and clad boat house located above the foreshore within the western portion site. The boat house was supported on timber piers and set back approximately 1m from the common boundary. A paved area below the suspended boat house contained a timber retaining wall up to approximately 1.5m high which supported the adjacent ground surface levels. A timber staircase was also located between the boat house and southern site boundary which extended upslope to the east. Above the boat house, ground surface levels sloped moderately down to the west, with a loosely stacked sandstone wall up to approximately 1.3m high located mid slope. The wall was in a poor condition and contained voids up to approximately 0.25m wide and 0.5m deep which were likely the result of dislodgement of individual boulders. A three storey brick house (No. 3 Riverview Road) was located beyond the neighbouring property to the north-east.

A neighbouring two storey timber and brick house (No. 26 Hudson Parade) was set back several metres to the south-east of the sandstone block wall located on the eastern side of the lower ground floor level. As outlined above, the block wall provided up to approximately 3.1m of support to the neighbouring house and adjacent grass area.

Old Wharf Reserve was located to the south-west of the subject site. The reserve sloped steeply down to the west at approximately 35° with the natural topography, was densely vegetated with small and large sized bushes and trees, and comprised an asphaltic concrete access road that serpentined down toward the Avalon Yacht Club at the base of the hillside. The trees within the reserve had rotated as much as 30° downslope to the west. Ground surface levels across the common boundary appeared similar.

Based on a cursory inspection from within the subject site and street frontages, all of the buildings and structures mentioned above generally appeared to be in good condition unless described otherwise.

3.2 Inferred Subsurface Conditions

The 1:100,000 geological map of Sydney indicates that the site is underlain rock of the Narrabeen Group. From our observations on site, sandstone bedrock is present both within the intertidal zone at the base of the hillside and on the eastern side of Hudson Parade. Though the material that caused refusal of the DCP tests cannot be confirmed, judging by the sandstone exposures mentioned above, the refusal depths of the DCP tests have been interpreted to indicate the surface of weathered sandstone bedrock between approximately 1.3m and 1.5m below ground levels. We expect a combination of poorly compacted surficial fill and natural residual and colluvial sands and clays would overlie the weathered bedrock.

4 PROPOSED DEVELOPMENT AND GEOTECHNICAL APPRAISAL

The proposed development comprises the construction of a new inclinator which will extend from the existing timber deck adjacent to the lower ground floor level down to below the timber deck along the Pittwater foreshore. The proposed inclinator will require excavations to a maximum depth of approximately 1m below existing surface levels, generally at the base of the proposed inclinator rail beside the boat shed. Elsewhere, we anticipate that only local trimming and battering of ground levels will be required along with the removal of individual sandstone blocks/boulders from the existing retaining walls. Concrete columns to support the inclinator rail have also been proposed at five locations.

Site preparation prior to the construction of the inclinator rail will be relatively straight forward, with the exception of the proposed excavation toward the base of the hillside. Due to the site constraints in this area, temporary batters formed through the inferred poorly compacted fill may not be possible, and a shoring system would be required prior to excavation commencing. A suitable retention system would include a contiguous piled shoring wall with the gaps between piles rectified progressively during excavation, such as by using concrete or non-shrink grout.

Due to limited access on to the site for a piling rig or small excavator, we expect that the piles to support both the proposed inclinator rail and excavation would be drilled using portable hand operated equipment. We note that hand augered piles cannot penetrate bedrock, and a vertical dowel through the centre of the piles would likely be required to provide additional lateral capacity.

The lateral stability of the shoring wall should be provided by a combination of the vertical dowels into the rock and either a capping beam or ring beam. The design of the footing and retention systems must be reviewed by the geotechnical engineer prior to construction commencing.

Specific geotechnical recommendations for appropriate retaining walls are provided in Section 6.1 below.

5 GEOTECHNICAL ASSESSMENT

Within the western portion of the site, surface levels generally sloped down to the west toward the Pittwater foreshore at a maximum of about 27°. In the vicinity of the proposed inclinator rail, surface levels sloped more gently at a maximum of approximately 13°, but several retaining walls of either sandstone block, sandstone boulder or timber construction provided up to approximately 4.3m of support to the adjacent hillside.

Based on the results of the walkover assessment and limited subsurface investigation, where soil cover is present, we anticipate that sandstone bedrock will be encountered at relatively shallow depths not exceeding about 1m to 2m.

In this risk assessment, we have assumed that the existing/recent construction of the two storey house and site structures (i.e. pool, boat shed etc) was completed under the Council Geotechnical Risk Management

Policy For Pittwater, such that all requirements of the Martens Consulting Engineers report have been addressed.

5.1 Potential Landslide Hazards

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

A. Instability of sandstone block retaining walls on the western side of the lower ground floor timber deck.
B. Instability of sandstone block retaining walls at the toe of the hillside (i.e. adjacent to the concrete stairs and above the timber deck).
C. Instability of sandstone block retaining wall supporting the hillside to the east of the boat shed.
D. Instability of various retaining walls (including the driveway walls) up to approximately 1.5m high.
E. Instability of existing fill and/or natural soil slope in excess of 15° within the western rear yard.
F. Instability of sandstone block retaining wall supporting the hillside above the lower ground floor level.
G. Instability of shoring wall supporting the inclinator receiving pit.

We have assessed the potential landslide hazard of near surface soil creep (i.e. slow moving) within the site, however we consider the consequence of this hazard to be insignificant if it occurs, and as such the potential hazard has not been considered further in this report.

5.2 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 Low and 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 about 6.7×10^{-8}, which would be considered to be 'acceptable' in accordance with the criteria provided in Reference 1.

5.3 Risk Assessment

It is recognised that, due to the many complex factors that can affect a site, the subjective nature of a risk analysis, and the imprecise nature of the science of geotechnical engineering, the risk of instability for a site and/or development cannot be completely removed. It is, however, essential that risk be reduced to at least that which could be reasonably anticipated by the community in everyday life and that landowners are made aware of reasonable and practical measures available to reduce risk as far as possible. Therefore, the recommendations provided below are aimed at reducing risk, but it does not require the geotechnical engineer to warrant that risk has been completely removed, only reduced, as removing risk is not currently scientifically achievable.

In preparing our recommendations given below we have assumed that no activities on surrounding land which may affect the risk on the subject site would be carried out. We have further assumed that all Council's buried services are, and will be regularly maintained to remain, in good condition.

We consider that our risk analysis has shown that the site and existing and proposed inclinator can achieve the 'Acceptable Risk Management' criteria provided that the recommendations given in Section 6 below are adopted. These recommendations form an integral part of the Landslide Risk Management Process.

6 COMMENTS AND RECOMMENDATIONS

The proposed inclinator rail should be designed and constructed in accordance with the following recommendations. The details of good hillside construction practice provided in Appendix B should also be implemented on this site.

6.1 Conditions Recommended to Establish the Design Parameters

6.1.1 A copy of Form 3 from the existing development must be sourced and provided to the geotechnical and structural engineers

6.1.2 All footings for the proposed inclinator must be founded in sandstone bedrock of at least low strength. The footings should be designed for an allowable bearing pressure of 700kPa, subject to inspection by a geotechnical engineer prior to pouring concrete. Rock dowels should also be designed for an allowable bond strength of 200kPa assuming they are socketed at least 0.5m into sandstone bedrock of at least low strength.

6.1.3 Subject to inspection by a geotechnical engineer and where space permits, temporary batters for any excavations associated with the proposed inclinator should be no steeper than 1 Vertical (V) in 2 Horizontal (H) within the soil profile. All surcharge and footing loads must be kept well clear of the excavation perimeter.

6.1.4 Proposed new retaining walls, including the anticipated shoring wall, should be designed using the following parameters:

- For conventional walls where minor movements may be tolerated (i.e. landscape walls), adopt a triangular lateral earth pressure distribution and an 'active' earth pressure coefficient, K_a, of 0.35 for the retained height, assuming a horizontal backfill surface.
- Where movements behind the walls must be limited, adopt a triangular earth pressure distribution with an 'at rest' earth pressure coefficient, K_0, of 0.5 for the retained height, assuming a horizontal backfill surface.
- The structural design must ensure that the active (or at-rest) pressure acting on the shoring wall can be distributed without providing any passive restraint from the adjacent boat shed.

- A bulk unit weight of 20kN/m^3 should be adopted for the soil profile.
- Any surcharge affecting the walls (e.g. nearby footings, sloping retaining surfaces, construction loads etc) should be allowed for in the design. The shoring wall should also be designed to withstand full hydrostatic pressures with a design groundwater level equivalent to the surrounding surface level.
- Conventional retaining walls should be designed as permanently drained and provision made for permanent and effective drainage of the ground behind the walls. Subsurface drains should incorporate a non-woven geotextile fabric, such as Bidim A34, to act as a filter against subsoil erosion. The subsoil drains should discharge into the stormwater system.
- Lateral restraint of any landscape walls founded in the soil profile below adjacent surface levels may be provided by the passive pressure of the soil below these levels. A 'passive; earth pressure coefficient, K_p, of 3 may be adopted, using a triangular pressure distribution and provided a Factor of Safety of at least 2 is used in order to reduce the high deflections that are associated with achieving a full passive case.
- Lateral resistance of the walls may be achieved by pouring the concrete onto a clean and rough bedrock surface, where a friction angle of 35° would apply.
- All concrete and steel elements (including dowels) will need to be designed with due regard for long term corrosion.

6.1.4 The guidelines for Hillside Construction given in Appendix B should also be adopted.

6.2 Conditions Recommended to the Detailed Design to be Undertaken for the Construction Certificate

6.2.1 As shown on Sheet 3 of the PRKS drawings, the footing (FDN1) below the eastern portion of the proposed inclinator rail may be incorporated into the adjacent sandstone block wall. In this instance, a structural engineer must assess the stability and capacity of the block wall to support any additional loads imposed by the new footing. A geotechnical inspection comprising test pit excavations to confirm that the block wall is founded on sandstone bedrock would also be required.

6.2.2 All structural design drawings must be reviewed by the geotechnical engineer who should endorse that the recommendations contained in this report have been adopted in principle.

6.2.3 Dilapidation surveys must be carried out on the neighbouring boat house to the north of the proposed inclinator receiving pit. A copy of the dilapidation report must be provided to the neighbour property owners, and they should be asked to to confirm that the reports present a fair record of existing conditions.

6.3 Conditions Recommended During the Construction Period

6.3.1 Prior to the commencement of site works, a meeting must be held on site with the contractor, structural engineer and geotechnical engineer present. At this meeting, the contractor must provide a detailed explanation of their work methods to be employed to achieve the required shoring and footing requirements.

6.3.2 Sandstone bedrock is expected to be encountered at between approximately 1m and 2m depth below surface levels which will require the use of piled footings to support the proposed inclinator. Bored piles using hand operated equipment would most likely require temporary liners to support the inferred poorly compacted fill and potentially collapsible sands and clays.

6.3.3 All piled footings to support the proposed inclinator should be set well back (or in front) of the crest of any buried sandstone cliff lines. To assist in identifying any buried cliff lines at the site, we recommend completing a number of DCP tests both above (upslope) and below (downslope) the proposed footing locations prior to the commencement of drilling. This will be of particular importance for the piled footings below the eastern portion of the proposed inclinator (i.e. FDN1 and FDN2) where vertical steps in the sandstone bedrock profile are expected.

6.3.4 If the inclinator pit shoring piles encountered bedrock above the proposed excavation level, the geotechnical engineer must be contacted immediately to visit site and make an assessment of the effect of this on the shoring.

6.3.5 The geotechnical engineer must inspect all footing excavations prior to placing reinforcement or pouring the concrete.

6.3.6 If sandstone bedrock is encountered above the proposed excavation level in the lower receiving pit, the geotechnical engineers must be called to visit the site and assess any impacts on the shoring walls.

6.3.7 The geotechnical engineer must confirm that the proposed inclinator has been completed in accordance with the geotechnical report.

We note that all of the above Conditions must be complied with. Where this has not been done, it may not be possible for a Form 3, which is required for the Occupation Certificate, to be signed by the geotechnical engineer.

6.4 Conditions Recommended for Ongoing Management of the Site/Structure(s)

The following recommendations have been included so that the current and future owners of the subject property are aware of their responsibilities:

6.4.1 No cut or fill in excess of 0.5m (e.g. for landscaping, buried pipes, retaining walls, etc), is to be carried out on site without prior consent from Northern Beaches Council.

6.4.2 Where the structural engineer has indicated a design life of less than 100 years then the structure and/or structural elements must be inspected by a structural engineer at the end of their design life; including a written report confirming scope of work completed and identifying the required remedial measures to extend the design life over the remaining 100 year period.

7 OVERVIEW

The site in its existing condition and with the installation of the proposed inclinator poses an acceptable risk to both life and property.

It is possible that the subsurface soil, rock or groundwater conditions encountered during construction may be found to be different (or may be interpreted to be different) from those inferred from our surface observations in preparing this report. Also, we have not had the opportunity to observe surface run-off patterns during heavy rainfall and cannot comment directly on this aspect. If conditions appear to be at variance or cause concern for any reason, then we recommend that you immediately contact this office.

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.

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

TABLE A

SUMMARY OF RISK ASSESSMENT TO PROPERTY

POTENTIAL LANDSLIDE HAZARD	**A**	**B**	**C**	**D**	**E**	**F**	**G**
	Instability of sandstone block retaining walls on western side of lower ground floor timber deck	Instability of sandstone block retaining walls at the toe of the hillside (i.e. adjacent to concrete stairs and above timber deck)	Instability of sandstone block retaining wall supporting the hillside to the east of boat shed	Instability of various retaining walls (including the driveway walls) up to approximately 1.5m high	Instability of existing fill and/or natural soil slope in excess of 15° within the western rear yard	Instability of sandstone block retaining wall supporting the hillside above lower ground floor level	Instability of shoring wall supporting inclinator receiving pit
Assessed Likelihood	Rare	Rare	Rare	Possible	Unlikely	Rare	Rare
Assessed Consequence	Minor	Minor	Medium	Insignificant	Minor	Medium	Insignificant
Risk	Very Low	Very Low	Low	Very low	Low	Low	Very Low
Comments	Assumes that the sandstone block retaining walls have been designed and constructed as engineered structures and that only local instability of the walls (i.e. <4m length) would occur.			Assumes only local instability of the walls (i.e. 4m length) would occur.	Based on the results of the walkover assessment and limited subsurface investigation, it appears there is shallow bedrock, and there are no obvious signs of deep seated instability within the subject site or in the surrounding properties.	Assumes that the sandstone block retaining walls have been designed and constructed as engineered structures and that only local instability of the walls (i.e. <4m length) would occur.	Assumes that the shoring wall is designed and constructed as an engineered structure.

TABLE B

SUMMARY OF RISK ASSESSMENT TO LIFE

POTENTIAL LANDSLIDE HAZARD	A	B	C	D	E	F	G
	Instability of sandstone block retaining walls on western side of lower ground floor timber deck	Instability of sandstone block retaining walls at the toe of the hillside (i.e. adjacent to concrete stairs and above timber deck)	Instability of sandstone block retaining wall supporting the hillside to the east of boat shed	Instability of various retaining walls (including the driveway walls) up to approximately 1.5m high	Instability of existing fill and/or natural soil slope in excess of 15° within the western rear yard	Instability of sandstone block retaining wall supporting the hillside above lower ground floor level	Instability of shoring wall supporting inclinator receiving pit
Assessed Likelihood	Rare	Rare	Rare	Possible	Unlikely	Rare	Rare
Indicative Annual Probability	10^{-5}	10^{-5}	10^{-5}	10^{-3}	10^{-4}	10^{-5}	10^{-5}
Persons at risk	Person gardening	Person using concrete stairs or timber deck along foreshore	Person within the boat shed	Person within the rear yard or using driveway	Person using concrete stairs or timber deck along foreshore	Person within a bedroom inside the house	Person using the inclinator
Number of Persons Considered	1						
Duration of Use of area Affected (Temporal Probability)	$6x10^{-3}$ (i.e. 1hr per week)	$1.4x10^{-3}$ (i.e. 2mins per day)	$6x10^{-3}$ (i.e. 1hr per week)	$3x10^{-3}$ (i.e. 0.5hrs per week)	$1.4x10^{-3}$ (i.e. 2mins per day)	0.33 (i.e. 8hrs per day)	$1.4x10^{-3}$ (i.e. 2mins per day)
Probability of not Evacuating Area Affected	0.1 (i.e. prior warning likely)	0.1 (i.e. prior warning likely)	0.9 (i.e. warning unlikely)	0.05 (i.e. prior warning likely)	0.8 (i.e. prior warning unlikely)	0.1 (i.e. prior warning likely)	0.01 (i.e. prior warning likely)
Spatial Probability	0.3 (i.e. 4m wide instability impacting 15m long wall)	0.25 (i.e. 4m wide instability impacting 16m long wall)	0.5 (i.e. instability impacting rear portion of the boat shed only)	0.4 (i.e. 2m wide instability impacting 10m long wall)	0.33 (i.e. 5m wide soil slump impacting 15m wide section of the stairs and deck)	0.25 (i.e. 4m wide instability impacting 16m long wall)	1 (i.e. any instability would impact the receiving pit)
Vulnerability to Life if Failure Occurs Whilst Person Present	0.9 (i.e. likely to be buried)	0.9 (i.e. likely to be buried)	0.9 (i.e. likely to be buried)	0.05 (i.e. very unlikely to be buried)	0.8 (i.e. likely to be buried)	0.1 (i.e. unlikely to have significant debris penetrating the wall of the house)	0
Risk for Person most at Risk	$1.6x10^{-9}$	$3.15x10^{-10}$	$2.4x10^{-8}$	$3x10^{-9}$	$3x10^{-8}$	$8.3x10^{-9}$	N/A As the vulnerability to life is 0, there is no risk to life should this hazard occur.

Note: From the summation of risk for person most at risk, the total risk for the person most at risk is 6.7×10^{-8}

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DYNAMIC CONE PENETRATION TEST RESULTS

Client:	PAM WALLIS
Project:	PROPOSED INCLINATOR
Location:	26a HUDSON PARADE, CLAREVILLE, NSW

Job No.	33521PE	Hammer Weight & Drop: 9kg/510mm
Date:	17-9-20	Rod Diameter: 16mm
Tested By:	M.E.	Point Diameter: 20mm

Test Location	**1**	**2**	**3**				
Surface RL	≈6.3m	≈7.7m	≈2.7m				
Depth (mm)	Number of Blows per 100mm Penetration						
0 - 100	SUNK	SUNK	SUNK				
100 - 200	↓	4					
200 - 300	1	4					
300 - 400	1	8					
400 - 500	1	16	↓				
500 - 600	4	11	2				
600 - 700	5	8	5				
700 - 800	4	7	6				
800 - 900	4	8	6				
900 - 1000	4	7	8				
1000 - 1100	5	12	12				
1100 - 1200	5	7	7				
1200 - 1300	4	14	11/90mm				
1300 - 1400	5	10/60mm	REFUSAL				
1400 - 1500	7/100mm	REFUSAL					
1500 - 1600	REFUSAL						
1600 - 1700							
1700 - 1800							
1800 - 1900							
1900 - 2000							
2000 - 2100							
2100 - 2200							
2200 - 2300							
2300 - 2400							
2400 - 2500							
2500 - 2600							
2600 - 2700							
2700 - 2800							
2800 - 2900							
2900 - 3000							

Remarks:
1. The procedure used for this test is described in AS1289.6.3.2-1997 (R2013)
2. Usually 8 blows per 20mm is taken as refusal
3. Datum of levels is AHD

AERIAL IMAGE SOURCE: MAPS.AU.NEARMAP.COM

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

Title:	SITE LOCATION PLAN
Location:	29A HUDSON PARADE, CLAREVILLE, NSW
Report No: 33521PE	Figure No: 1

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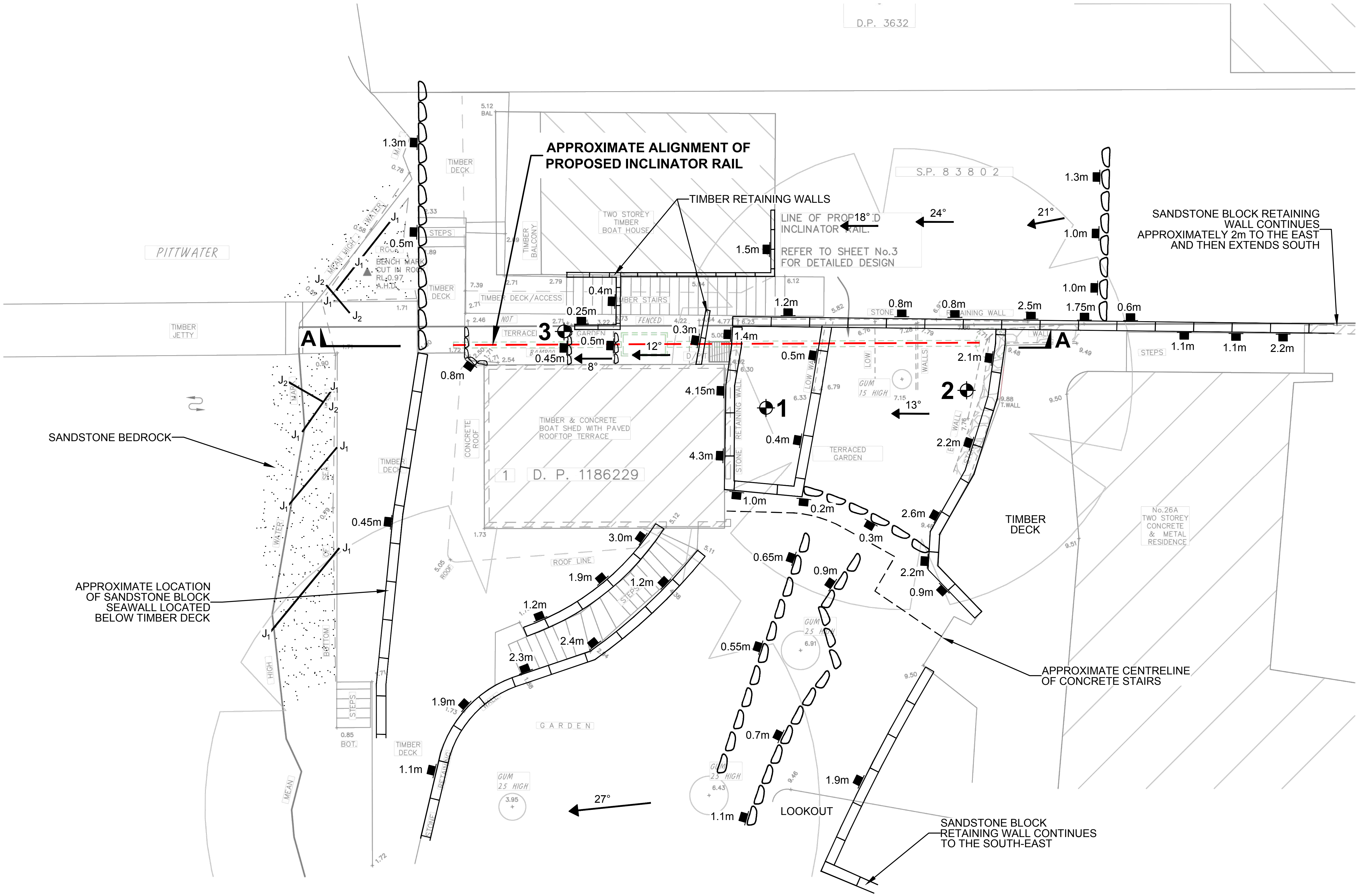
PLOT DATE: 29/10/2020 1:28:23 PM DWG FILE: Y:\33000'S\33521PE CLAREVILLE\CAD\33521PE.DWG



LEGEND

DCP TEST

NOTES:

1. REFER TO FIGURE 3 FOR SECTION A-A.
2. REFER TO FIGURE 4 FOR GEOTECHNICAL MAPPING SYMBOLS.

0 1 2 3 4 5

SCALE 1:100 @A3 METRES

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

Title: **GEOTECHNICAL SITE PLAN**

Location: 29A HUDSON PARADE, CLAREVILLE, NSW

Report No: 33521PE

Figure No: 2

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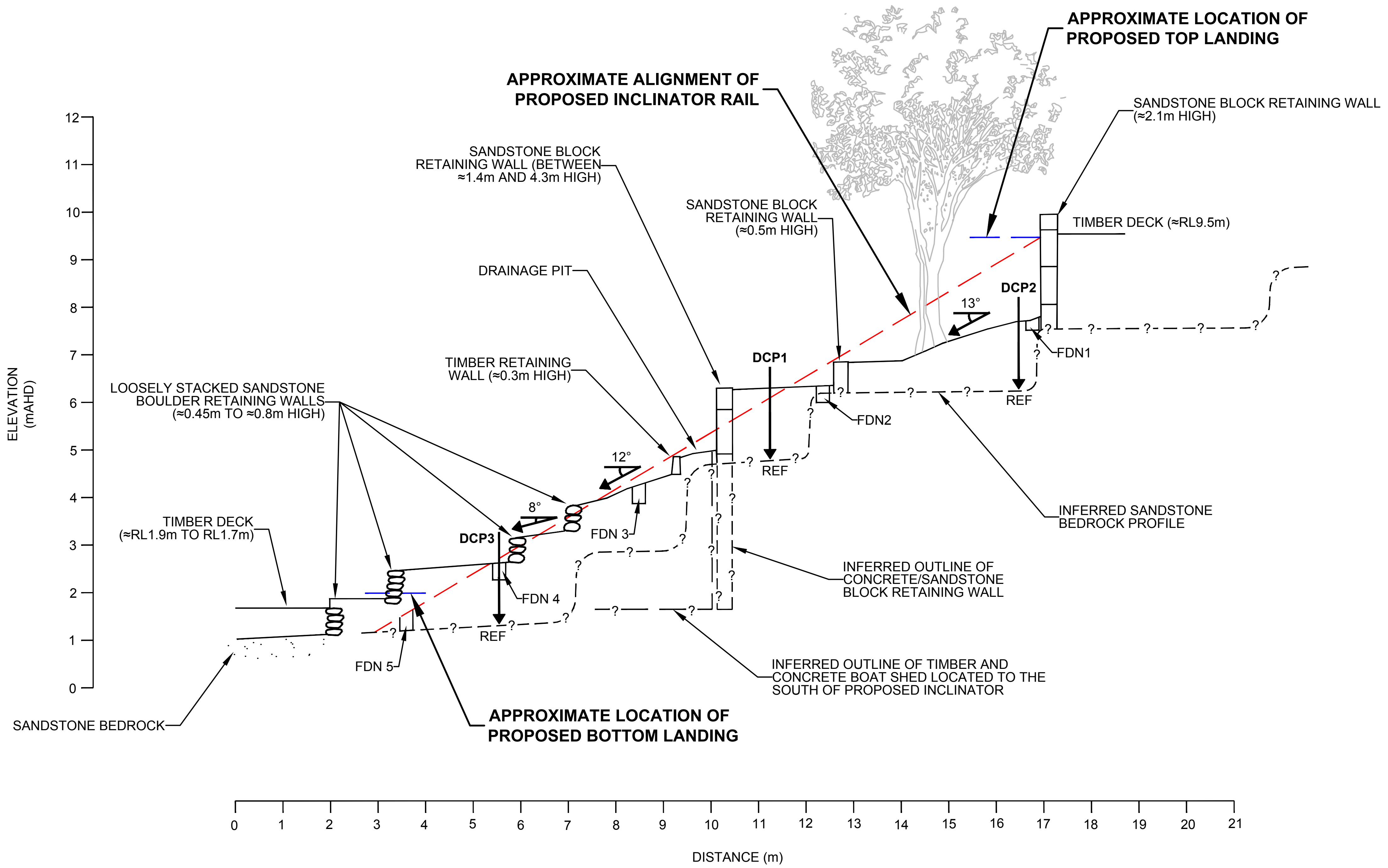
PLOT DATE: 6/11/2020 9:50:13 AM DWG FILE: Z:\6 GEOTECHNICAL\6F GEOTECHNICAL JOBS\33000'S\33521PE CLAREVILLE\CAD\33521PE.DWG



NOTE:
1. PROPOSED COLUMN LOCATIONS (FDN1 TO FDN5) ARE INDICATIVE ONLY.

SCALE 0 1 2 3 4 5 METRES 1:100 @A3

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

Title: **SECTION A-A LOOKING NORTH**

Location: 29A HUDSON PARADE, CLAREVILLE, NSW

Report No: 33521PE

Figure No: 3

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PLOT DATE: 6/11/2020 9:51:30 AM DWG FILE: Z:\6 GEOTECHNICAL\6F GEOTECHNICAL JOBS\33000'S\33521PE CLAREVILLE\CAD\33521PE.DWG

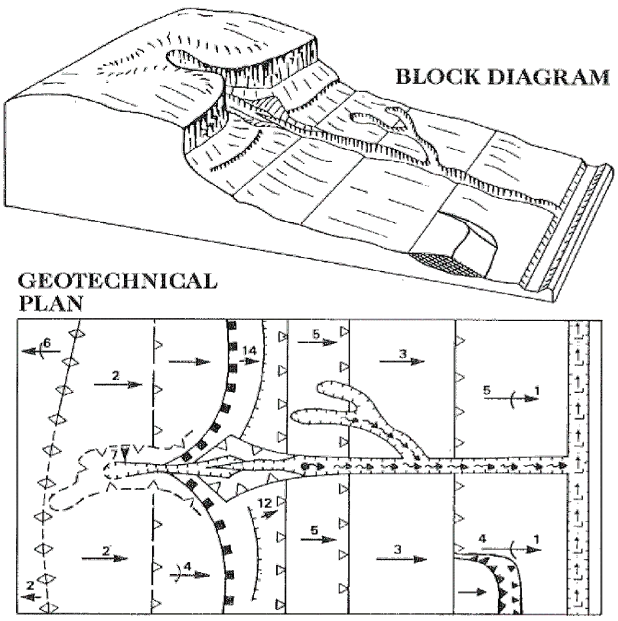
TOPOGRAPHY

Symbol	Ground Profile		
		convex	well defined or angular break of slope
		concave	
		convex	poorly defined or smooth change of slope
		concave	
	breaks of slope		convex and concave too close together to allow the use of separate symbols
	changes of slope		
	sharp		ridge crest
	rounded		
3	Cliff or escarpment or sharp break 40° or more (estimated height in metres)		
15	Uniform Slope		Slope direction and angle (Degrees)
10	Concave Slope		
8	Convex Slope		
	Top		Cut or fill slope, arrows pointing down slope
	Bottom		
	Hummocky or irregular ground		

OTHER FEATURES

- Boulder
- Seepage/spring
- Swallow hole for runoff
- Natural water course
- Open drain, unlined
- Open drain, lined
- Fenceline
- Property boundary
- Dry Stone Wall
- J ——— J 200 — Major joint in rock face (opening in millimetres)
- – T – T – 10 — Tension crack (opening in millimetres)
- Masonry or concrete wall
- Ponding water
- Boggy or swampy area

EXAMPLE OF USE OF TOPOGRAPHIC SYMBOLS:



(After Gardiner, V & Dackombe, R. V. (1983), Geomorphological Field Manual; George Allen & Unwin).

Title:	GEOTECHNICAL MAPPING SYMBOLS
Location:	29A HUDSON PARADE, CLAREVILLE, NSW
Report No:	33521PE
Figure No:	4

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

PLOT DATE: 29/10/2020 1:29:29 PM DWG FILE: Y:\33000'S\33521PE CLAREVILLE\CAD\33521PE.DWG

APPENDIX A

LANDSLIDE RISK

MANAGEMENT

TERMINOLOGY

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.

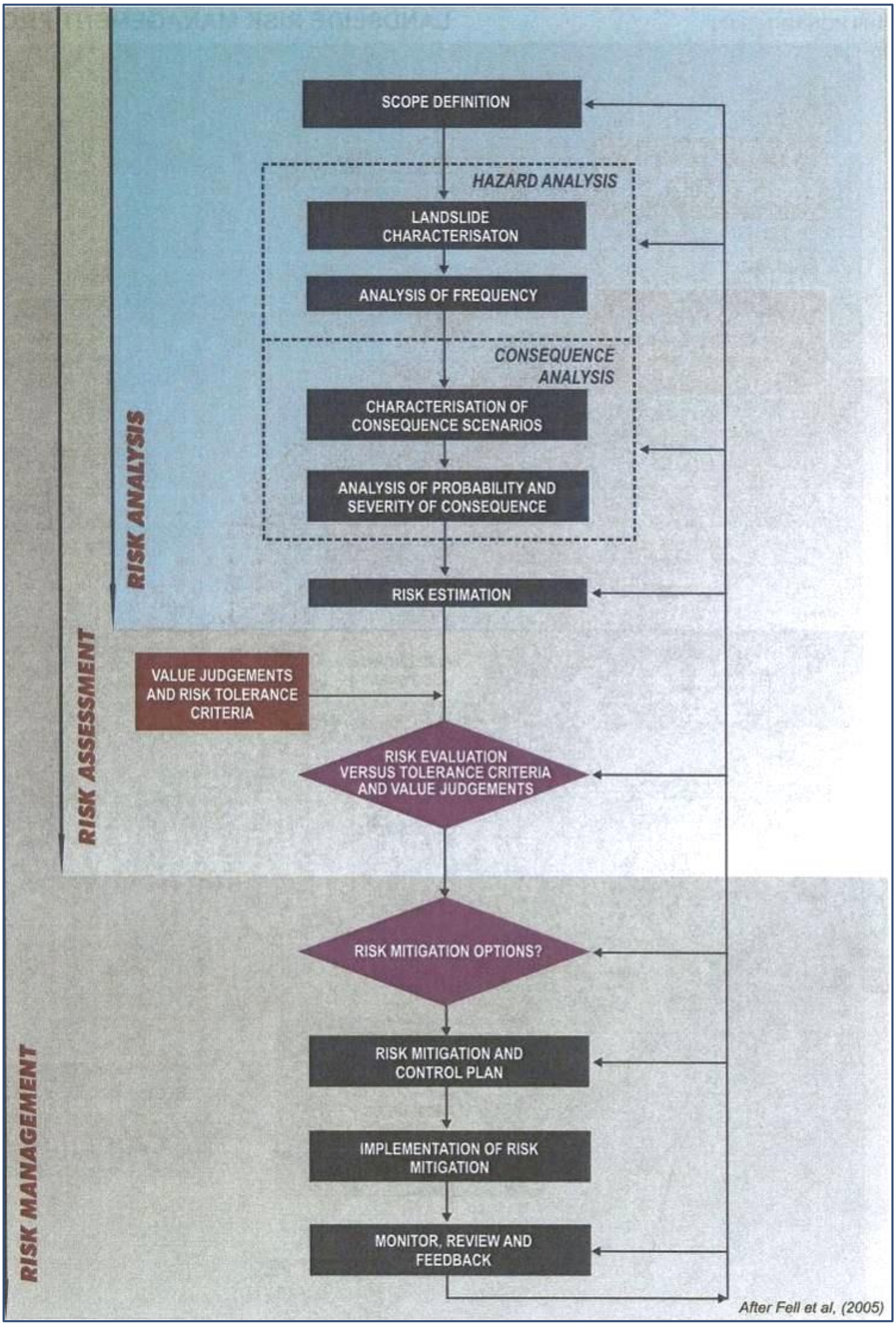

FIGURE A1: Flowchart for Landslide Risk Management.

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}	$5{\times}10^{-2}$	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	$5{\times}10^{-3}$	100 years	200 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	$5{\times}10^{-4}$	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	$5{\times}10^{-5}$	10,000 years	20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	$5{\times}10^{-2}$	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.

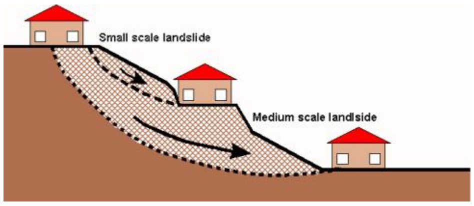

Figure 1

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.

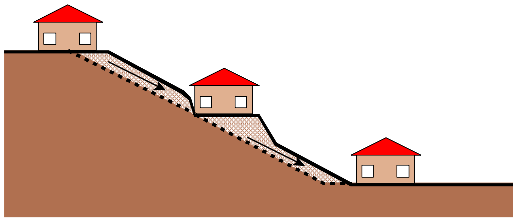

Figure 2

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.

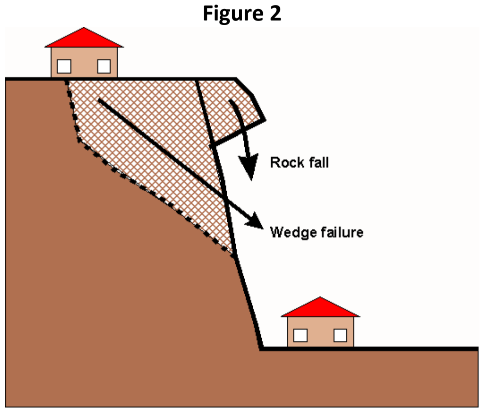

Figure 3

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.

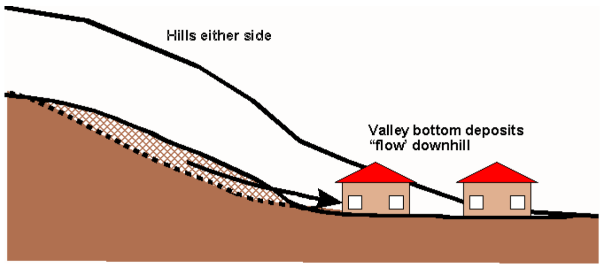

Figure 4

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- GeoGuide LR4 - Rock Slopes
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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.

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 tends to lack 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 temporary loss of use if the landslide occurs. These two factors are combined by the geotechnical practitioner to determine the Qualitative Risk.

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", "may be 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 of risk to property for developments within their jurisdictions. In these situations the risk must be assessed by a geotechnical practitioner. If stabilisation works are needed to meet the stipulated requirements these will normally have to be carried out as part of the development, or consent will be withheld.

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.

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

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APPENDIX B

SOME GUIDELINES

FOR

HILLSIDE CONSTRUCTION

SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

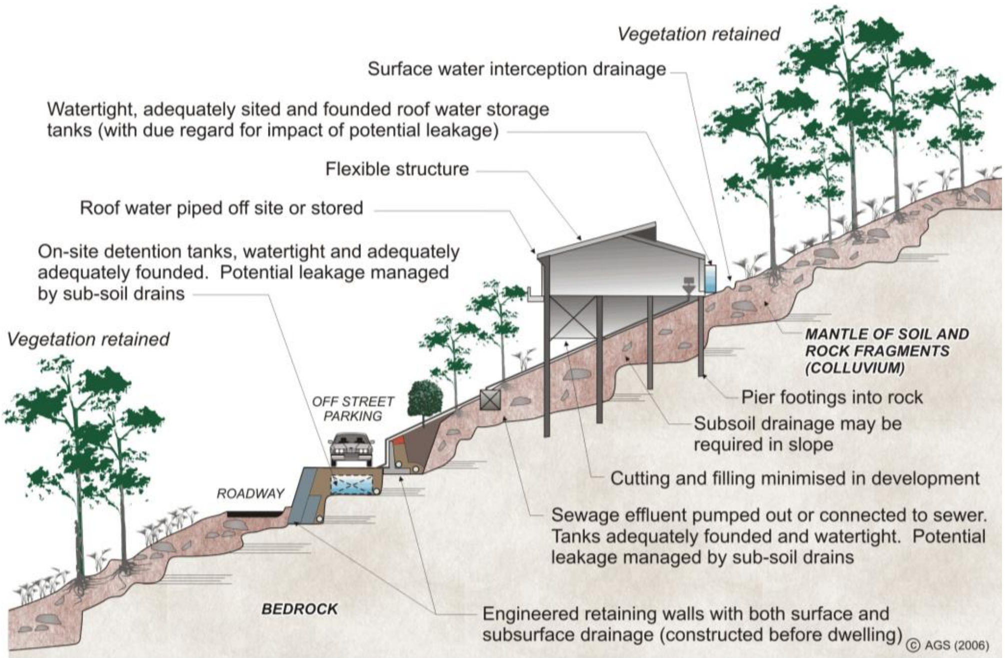
	GOOD ENGINEERING PRACTICE	POOR ENGINEERING PRACTICE
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical consultant at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having 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 extracted 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)

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.

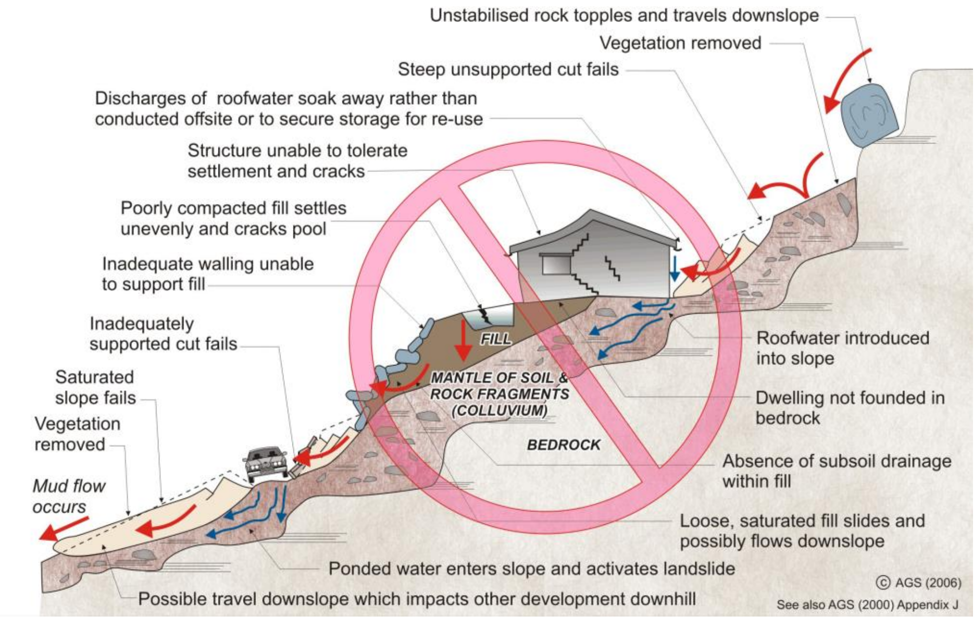
Flexible structures - have been used because they can tolerate a certain amount of movement with minimal signs of distress and maintain their functionality.

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

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:

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