Douglas Partners
Geotechnics / Environment / Groundwater

Integrated Practical Solutions

Report on
Geotechnical Assessment

Proposed Development
Lot 35 DP878862, Talbingo

Prepared for
Ironstone Development Group Pty Ltd

Project 206726.01
April 2023

Douglas Partners
Geotechnics / Environment / Groundwater

Document History

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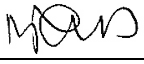
The undersigned, on behalf of Douglas Partners Pty Ltd, confirm that this document and all attached drawings, logs and test results have been checked and reviewed for errors, omissions and inaccuracies.

	Signature	Date
Author		28 April 2023
Reviewer		28 April 2023

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Douglas Partners
Geotechnics / Environment / Groundwater

Table of Contents

Page

Report on Geotechnical Assessment
Proposed Development
Lot 35 DP878862, Talbingo

1. Introduction

This report presents the results of a geotechnical assessment (updated) undertaken for a proposed development at Lot 35 DP878862, Talbingo. The investigation was commissioned in an email dated 9 February 2023 by Andrew Craddock on behalf of Ironstone Development Group Pty Ltd and was undertaken in accordance with Douglas Partners' proposal 206726.01.P.001.Rev0 dated 14 February 2023.

It is understood that a residential subdivision is proposed for the site.

DP has previously undertaken field mapping of the proposed site in 2006 (DP, 2006). The 2006 report comprised a review of published information, qualitative assessment of site stability considerations, sampling of selected surface soils and laboratory test results as well as preliminary comments relating to design and construction practice.

Given the time that has elapsed since the 2006 report, we understood that an updated geotechnical report was required for submission with the Development Application.

The scope of the current assessment included a review of DP 2006 report, site walkover and preparation of an updated geotechnical report detailing the applicability of the 2006 report to the current site conditions and general comments relevant to the proposed development.

This report must be read in conjunction with the attached notes “About this Report”.

2. Proposed development

Based on the Talbingo West Master Plan provided by the client (Concept Drawing No. PL 01 dated 04 May 2021, as shown in Figure 1 below), it is understood that the proposed development involves various features including, but not limited to, 59 residential lots, a spa hotel, six commercial / retail spaces, an early learning centre, a playground, a landscape watercourse, boat and car parking facilities. Bulk earthworks are expected to achieve design levels, though to what extent is unclear at this stage.

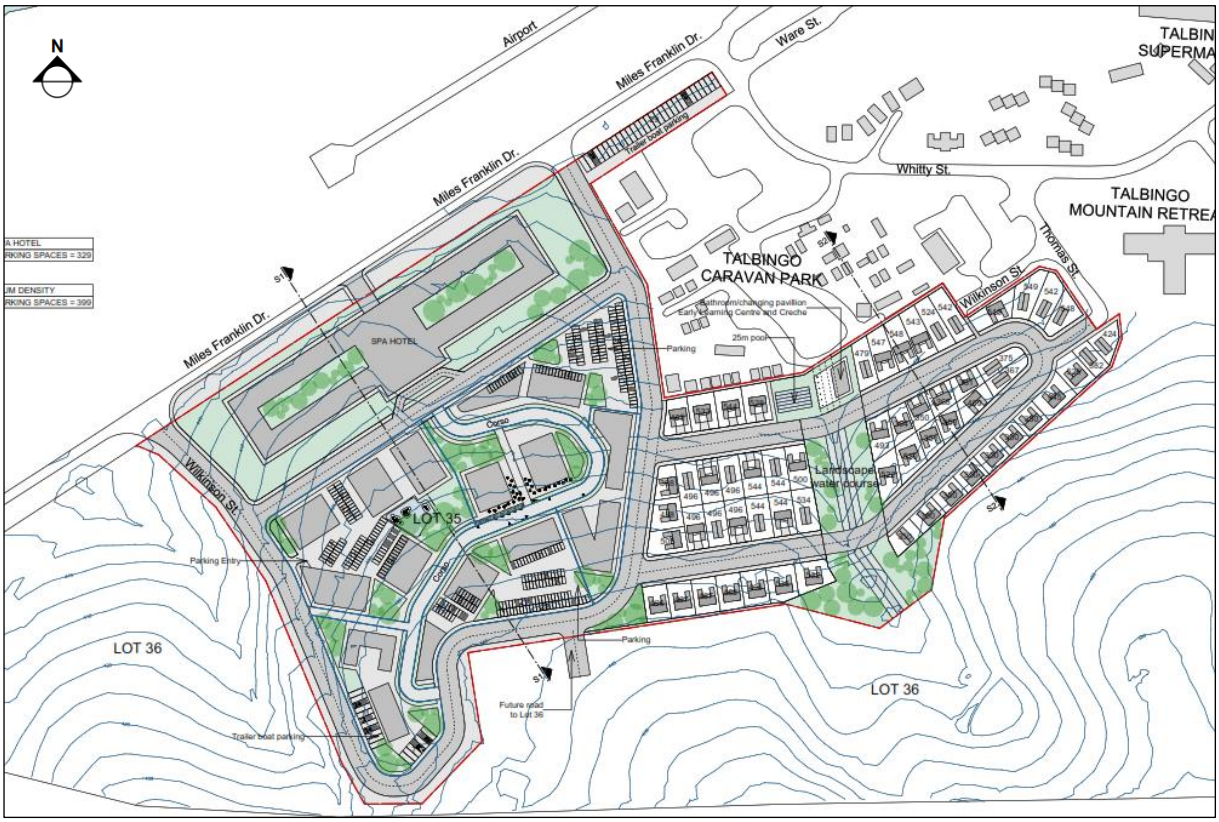

Figure 1: Proposed site master plan (Extract of Talbingo West Master Plan, Concept Drawing No. PL 01 dated 04 May 2021)

3. Site Description

The site located at Lot 35 DP 878862, which is an irregularly shaped lot of about 15 ha with maximum north-south and east-west dimensions of 350 m and 710 m respectively. The site is bounded by Miles Franklin Drive to the north/northwest, by Talbingo Caravan Park and Talbingo Mountain Retreat to the northeast and by undeveloped agricultural land to other directions. Talbingo Airstrip and Tumut River are located approximately 60 m and 300 m northwest of the proposed site.

Site levels fall generally from the south to the north/northwest. Based on the Talbingo West Master Plan provided by the client (Drawing No. PL 01, dated 04 May 2021), the surface levels vary from ~ 443 m AHD (Australian Height Datum) at the southern end of the proposed site to ~410 m AHD at the northern/north-western section of the site.

A site walkover was undertaken on 22 March 2023. Site features are shown on Drawing 1 in Appendix B and Photo Plates 1 – 13 included in Appendix C.

The following was observed during the site walkover:

- The site was vacant and fenced on the southern and western boundaries only, which had open access to vehicles;
- An existing road network (sealed with gravel shoulders in places and concrete kerbs in others) was noted through the central portion of the site, including Wilkinson Street, Yan Street, and Thomas Street;
- The site was generally moderately to heavily grass vegetated with matured trees mainly located in the south-eastern/eastern sections of the site;
- The north-western section of the site appeared to be an undeveloped vegetated paddock with a gully running in a north-south direction approximately 50 m to the western boundary of the site;
- Evidence of previous development in the form of levelled terraces mainly asphaltic concrete surfaced (remnant pavements) and some concrete slabs (previous buildings) across the central and eastern section of the site, with small stockpiles of building materials;
- Parallel and intersecting linear concrete paths/concrete drainage lines were observed throughout the central portion of the site;
- Disturbed ground associated with removed trees and possibly previous structures were observed across the southern and eastern sections of the site;
- Large hardstand area (including both asphaltic concrete surface and concrete slabs) was observed in the north-eastern corner of the site, which was accessible vis Miles Franklin Drive. Large stockpiles of soils, construction debris/materials and green waste materials were noted across the area;
- An embankment of up to ~6 m in height was noted in the northern (central) portion of the site; relatively soft ground was observed in the southern corner at the bottom of the embankment, which may be due to the recent above average rainfall;
- The site exposed along sections of the fence line and site cut, silty sandy clays typical of soils derived from the weathering of the underlying bedrock;
- Weathered rock was exposed in the road cuttings along the north-western site boundary, part of western site boundary, as well as part of the southern site boundary;
- A shallow cover of residual soil observed in the road cuttings;
- Pieces of farming equipment, building material and other miscellaneous rubbish was scattered across parts of the site;
- Rock outcrops were noted across most of the site, especially at the north-western and western sections;
- An existing structure was noted in the eastern section of the site, which was previously used as the “Talbingo Fire-Squad Training Area” as indicated by signage on the structure. A ~1:1 (H:V) site cut up to 1.0 m in height was located at the back of the structure with sandy clayey soil exposed.
- A gully with dense vegetation (former creek line) was located in the eastern portion of the site running in a north-south direction. Several trees located within this area were leaning or fallen, probably as a result of erosion in the gullies or blown over in wind storms;
- An electricity easement was located to the west of the gully (former creek line) in a north-south direction;
- A farm dam was located in the middle of the southern site boundary. Thick vegetation precluded close inspection of the dam.

4. Regional Geology

C & A (1966) indicates that the site is underlain by Blowering Porphyry of Silurian age, which typically comprises quartz feldspar, porphyry with minor slate greywacke, sandstone, quartzite, tuff and andesite.

5. Laboratory Testing

During the previous geotechnical assessment (DP, 2006), two surface soil samples were tested in the laboratory for measurement of Emerson stability class, pH, electrical conductivity, sulphate and chloride.

These tests provide an indication of the dispersity potential and salinity of the site soils. The detailed test report sheets are given in Appendix D and are summarised in Table 1.

Table 1: Results of Laboratory Testing

Sample No.	pH	ESN	Chloride (mgCl/kg)	Sulphate (mgSO4/kg)	EC (dS/m) (1)	Factor	ECe (2) (dS/m)	Material
X1	5.8	7	20	100	0.05	8.5	0.43	Silty Clay
X2	6.1	7	40	190	0.16	8.5	1.36	Silty Clay

Note (1): 1dS/m = 1mS/cm
(2): ECe = EC x factor

Where ECN = Emerson stability class; Factor = Soil texture factor (Richards, 1954 and DLWC, 2002)
EC = Electrical Conductivity; ECe = Electrical conductivity of a saturated extract

The results of the Emerson stability class testing have indicated that the soil tested have a low erosion potential. Comments on the salinity testing are given in Section 6.6.

On the basis of the chloride and sulphate testing, the soil conditions are considered to be *non-aggressive* for concrete and steel piles (AS 2159: 2009).

6. Comments

6.1 General

The following comments are based on the results of site walkover, previous laboratory testing (DP, 2006) and our experience in similar projects. It is understood that a residential subdivision is proposed, and that further investigation will be undertaken at the appropriate time as the planning and design of the subdivision proceeds. Accordingly, this report and the comments given within must be considered as being preliminary in nature.

6.2 General Development Considerations

6.2.1 Site Classification

In respect of AS 2870:2011 guidelines for residential site classification, it is expected that the natural subsurface profiles (from a reactivity perspective only) would range from Class S (slightly reactive) to Class M (moderately reactive) in areas of shallow bedrock, or in downslope, flatter areas where deeper, higher plasticity soil profiles are present, Class M and Class H1/2 (highly reactive) site can be expected.

Areas where uncontrolled fill is present would necessitate Class P site classifications.

The presence of mature trees, either existing or removed, would also influence the site classifications, as tree roots cause additional shrink/swell movements and necessitate a Class P site classification. In some cases, the additional shrink/swell movements from the tree influence can increase the site classification to the next higher classification (from a reactivity perspective).

Due to the presence of outcropping rock at the site, some allotments may be required to be classified as Class P due to non-uniform foundation conditions and/or adverse water conditions/groundwater seepages. To overcome the non-uniform foundation condition, some over-excavation of outcropping rock and replacement with controlled filling to avoid sharp transitions between low and high stiffness foundation conditions may be required.

Class P conditions could also exist where moisture impacted soils, shallow groundwater seepages are occurring and/or thick surficial silt/sandy deposits are present as these soils are of insufficient strength and in the case of silt/sands particularly susceptible to inundation and loss of strength in periods of wet weather.

The topographic slope in various sections of the site (i.e. adjacent drainage gully) is moderate/low to moderate risk of instability (refer Drawing 2) and accordingly, it is anticipated that some allotments need to consider design and construction techniques that take account of the ground slope and Class P conditions. Classifications within these areas would also be dependent on the extent of bulk earthworks.

All site classifications, would be heavily dependent on the extent of earthworks and subject to change.

6.2.2 Stability Assessment

The site has been assessed with reference to the AGS – Landslide Risk Management Concepts and Guidelines:20007. Based on the observations made during the inspection, assessment has been undertaken for two distinct zones:

- areas of slight relief (most of the site);
- areas of moderate relief (refer Drawing 2).

The results of the assessment for each of these areas are outlined in Tables 2 and 3.

Table 2: Slope Stability Assessment (Area of Slight Relief)

Hazard	Likelihood	Consequence to Proposed Development	Risk to Proposed Development
Creep of surface soils	Unlikely	Minor	Very Low to Low
Active / deep seated slide	Not credible	Major	Very Low

Table 3: Slope Stability Assessment (Area of Moderate Relief)

Hazard	Likelihood	Consequence to Proposed Development	Risk to Proposed Development
Creep of surface soils	Possible	Minor	Low to Moderate
Active / deep seated slide	Rare	Major	Low to Moderate

In summary, it is considered that most of the site is classified as VERY LOW to LOW risk of damage to property occurring as a result of slope instability. Three areas are considered of LOW to MODERATE risk (refer Drawing 2) due to the greater ground slopes. Notwithstanding the various risk categories nominated, development of the site for residential purposes is considered feasible with erosion control measures and suitable dwelling design required in the slightly steeper areas in the north and southwestern sections of the site and the central eastern portion around the gully (form creek line) and the existing farm dam.

6.2.3 Footings

All footing systems should be designed and constructed in accordance with AS2870:2011 for the appropriate classification. In areas, requiring a P classification, footing design must be based on engineering principles and undertaken by a suitably qualified structural engineer taking into consideration any onsite or offsite constraints.

Dwelling design will need to ensure suitable drainage and uniform moisture conditions are maintained in the vicinity of the footings otherwise footing performance could be compromised.

All footings should found within a uniform bearing stratum of suitable strength/material as detailed in AS 2870:2011, below the zone of influence of any uncontrolled fill, service trenches or pipes, silty soils, retaining walls or underground structures. Masonry walls should be articulated in accordance with current best practice.

For hillside lot construction, reference should be made to the publication by AGS (2007), relevant extracts of which are included in Appendix D.

6.3 Site Preparation and Earthworks

Prior to commencement of bulk excavation or controlled filling works on the site, surface preparations should include:

- Removal of vegetation and any root affected soils;
- Stripping of topsoil and stockpiling for possible use in landscaping areas;

- Removal of sandy/silty slopewash from proposed pavement and slab subgrades and possibly from future controlled fill areas (see comments below);
- Removal of any moisture weakened soil and existing fill encountered;
- Install drainage measure as required to control groundwater springs where encountered; and
- Removal of any corestones or protruding rock outcrops.

In areas that require filling, the stripped surfaces must be test rolled in the presence of a geotechnical engineer. Areas exhibiting significant deflections under test rolling should be treated either by over-excavation and replacement with approved filling material, by placement of a bridging layer (pavement areas only), or by other suitable remedial treatment.

All controlled fill in building areas, and subgrade fill 1.0 m below design subgrade level of pavement areas, should be compacted to a minimum 98% standard maximum dry density. Filling within 1.0 m of design subgrade level in pavement areas could be compacted to a minimum 100% standard maximum dry density. It is recommended that filling be placed in not thicker than 200 mm thick compacted layers with a maximum particle size of 75 mm. A few percent by volume of particles to a maximum 150 mm size would be acceptable, though approved by a geotechnical engineer. All batters should be constructed no steeper than 3:1 (H:V) and appropriately vegetated to reduce the effects of erosion.

To validate compaction levels within the controlled filling, field inspections and in-situ testing of future earthworks must be undertaken in order to satisfy the requirements of a Level 1 inspection and testing service as defined in AS 3798:2007.

Earthworks required for pavement construction will need to be based on batters formed no steeper than 3:1 (H:V) in the residual clays and 1.5:1 (H:V) in weathered rock. All batters should be suitable protected against erosion with toe and spoon drains constructed as a means of controlling surface flows on the batters.

It is understood that the farm dam located onsite is not required to be filled according to the Talbingo West Master Plan. Should future development be proposed within the area of the dam, the dam will require dewatering and removal of all uncontrolled fill associated with the embankment and soft sediments from the dam base prior to commencement of fill operations. An assessment of any groundwater seepages and subsequent drainage measures would be required prior to backfilling.

6.4 Site Maintenance and Drainage

The developed lots should be maintained in accordance with the CSIRO publication "Guide to Homeowners on Foundation Maintenance and Footing Performance", a copy of which is included in Appendix D. Whilst it must be accepted that minor cracking in most structures is inevitable, the guide describes suggested site maintenance practices aimed at minimising foundation movement to keep cracking within acceptable limits. Adequate surface and subsurface drainage should be installed and maintained at the site. All collected stormwater, groundwater and roof runoff should be discharged into the stormwater disposal system.

6.5 Pavements

6.5.1 Preliminary Thickness Designs

Table 4 summarises a range of pavement thickness designs based on the procedures given in Austroads (2017) for varying traffic loadings and subgrade CBR values. Suggested material quality and compaction requirements are given in Table 5.

Table 4: Preliminary Pavement Thickness Design

Traffic Loading (ESA)	Total Pavement Thickness (mm)			
	CBR < 3%	CBR 3%	CBR 4%	CBR 5%
1×10^4	325 (475)	325	275	245
5×10^4	365 (515)	365	320	280
1×10^5	385 (535)	385	340	300
5×10^5	480 (630)	480	420	360
1×10^6	520 (670)	520	450	395

Note: Bracketed figures indicate total boxing depth, taking into account 150 mm of subgrade replacement.

The pavement gravels should be placed and compacted in layers no thicker than 150 mm with control exercised over placement moisture contents. If layer thicknesses greater than 150 mm are proposed, it may be necessary to test the top and bottom of the layer to ensure that the minimum level of compaction has been achieved through the layer.

Table 5: Pavement Material Quality and Compaction

Layer	Material Quality	Minimum Compaction
Wearing Course	To conform to APRG – Report 21 (1997)	To conform to APRG – Report 21 (1997)
Base Course	To conform to APRG – Report 21 (1997) Soaked CBR ≥ 80%, PI ≤ 6%	Minimum dry density ratio of 98% Modified (AS 1289.5.2.1 (2017))
Sub-base Course	To conform to APRG – Report 21 (1997) Soaked CBR ≥ 30%, PI ≤ 12%	Minimum dry density ratio of 95% Modified (AS 1289.5.2.1 (2017))
Subgrade Replacement	Soaked CBR ≥ 20%	Minimum dry density ratio of 100% Standard (AS 1289.5.1.1 (2017))
Subgrade	-	Minimum dry density ratio of 100% Standard (AS 1289.Test 5.1.1 (2017))

Where PI = plasticity index

Whilst the use of lesser quality pavement materials than that detailed in Table 5 may be feasible, some compromise in either performance and/or pavement life must be anticipated and accepted. It is also suggested that advice be sought from Council if lesser quality pavement materials are proposed.

6.5.2 Drainage

Surface and subsurface drainage must be installed and maintained to protect the pavement and subgrade. The subsurface drains should be located at a minimum of 0.5 m depth below the excavation level. Guidelines on the arrangement of subsurface drainage is given on Page 20 of ARRB – SR41 (1989). It should be noted that if the sub-base is of low permeability relative to the base layer, then the subsurface drain must intersect all pavement layers as shown in ARRB – SR41 (1989).

6.6 Salinity Assessment

The following sub-section reproduces the comments provided in the DP (2006) report with regards to the laboratory test results for salinity potential.

pH: DIPNR (formerly Department of Land and Water Conservation, DLWC) classify neutral soils as those with a 1:5 soil:water extract pH in the range 6.6 – 7.3, acid soils as those having a pH of below 6.6 and alkaline soils as having a pH greater than 7.3. Plant growth is usually sustained with a pH in the range 5.5 – 8. In strongly acidic soils (ie: below pH 5.5) metals are more readily available to plants, potentially reaching toxic levels (to plants) and some nutrients become unavailable. At pH levels above 8, molybdenum becomes more readily available and nutrients including iron, copper and zinc become less available. Surface samples X1 and X2 had pH levels within the 5.5 – 8 range and as such, can be considered to be within the ideal range to promote plant growth.

Electrical Conductivity: According to Hazelton & Murphy (Hazelton & Murphy, 1992), electrical conductivity (ECe) values below 2 dS/m are classified as *"non-saline"*, 2 – 4 dS/m as *"slightly saline"* and 4 – 8 dS/m as *"moderately saline"*. The soil sample tested indicated *"non-saline"* conditions and as such, the results of the limited testing completed to date indicate a low salinity potential.

6.7 Site Contamination

A preliminary site investigation (contamination) has been reported separately by DP (DP, 2023).

6.8 Summary

The preliminary site assessment has indicated that the site is suitable for residential development with comments given on salinity potential, earthworks, likely lot classification, stability and pavement thicknesses. It must be noted, given the higher than average rainfall experienced at the site over the previous two years, it is highly likely to almost certain that groundwater springs or flows would be encountered during construction. The extent and locality cannot be determined at this stage and most likely would only present during construction works at which time control measures can be installed. Conceptual comments on design and construction aspects are also given in the report. Further testing and assessment will be required as the design of the subdivision proceeds and as such, this report must be considered as being preliminary in nature.

7. References

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AGS. (2007). *Practice Note Guidelines for Landslide Risk Management.* Australian Geomechnics, Volume 42, No 1: Australian Geomechanics Society, Landslide Taskforce, Landslide Practice Note Working Group.

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ARRB. (1989). *A structural Design Guide for Flexible REsidential Street Pavements - Special Report No. 41.* Australian Road Research Board.

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AS 2870. (2011). *Residential Slabs and Footings.* Standards Australia.

AS 3798. (2007). *Guidelines on Earthworks for Commercial and Residential Developments.* Standards Australia.

Austroads. (2017). *Guide to Pavement Technology Part 2: Pavement Structural Design.* Publication No. AGPT02-17: Austroads Ltd.

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DP. (2006). *Report on Geotechnical Assessment, Proposed Residential Sbudivision, Talbingo Village, Talbingo.* Douglas Partners Pty Ltd.

DP. (2023). *Report on Preliminary Site Investigation (Contamination), Proposed Residential Subdivision Development, Lot 35 / DP 878862, Miles Franklin Drive, Talbingo, NSw.* Douglas Partners Pty Ltd.

Hazelton, P., & Murphy, B. (1992). *What do all the Numbers Mean? A Guide for the Interpretation of Soil Test Resutls.* Sydney: Department of Infrastructure Planning and Natural Resources.

Richards, L. A. (1954). *Diagnosis of Saline and Alkaline Soils.* Washington D.C: US Department of Agriculture.

8. Limitations

Douglas Partners (DP) has prepared this report for this project at Lot 35 DP878862, Talbingo in accordance with DP's proposal 206726.01.P.001.Rev0 dated 14 February 2023 and acceptance received from Ironstone Development Group Pty Ltd dated 15 February 2023. The work was carried out under DP's Conditions of Engagement. This report is provided for the exclusive use of Ironstone Development Group Pty Ltd for this project only and for the purposes as described in the report. It should not be used by or relied upon for other projects or purposes on the same or other site or by a

third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

The results provided in the report are indicative of the sub-surface conditions on the site only at the specific sampling and/or testing locations, and then only to the depths investigated and at the time the work was carried out. Sub-surface conditions can change abruptly due to variable geological processes and also as a result of human influences. Such changes may occur after DP's field testing has been completed.

DP's advice is based upon the conditions encountered during this investigation. The accuracy of the advice provided by DP in this report may be affected by undetected variations in ground conditions across the site between and beyond the sampling and/or testing locations. The advice may also be limited by budget constraints imposed by others or by site accessibility.

The assessment of atypical safety hazards arising from this advice is restricted to the geotechnical components set out in this report and based on known project conditions and stated design advice and assumptions. While some recommendations for safe controls may be provided, detailed 'safety in design' assessment is outside the current scope of this report and requires additional project data and assessment.

This report must be read in conjunction with all of the attached and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion stated in this report.

This report, or sections from this report, should not be used as part of a specification for a project, without review and agreement by DP. This is because this report has been written as advice and opinion rather than instructions for construction.

The scope of work for this investigation/report did not include the assessment of surface or sub-surface materials or groundwater for contaminants, within or adjacent to the site. Should evidence of fill of unknown origin be noted in the report, and in particular the presence of building demolition materials, it should be recognised that there may be some risk that such fill may contain contaminants and hazardous building materials.

Douglas Partners Pty Ltd

Appendix A

About This Report

About this Report

Douglas Partners

Introduction

These notes have been provided to amplify DP's report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

DP's reports are based on information gained from limited subsurface excavations and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

Copyright

Borehole and Test Pit Logs

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

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes or pits, the frequency of sampling, and the possibility of other than 'straight line' variations between the test locations.

Groundwater

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

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole 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. They may not be the same at the time of construction as are indicated in the report; and
- 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 first be washed out of the hole if water measurements are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or 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 a perched water table.

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP 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 and environmental aspects, and recommendations or suggestions for design and construction. However, DP cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

If these occur, DP will be pleased to assist with investigations or advice to resolve the matter.

About this Report

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, DP requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed rather than at some later stage, well after the event.

Information for Contractual Purposes

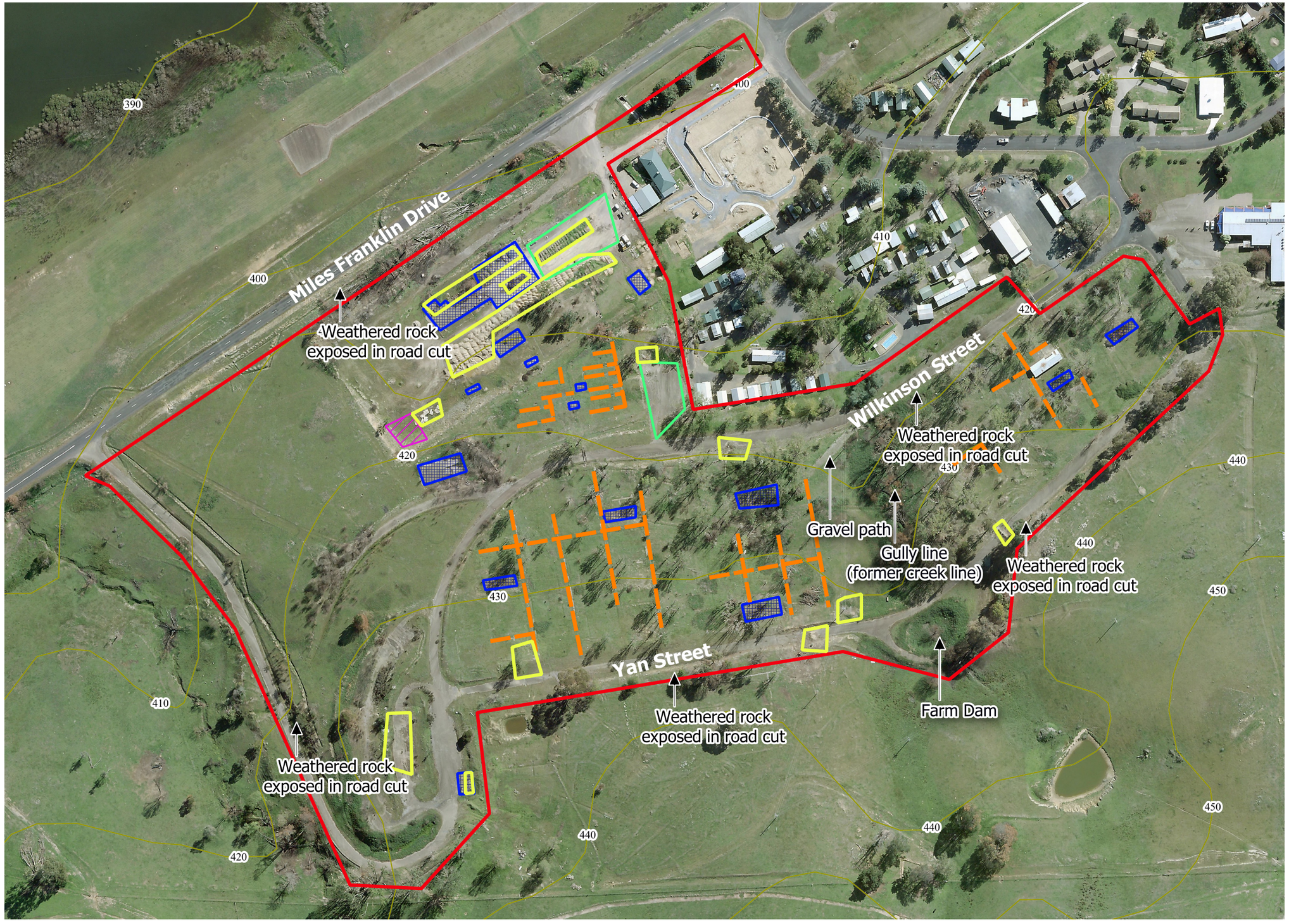
Where information obtained from this report is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

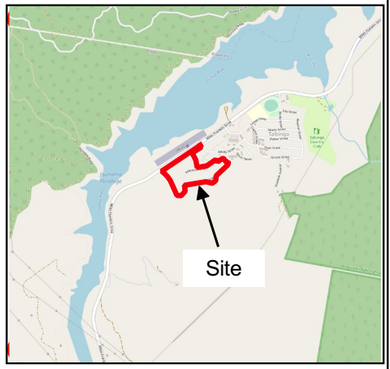
Site Inspection

The company will always be pleased to provide engineering inspection services for geotechnical and environmental aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.

Appendix B

Drawings 1 and 2





Site Location

Legend

- site boundary
- Concrete Slab
- Concrete Path/ Concrete Drainage Lines
- Soft Ground
- Stockpile
- Asphalt Paved Area

Drawing adapted from aerial imagery from MetroMap dated 12/04/2023.
Site features are approximate only.

0 50 100 150 200 m

Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT: Ironstone Development Group Pty Ltd		
OFFICE: Canberra	DRAWN BY: GM	
SCALE: 1:3,000 @ A3	DATE: 25.April.2023	

TITLE: **Site Plan**
Proposed Development
Lot 35 DP 878862, Talbingo

N

Project:	206726.01
DRAWING No:	1
REVISION:	0

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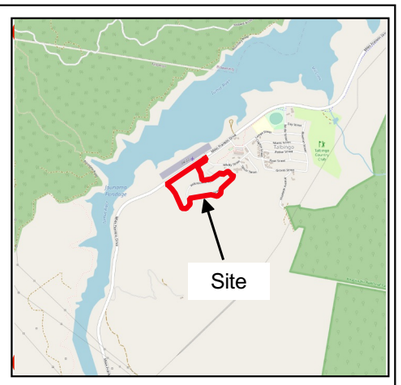

Site Location

Legend

- Site Boundary
- Approximate Area of Moderate Relief / Low to Moderate Risk of Instability

Drawing adapted from aerial imagery from MetroMap dated 12/04/2023, and Talbingo West Master Plan Concept Drawing No. PL 01, dated 04/05/2021.

0 50 100 150 200 m

Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT: Ironstone Development Group Pty Ltd		
OFFICE: Canberra	DRAWN BY: GM	
SCALE: 1:3,000 @ A3	DATE: 28.April.2023	

TITLE: **Slope Stability Assessment Plan**
Proposed Development
Lot 35 DP 878862, Talbingo

N

Project:	206726.01
DRAWING No:	2
REVISION:	0

DP.QGIS.A3LandScapeDrawingLayout.DftA

Appendix C

Photo Plates 1 - 13

Photo 1: General view of Wilkinson Street

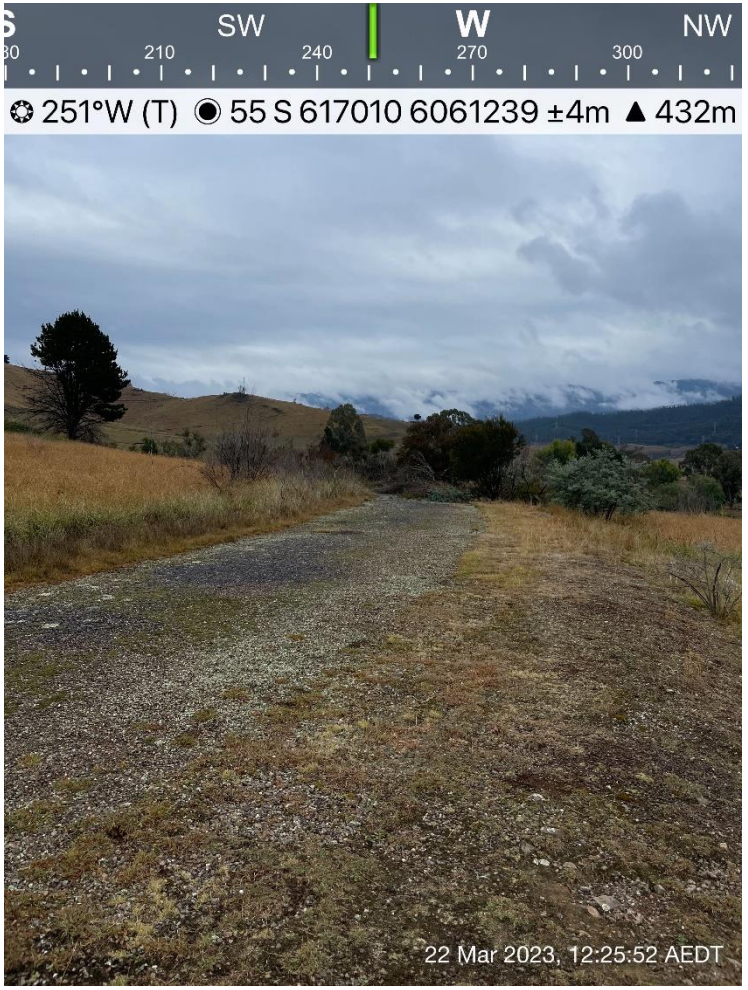

Photo 2: Generals view of an asphaltic sealed road off Wilkinson Street

Douglas Partners Geotechnics / Environment / Groundwater	CLIENT:	Ironstone Development Group Pty Ltd	**Site Photographs**	PROJECT No:	206726.01
	OFFICE:	Canberra	**Proposed Development**	PLATE No:	1
	DATE:	25.04.2023	**Lot 35 DP 878862, Talbingo**	REVISION:	0

Photo 3: General view of Yan Street.

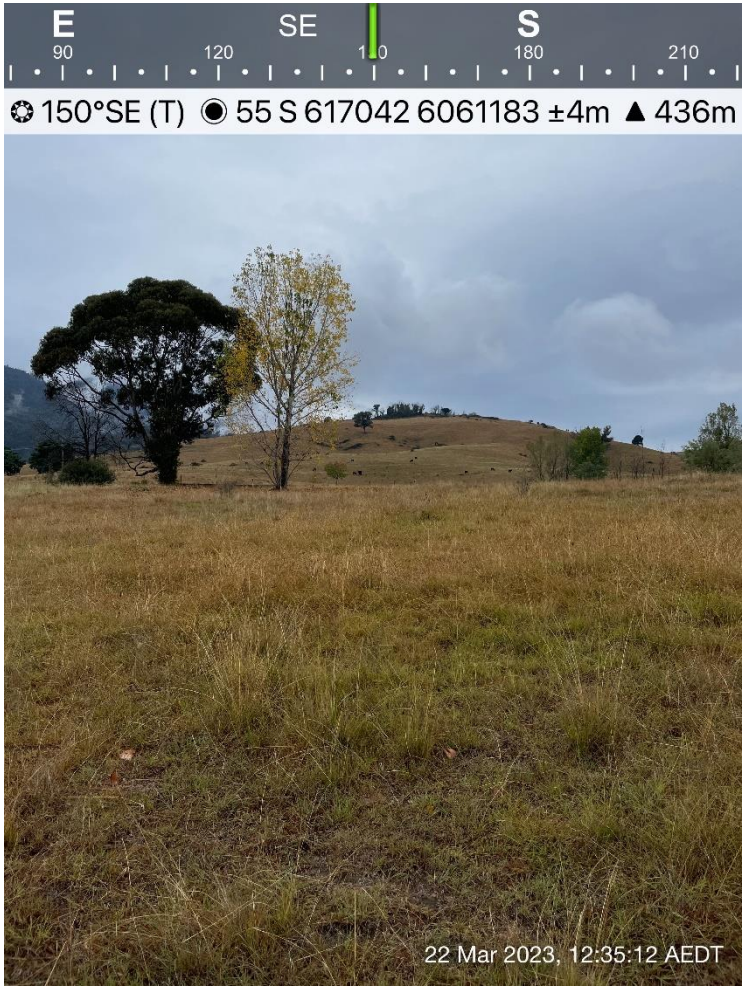

Photo 4: General conditions of the south-western section of the site.

Douglas Partners Geotechnics / Environment / Groundwater	CLIENT:	Ironstone Development Group Pty Ltd	**Site Photographs**	PROJECT No:	206726.01
	OFFICE:	Canberra	**Proposed Development**	PLATE No:	2
	DATE:	25.04.2023	**Lot 35 DP 878862, Talbingo**	REVISION:	0

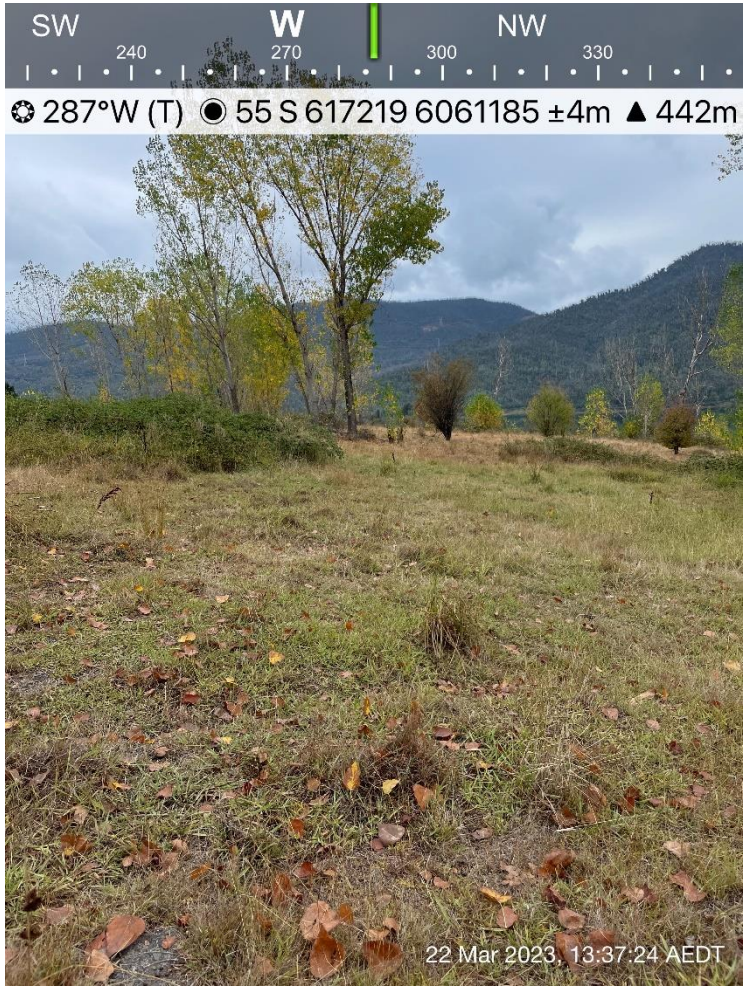

Photo 5: General conditions of the central section of the site.

Photo 6: General conditions of the eastern section of the site.

Douglas Partners Geotechnics / Environment / Groundwater	CLIENT:	Ironstone Development Group Pty Ltd	**Site Photographs**	PROJECT No:	206726.01
	OFFICE:	Canberra	**Proposed Development**	PLATE No:	3
	DATE:	25.04.2023	**Lot 35 DP 878862, Talbingo**	REVISION:	0

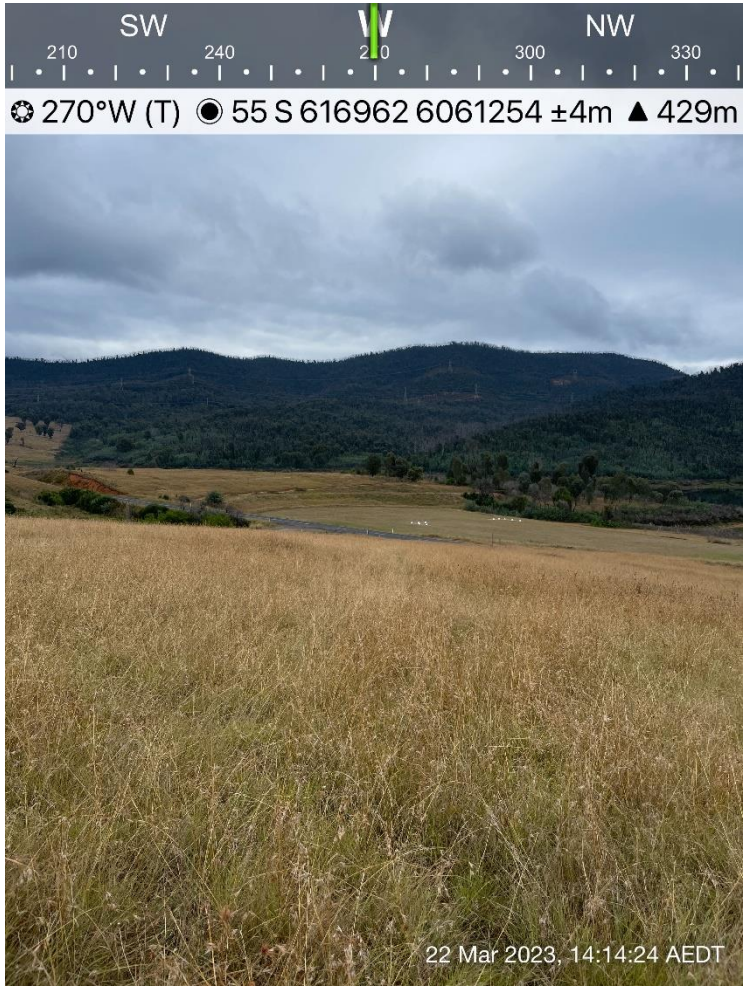

Photo 7: General conditions of the north-western section of the site.

Photo 8: General view of concrete slabs located at the eastern portion of the site.

Douglas Partners Geotechnics / Environment / Groundwater	CLIENT:	Ironstone Development Group Pty Ltd	**Site Photographs**	PROJECT No:	206726.01
	OFFICE:	Canberra	**Proposed Development**	PLATE No:	4
	DATE:	25.04.2023	**Lot 35 DP 878862, Talbingo**	REVISION:	0

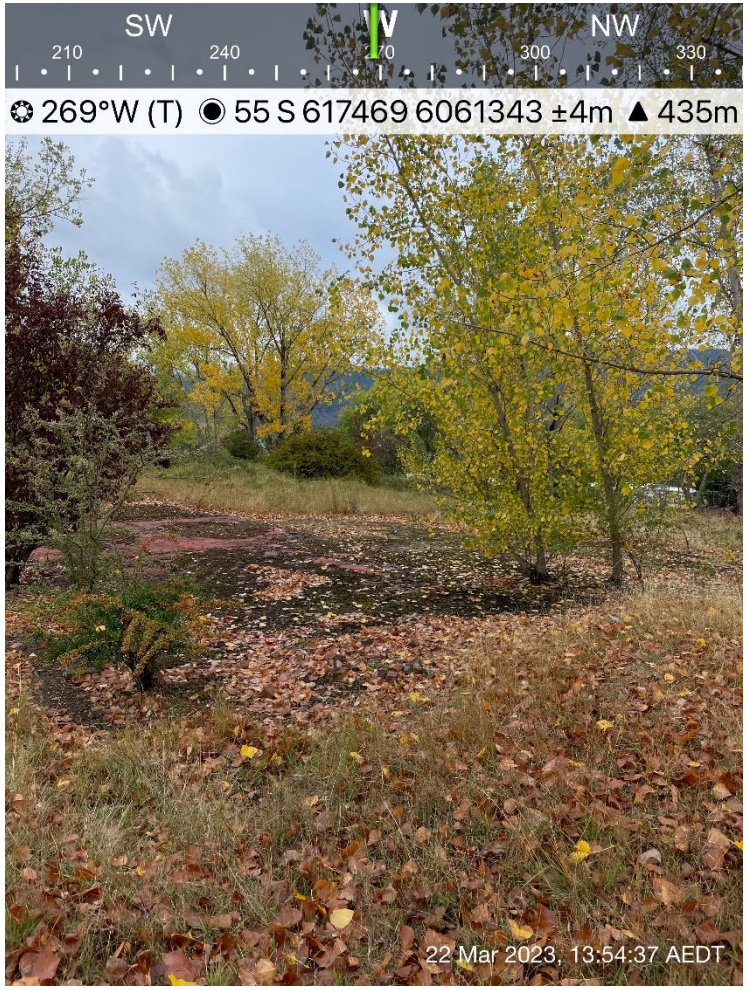

Photo 9: General view of levelled terraces located at the eastern corner of the site.

Photo 10: General view of a concrete slab located at the northern section of the site on top of the ~6 m high embankment.

Douglas Partners Geotechnics / Environment / Groundwater	CLIENT:	Ironstone Development Group Pty Ltd	**Site Photographs**	PROJECT No:	206726.01
	OFFICE:	Canberra	**Proposed Development**	PLATE No:	5
	DATE:	25.04.2023	**Lot 35 DP 878862, Talbingo**	REVISION:	0

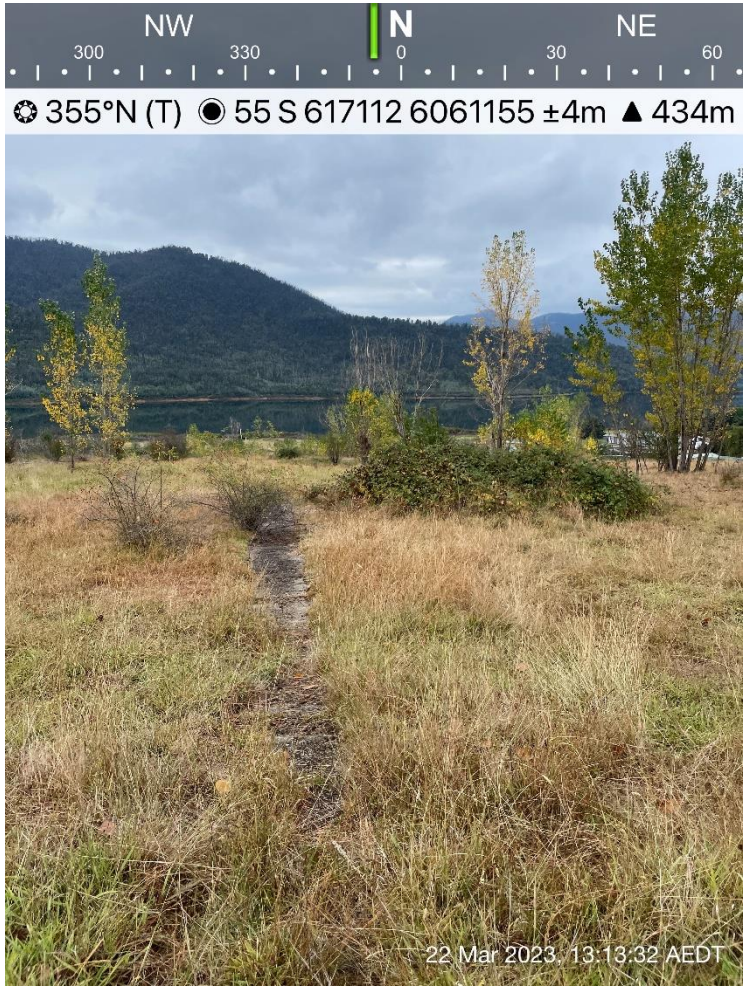

Photo 11: Typical linear concrete path/concrete drainage line located in the central portion of the site.

Photo 12: General view of disturbed ground.

Douglas Partners Geotechnics / Environment / Groundwater	CLIENT:	Ironstone Development Group Pty Ltd	**Site Photographs**	PROJECT No:	206726.01
	OFFICE:	Canberra	**Proposed Development**	PLATE No:	6
	DATE:	25.04.2023	**Lot 35 DP 878862, Talbingo**	REVISION:	0

Photo 13: View of a gravel path located in the central portion of the site near the electricity easement.

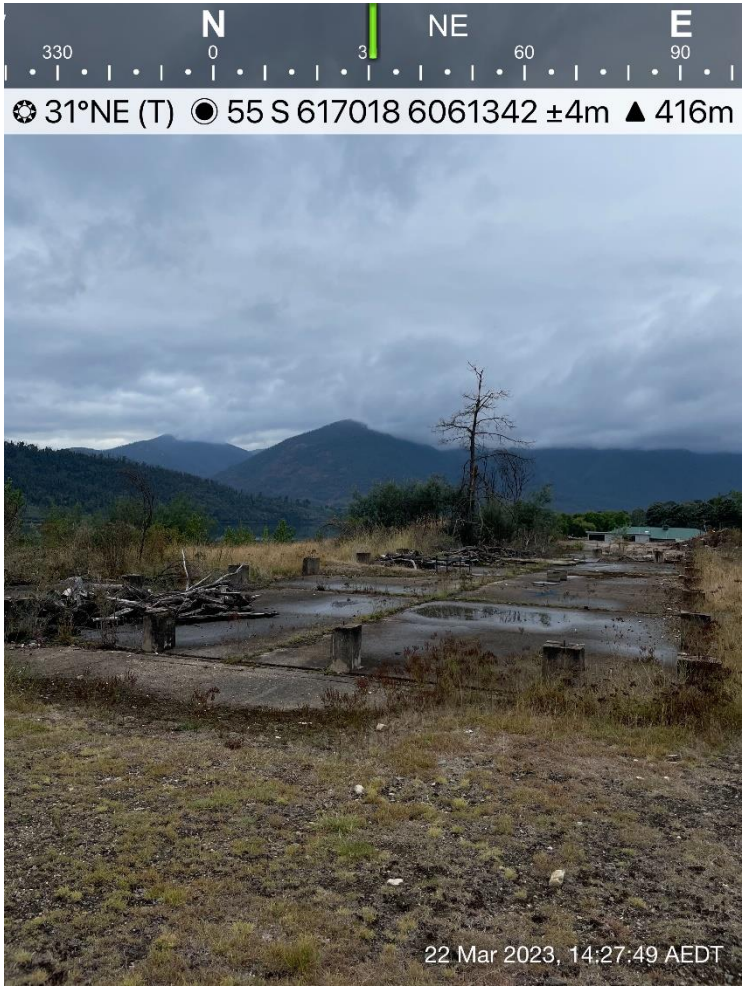

Photo 14: General view of a large hardstand area located in the north-eastern corner of the site.

Douglas Partners Geotechnics / Environment / Groundwater	CLIENT:	Ironstone Development Group Pty Ltd	**Site Photographs**	PROJECT No:	206726.01
	OFFICE:	Canberra	**Proposed Development**	PLATE No:	7
	DATE:	25.04.2023	**Lot 35 DP 878862, Talbingo**	REVISION:	0

Photo 15: General view of a large hardstand area located in the north-eastern corner of the site, with stockpiles.

Photo 16: General view of stockpiles of green waste and materials and miscellaneous rubbish located at the large hardstand area at the north-eastern corner of the site.

Douglas Partners Geotechnics / Environment / Groundwater	CLIENT: Ironstone Development Group Pty Ltd	**Site Photographs**	PROJECT No: 206726.01
	OFFICE: Canberra	**Proposed Development**	PLATE No: 8
	DATE: 25.04.2023	**Lot 35 DP 878862, Talbingo**	REVISION: 0

Photo 17: General view of the relatively soft ground located in the southern corner of the bottom of the up to ~ 6 m high embankment.

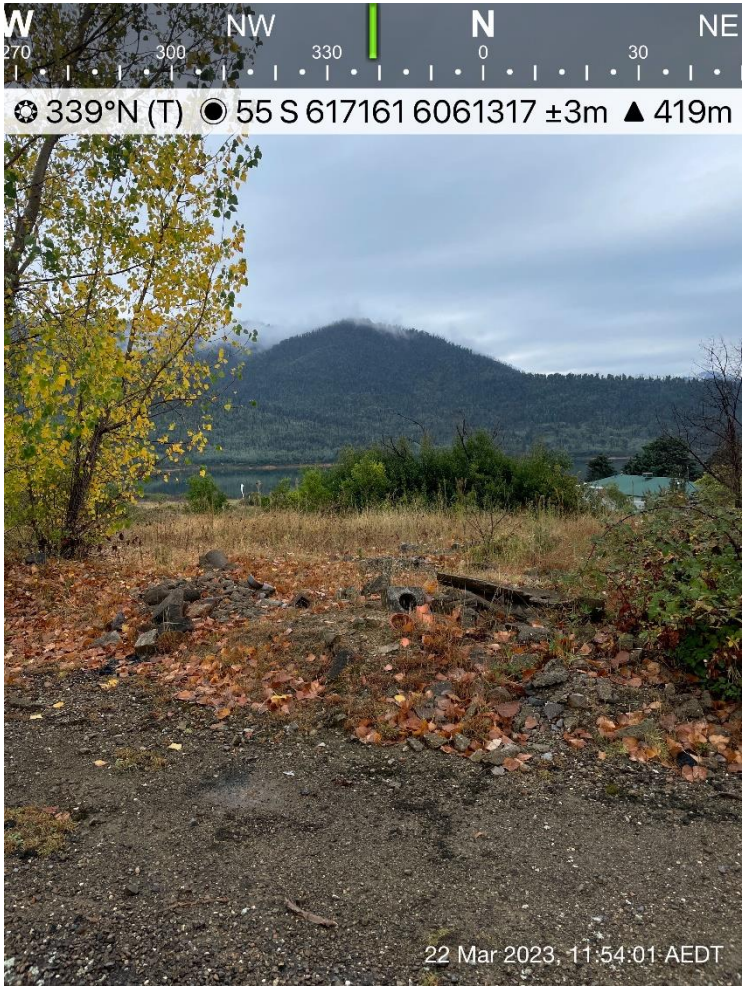

Photo 18: General view of a stockpile of soils and building rubbles.

Douglas Partners Geotechnics / Environment / Groundwater	CLIENT: Ironstone Development Group Pty Ltd	**Site Photographs**	PROJECT No: 206726.01
	OFFICE: Canberra	**Proposed Development**	PLATE No: 9
	DATE: 25.04.2023	**Lot 35 DP 878862, Talbingo**	REVISION: 0

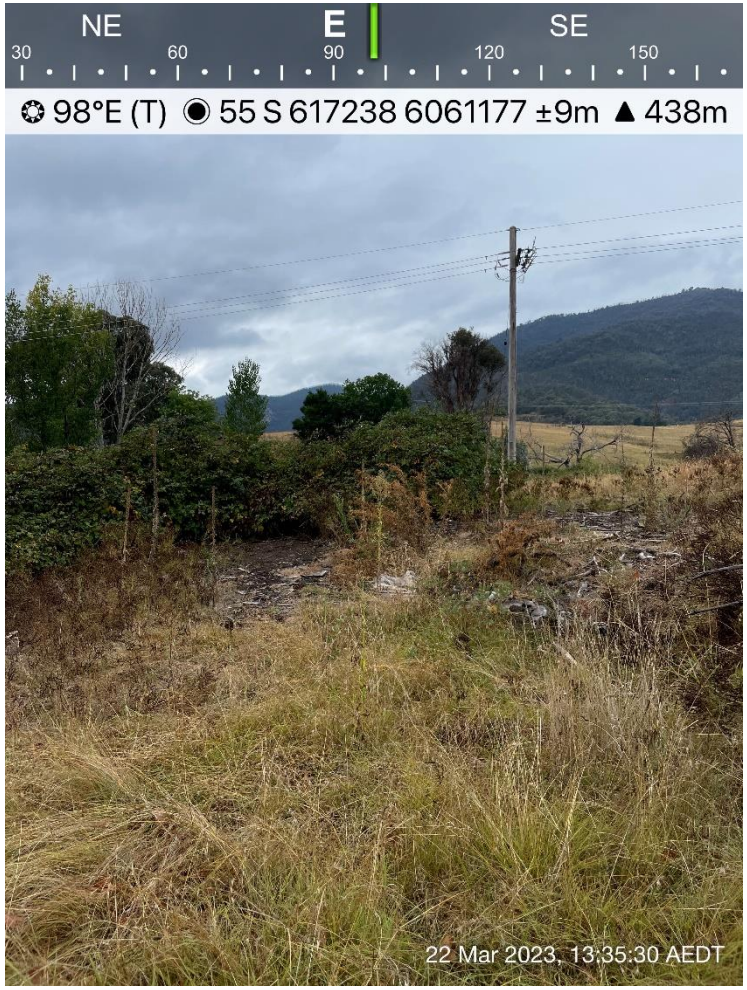

Photo 19: General view of a stockpile of building material and other miscellaneous rubbish.

Photo 20: General view of rock outcrops located on top of the ~6 m high embankment at the northern portion of the site.

Douglas Partners Geotechnics / Environment / Groundwater	CLIENT:	Ironstone Development Group Pty Ltd	**Site Photographs**	PROJECT No:	206726.01
	OFFICE:	Canberra	**Proposed Development**	PLATE No:	10
	DATE:	25.04.2023	**Lot 35 DP 878862, Talbingo**	REVISION:	0

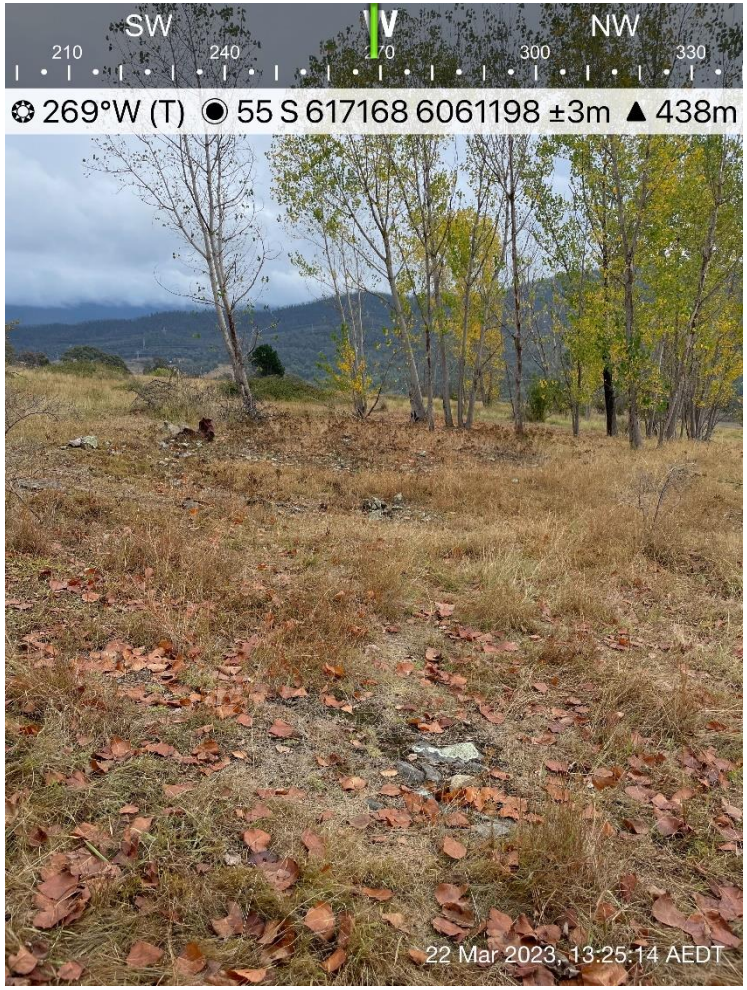

Photo 21: General view of rock outcrops at the central portion of the site.

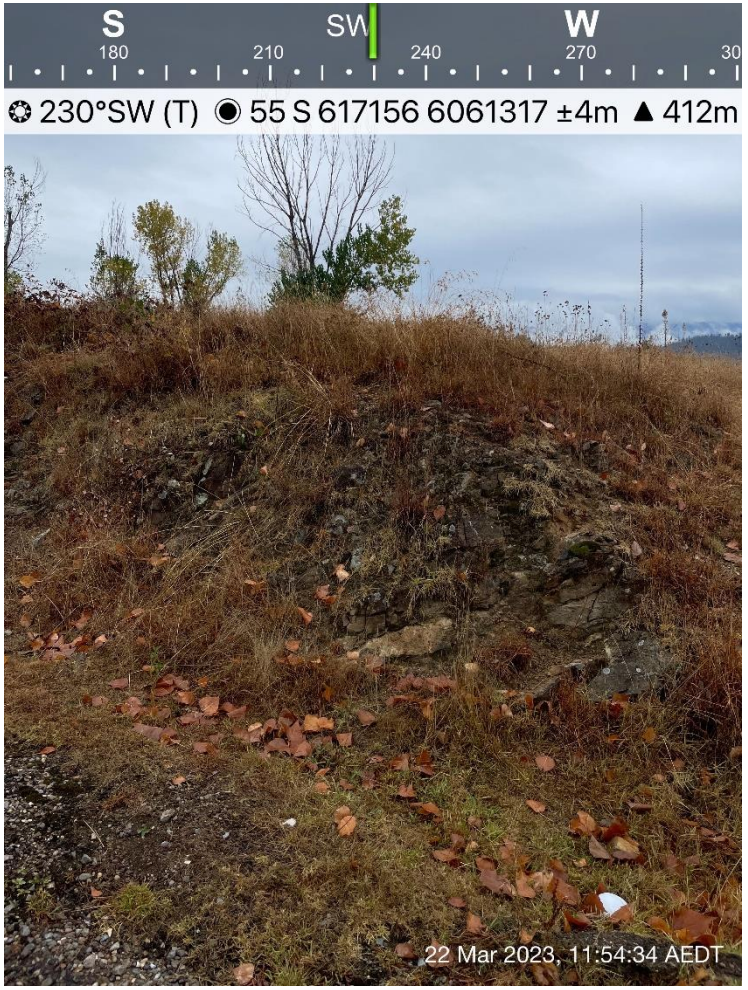

Photo 22: General view of weathered rock exposed in the embankment at the northern portion of the site.

Douglas Partners Geotechnics / Environment / Groundwater	CLIENT:	Ironstone Development Group Pty Ltd	**Site Photographs**	PROJECT No:	206726.01
	OFFICE:	Canberra	**Proposed Development**	PLATE No:	11
	DATE:	25.04.2023	**Lot 35 DP 878862, Talbingo**	REVISION:	0

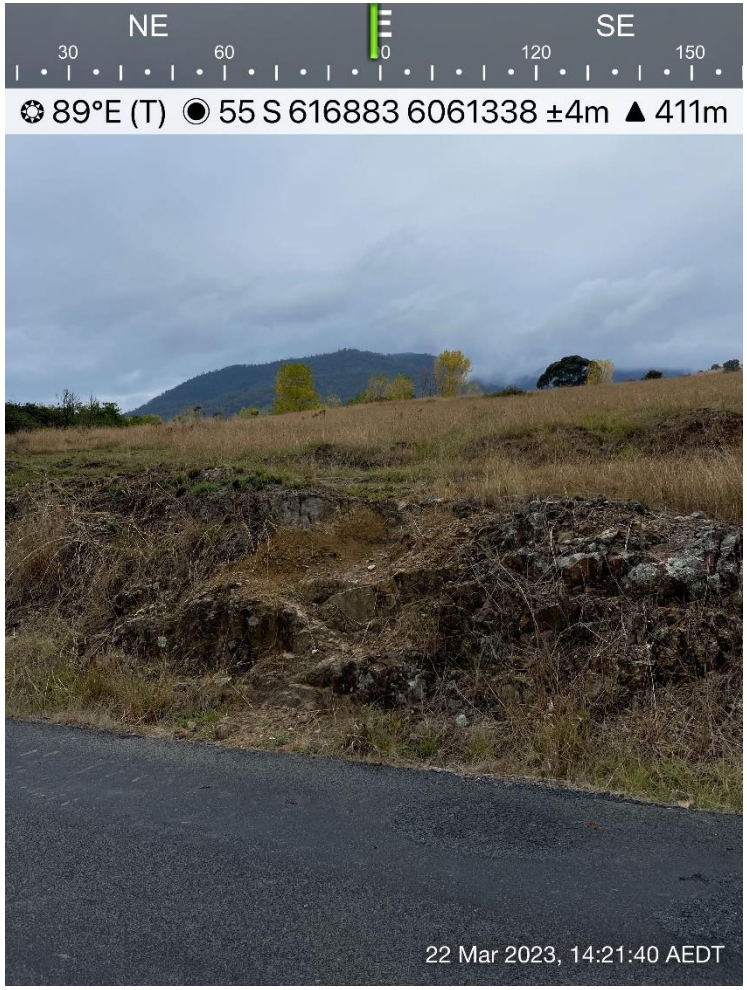

Photo 23: General view of weathered rock exposed in the road cuttings along Miles Franklin Drive.

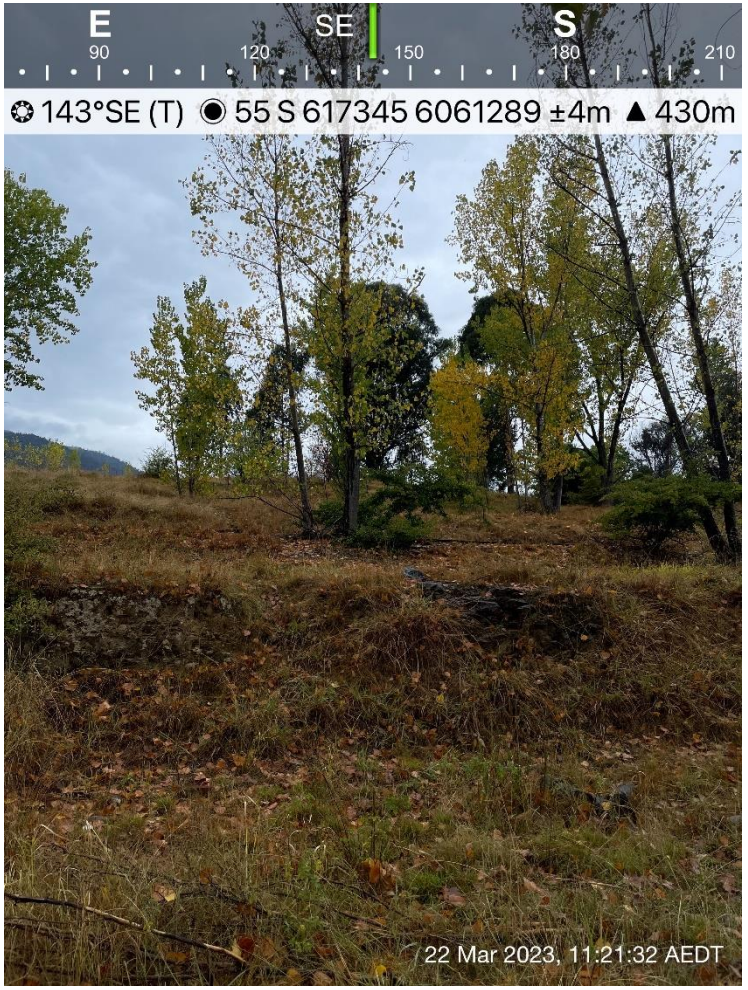

Photo 24: General view of weathered rock exposed in the road cuttings along Wilkinson Street.

Douglas Partners Geotechnics / Environment / Groundwater	CLIENT: Ironstone Development Group Pty Ltd	**Site Photographs**	PROJECT No: 206726.01
	OFFICE: Canberra	**Proposed Development**	PLATE No: 12
	DATE: 25.04.2023	**Lot 35 DP 878862, Talbingo**	REVISION: 0

Photo 25: General view of an existing structure (former Talbingo Fire-Squad Training Area) located in the eastern section of the site.

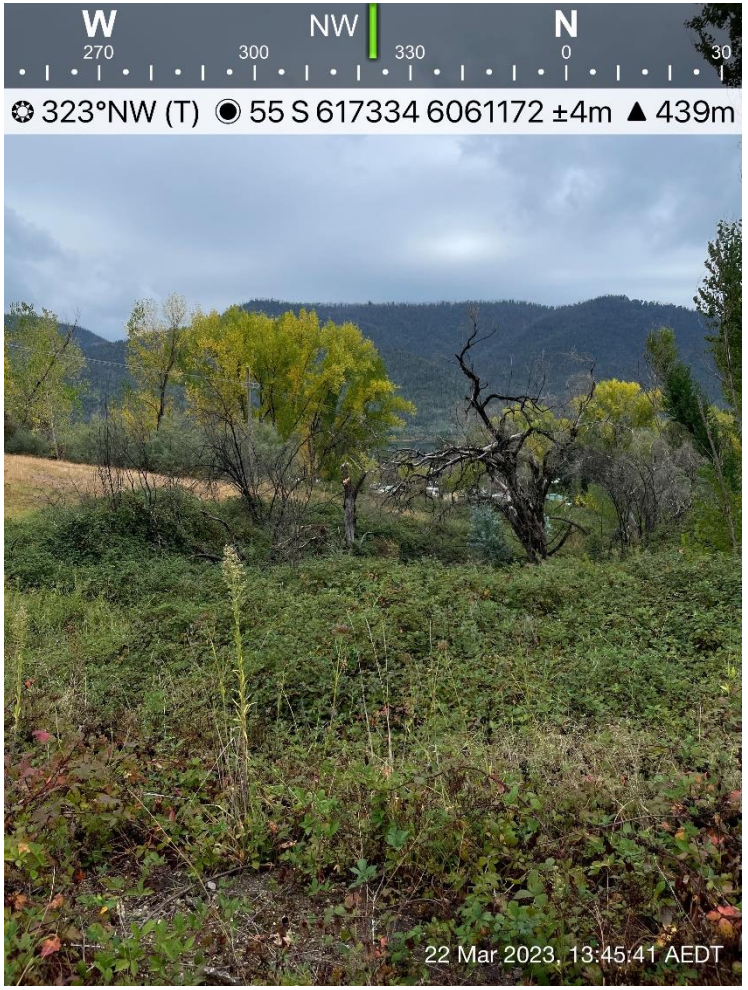

Photo 26: General view of an existing gully (former creek line) located in the eastern portion of the site.

Douglas Partners Geotechnics / Environment / Groundwater	CLIENT:	Ironstone Development Group Pty Ltd	**Site Photographs**	PROJECT No: 206726.01
	OFFICE:	Canberra	**Proposed Development**	PLATE No: 13
	DATE:	25.04.2023	**Lot 35 DP 878862, Talbingo**	REVISION: 0

Appendix D

Laboratory Test Report (2006)
CSIRO Publication
AGS Extract

Corrosion & Scaling Assessment: Soil Reporting Profile

Test Type I pHEC,SO4,Cl,EAT
Order No Job No: 40569
Reference Talbingo
Sample Name #1
Sample No. 96449
Date Received 22/03/2006 Total No Pages: 1 of 1
Client: Douglas Partners (Wollongong)
Michael Jones
PO Box 486
UNANDERRA NSW 2526

Quality System
Quality Endorsed Company
ISO 9001
Lic QEC21650
SAI Global

Sydney Environmental and Soil Laboratory
Specialists in Soil Chemistry, Agronomy and Contamination Assessments

Sydney Environmental & Soil Laboratory Pty Ltd
ABN 70 106 810 708
16 Chilvers Road
Thornleigh NSW 2120
Australia
Address mail to:
PO Box 357
Pennant Hills NSW 1715
Tel: 02 9980 6554
Fax: 02 9484 2427
Em: info@sesl.com.au
Web: www.sesl.com.au

TEST	RESULT	COMMENTS
pH in water (1:2)	5.8	medium acidity
EC mS/cm (1:2)	0.05	very low salt content
Texture Class		
Soil Permeability Class		

SOLUBLE ANION ANALYSIS

Sulphate (1:2)	$mgSO_4$ / kg	100	low, non-aggressive towards concrete
Chloride (1:2)	mgCl / kg	20	low, non-corrosive towards steel

* Resistivity Ω.m

* Resistivity tested on a saturated sample/paste (Note:- 10,000 mg/L = 1%)

Recommendations

Emerson Stability Class (H20): 7

This soil has medium acidity with a very low salt content. The acidity is considered mildly to non-aggressive towards concrete, and non-aggressive towards steel. To be more specific a soil permeability class needs to be assigned. The acidity should be treated with 300 g/sqm of lime incorporated into the surface 150 mm of the soil.

The chloride and sulfate levels are low and non-aggressive towards concrete and steel.

The Emerson Stability Class indicates the most stable classes of aggregates. Very few erosion problems, but swelling aggregates can be mechanically weak and should not be trafficked or ploughed when at or above field capacity.

Explanation of the Methods:
pH, EC, Soluble SO4: Bradley et al., (1983); **Cl,** (4500-Cl- E; APHA, 1998); **Texture Class,** AS2159:1995; **Resistivity,** AS1289.4.4.1:1997,

Checked by .....
M. Fraser Date of Report 06/04/2006

Consultant .....
S. Crook

Corrosion & Scaling Assessment: Soil Reporting Profile

Test Type I pHEC,SO4,Cl,EAT
Order No Job No: 40569
Reference Talbingo
Sample Name #2
Sample No. 96450
Date Received 22/03/2006 Total No Pages: 1 of 1
Client: Douglas Partners (Wollongong)
Michael Jones
PO Box 486
UNANDERRA NSW 2526

Quality System
Quality Endorsed Company
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Lic QEC21650
SAI Global

Sydney Environmental and Soil Laboratory
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PO Box 357
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Tel: 02 9980 6554
Fax: 02 9484 2427
Em: info@sesl.com.au
Web: www.sesl.com.au

TEST	RESULT	COMMENTS
pH in water (1:2)	6.1	slight acidity
EC mS/cm (1:2)	0.16	low salt content
Texture Class		
Soil Permeability Class		

SOLUBLE ANION ANALYSIS

Sulphate (1:2)	$mgSO_4$ / kg	190	low, non-aggressive towards concrete
Chloride (1:2)	mgCl / kg	40	low, non-corrosive towards steel

* Resistivity Ω.m

* Resistivity tested on a saturated sample/paste (Note:- 10,000 mg/L = 1%)

Recommendations

Emerson Stability Class (H20): 7

This soil has slight acidity with a low salt content. The acidity is considered mildly to non-aggressive towards concrete, and non-aggressive towards steel. To be more specific a soil permeability class needs to be assigned. The acidity should be treated with 200 g/sqm of lime incorporated into the surface 150 mm of the soil.

The chloride and sulfate levels are low and non-aggressive towards concrete and steel.

The Emerson Stability Class indicates the most stable classes of aggregates. Very few erosion problems, but swelling aggregates can be mechanically weak and should not be trafficked or ploughed when at or above field capacity.

Explanation of the Methods:
pH, EC, Soluble SO_4 (Bradley et al., (1983); **Cl,** (4500-Cl- E; APHA, 1998); **Texture Class,** AS2159:1995; **Resistivity,** AS1289.4.4.1:1997,

Checked by .....
M. Fraser Date of Report 06/04/2006

Consultant .....
S. Crook

FOUNDATION MAINTENANCE AND FOOTING PERFORMANCE

Understanding and preventing soil-related building movement

This Building Technology Resource is designed to identify causes of soil-related building movement, and to suggest methods of prevention of resultant cracking.

Buildings can and often do move. This movement can be up, down, lateral or rotational. The fundamental cause of movement in buildings can usually be related to one or more problems in the foundation soil. It is important for the home owner to identify the soil type in order to ascertain the measures that should be put in place in order to ensure that problems in the foundation soil can be prevented, thus protecting against building movement.

SOIL TYPES

The types of soils usually present under the topsoil in land zoned for residential buildings can be split into two approximate groups – granular and clay. Quite often, foundation soil is a mixture of both types. The general problems associated with soils having granular content are usually caused by erosion. Clay soils are subject to saturation and swell/shrink problems.

Classifications for a given area can generally be obtained by application to the local authority, but these are sometimes unreliable and if there is doubt, a geotechnical report should be commissioned. As most buildings suffering movement problems are founded on clay soils, there is an emphasis on classification of soils according to the amount of swell and shrinkage they experience with variations of water content. Table 1 below is a reproduction of Table 2.1 from Australian Standard AS 2870-2011, Residential slabs and footings.

CAUSES OF MOVEMENT

SETTLEMENT DUE TO CONSTRUCTION

There are two types of settlement that occur as a result of construction:

- Immediate settlement occurs when a building is first placed on its foundation soil, as a result of compaction of the soil under the weight of the structure. The cohesive quality of clay soil mitigates against this, but granular (particularly sandy) soil is susceptible.
- Consolidation settlement is a feature of clay soil and may take place because of the expulsion of moisture from the soil or because of the soil's lack of resistance to local compressive or shear stresses. This will usually take place during the first few months after construction but has been known to take many years in exceptional cases.

These problems may be the province of the builder and should be taken into consideration as part of the preparation of the site for construction.

EROSION

All soils are prone to erosion, but sandy soil is particularly susceptible to being washed away. Even clay with a sand component of say 10% or more can suffer from erosion.

SATURATION

This is particularly a problem in clay soils. Saturation creates a bog-like suspension of the soil that causes it to lose virtually all of its bearing capacity. To a lesser degree, sand is affected by saturation because saturated sand may undergo a reduction in volume, particularly imported sand fill for bedding and blinding layers. However, this usually occurs as immediate settlement and should normally be the province of the builder.

SEASONAL SWELLING AND SHRINKAGE OF SOIL

All clays react to the presence of water by slowly absorbing it, making the soil increase in volume (see table below, from AS 2870). The degree of increase varies considerably between different clays, as does the degree of decrease during the subsequent drying out caused by fair weather periods. Because of the low absorption and expulsion rate, this phenomenon will not usually be noticeable unless there are prolonged rainy or dry periods, usually of weeks or months, depending on the land and soil characteristics.

The swelling of soil creates an upward force on the footings of the building, and shrinkage creates subsidence that takes away the support needed by the footing to retain equilibrium.

SHEAR FAILURE

This phenomenon occurs when the foundation soil does not have sufficient strength to support the weight of the footing. There are two major post-construction causes:

- Significant load increase.
- Reduction of lateral support of the soil under the footing due to erosion or excavation.

In clay soil, shear failure can be caused by saturation of the soil adjacent to or under the footing.

TREE ROOT GROWTH

Trees and shrubs that are allowed to grow in the vicinity of footings can cause foundation soil movement in two ways:

- Roots that grow under footings may increase in cross-sectional size, exerting upward pressure on footings.

TABLE 1. GENERAL DEFINITIONS OF SITE CLASSES.

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites, which may experience only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which may experience moderate ground movement from moisture changes
H1	Highly reactive clay sites, which may experience high ground movement from moisture changes
H2	Highly reactive clay sites, which may experience very high ground movement from moisture changes
F	Extremely reactive sites, which may experience extreme ground movement from moisture changes

Source: Reproduced with the permission of Standards Australia Limited © 2011. Copyright in AS 2870-2011 Residential slabs and footings vests in Standards Australia Limited.

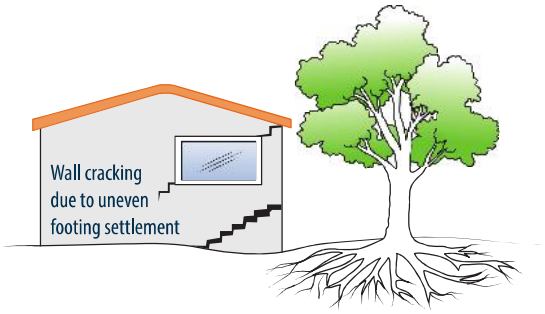

FIGURE 1 Trees can cause shrinkage and damage.

- Roots in the vicinity of footings will absorb much of the moisture in the foundation soil, causing shrinkage or subsidence.

UNEVENNESS OF MOVEMENT

The types of ground movement described above usually occur unevenly throughout the building's foundation soil. Settlement due to construction tends to be uneven because of:

- Differing compaction of foundation soil prior to construction.
- Differing moisture content of foundation soil prior to construction.

Movement due to non-construction causes is usually more uneven still. Erosion can undermine a footing that traverses the flow or can create the conditions for shear failure by eroding soil adjacent to a footing that runs in the same direction as the flow.

Saturation of clay foundation soil may occur where subfloor walls create a dam that makes water pond. It can also occur wherever there is a source of water near footings in clay soil. This leads to a severe reduction in the strength of the soil which may create local shear failure.

Seasonal swelling and shrinkage of clay soil affects the perimeter of the building first, then gradually spreads to the interior through absorption. The swelling process will usually begin at the uphill extreme of the building, or on the weather side where the land is flat. Shrinkage usually begins on the side of the building where the sun's heat is greatest.

EFFECTS OF UNEVEN SOIL MOVEMENT ON STRUCTURES

EROSION AND SATURATION

Erosion removes the support from under footings, tending to create subsidence of the part of the structure under which it occurs. Brickwork walls will resist the stress created by this removal of support by bridging the gap or cantilevering until the bricks or the mortar bedding fail. Older masonry has little resistance. Evidence of failure varies according to circumstances and symptoms may include:

- Step cracking in the mortar beds in the body of the wall or above/below openings such as doors or windows.
- Vertical cracking in the bricks (usually but not necessarily in line with the vertical beds or perpends).

Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

SEASONAL SWELLING/SHRINKAGE IN CLAY

Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends to create a dish effect, because the external footings are pushed higher than the internal ones.

The first noticeable symptom may be that the floor appears slightly dished. This is often accompanied by some doors binding on the floor or the door head, together with some cracking of cornice mitres. In buildings with timber flooring supported by bearers and joists, the floor can be bouncy. Externally there may be visible dishing of the hip or ridge lines.

As the moisture absorption process completes its journey to the innermost areas of the building, the internal footings will rise. If the spread of moisture is roughly even, it may be that the symptoms will temporarily disappear, but it is more likely that swelling will be uneven, creating a difference rather than a disappearance in symptoms. In buildings with timber flooring supported by bearers and joists, the isolated piers will rise more easily than the strip footings or piers under walls, creating noticeable doming of flooring.

As the weather pattern changes and the soil begins to dry out, the external footings will be first affected, beginning with the locations where the sun's effect is strongest. This has the effect of lowering the external footings. The doming is accentuated, and cracking reduces or disappears where it occurred because of dishing, but other cracks open up. The roof lines may become convex.

Doming and dishing are also affected by weather in other ways. In areas where warm, wet summers and cooler dry winters prevail, water migration tends to be toward the interior and doming will be accentuated, whereas where summers are dry, and winters are cold and wet, migration tends to be toward the exterior and the underlying propensity is toward dishing.

MOVEMENT CAUSED BY TREE ROOTS

In general, growing roots will exert an upward pressure on footings, whereas soil subject to drying because of tree or shrub roots will tend to remove support from under footings by inducing shrinkage.

COMPLICATIONS CAUSED BY THE STRUCTURE ITSELF

Most forces that the soil causes to be exerted on structures are vertical – i.e. either up or down. However, because these forces are seldom spread evenly around the footings, and because the building resists uneven movement because of its rigidity, forces are exerted from one part of the building to another. The net result of all these forces is usually rotational. This resultant force often complicates the diagnosis because the visible symptoms do not simply reflect the original cause. A common symptom is binding of doors on the vertical member of the frame.

EFFECTS ON FULL MASONRY STRUCTURES

Brickwork will resist cracking where it can. It will attempt to span areas that lose support because of subsided foundations or raised points. It is therefore usual to see cracking at weak points, such as openings for windows or doors.

In the event of construction settlement, cracking will usually remain unchanged after the process of settlement has ceased.

With local shear or erosion, cracking will usually continue to develop until the original cause has been remedied, or until the subsidence has completely neutralised the affected portion of footing and the structure has stabilised on other footings that remain effective.

In the case of swell/shrink effects, the brickwork will in some cases return to its original position after completion of a cycle, however it is more likely that the rotational effect will not be exactly reversed, and it is also usual that brickwork will settle in its new position and will resist the forces trying to return it to its original position. This means that in a case where swelling takes place after construction and cracking occurs, the cracking is likely to at least partly remain after the shrink segment of the cycle is complete. Thus, each time the cycle is repeated, the likelihood is that the cracking will become wider until the sections of brickwork become virtually independent.

With repeated cycles, once the cracking is established, if there is no other complication, it is normal for the incidence of cracking to stabilise, as the building has the articulation it needs to cope with the problem. This is by no means always the case, however, and monitoring of cracks in walls and floors should always be treated seriously.

Upheaval caused by growth of tree roots under footings is not a simple vertical shear stress. There is a tendency for the root to also

exert lateral forces that attempt to separate sections of brickwork after initial cracking has occurred.

The normal structural arrangement is that the inner leaf of brickwork in the external walls and at least some of the internal walls (depending on the roof type) comprise the load-bearing structure on which any upper floors, ceilings and the roof are supported. In these cases, it is internally visible cracking that should be the main focus of attention, however there are a few examples of dwellings whose external leaf of masonry plays some supporting role, so this should be checked if there is any doubt. In any case, externally visible cracking is important as a guide to stresses on the structure generally, and it should also be remembered that the external walls must be capable of supporting themselves.

EFFECTS ON FRAMED STRUCTURES

Timber or steel framed buildings are less likely to exhibit cracking due to swell/shrink than masonry buildings because of their flexibility. Also, the doming/dishing effects tend to be lower because of the lighter weight of walls. The main risks to framed buildings are encountered because of the isolated pier footings used under walls. Where erosion or saturation causes a footing to fall away, this can double the span which a wall must bridge. This additional stress can create cracking in wall linings, particularly where there is a weak point in the structure caused by a door or window opening. It is, however, unlikely that framed structures will be so stressed as to suffer serious damage without first exhibiting some or all of the above symptoms for a considerable period. The same warning period should apply in the case of upheaval. It should be noted, however, that where framed buildings are supported by strip footings there is only one leaf of brickwork and therefore the externally visible walls are the supporting structure for the building. In this case, the subfloor masonry walls can be expected to behave as full brickwork walls.

EFFECTS ON BRICK VENEER STRUCTURES

Because the load-bearing structure of a brick veneer building is the frame that makes up the interior leaf of the external walls plus perhaps the internal walls, depending on the type of roof, the building can be expected to behave as a framed structure, except that the external masonry will behave in a similar way to the external leaf of a full masonry structure.

WATER SERVICE AND DRAINAGE

Where a water service pipe, a sewer or stormwater drainage pipe is in the vicinity of a building, a water leak can cause erosion, swelling or saturation of susceptible soil. Even a minuscule leak can be enough to saturate a clay foundation. A leaking tap near a building can have the same effect. In addition, trenches containing pipes can become watercourses even though backfilled, particularly where broken rubble is used as fill. Water that runs along these trenches can be responsible for serious erosion, interstrata seepage into subfloor areas and saturation.

Pipe leakage and trench water flows also encourage tree and shrub roots to the source of water, complicating and exacerbating the problem. Poor roof plumbing can result in large volumes of rainwater being concentrated in a small area of soil:

- Incorrect falls in roof guttering may result in overflows, as may gutters blocked with leaves etc.
- Corroded guttering or downpipes can spill water to ground.
- Downpipes not positively connected to a proper stormwater collection system will direct a concentration of water to soil that is directly adjacent to footings, sometimes causing large-scale problems such as erosion, saturation and migration of water under the building.

SERIOUSNESS OF CRACKING

In general, most cracking found in masonry walls is a cosmetic nuisance only and can be kept in repair or even ignored. Table 2 below is a reproduction of Table C1 of AS 2870-2011.

AS 2870-2011 also publishes figures relating to cracking in concrete floors, however because wall cracking will usually reach the critical point significantly earlier than cracking in slabs, this table is not reproduced here.

PREVENTION AND CURE

PLUMBING

Where building movement is caused by water service, roof plumbing, sewer or stormwater failure, the remedy is to repair the problem. It is prudent, however, to consider also rerouting pipes away from the building where possible and relocating taps to positions where any leakage will not direct water to the building vicinity. Even where gully traps are present, there is sometimes sufficient spill to create erosion or saturation, particularly in modern installations using smaller diameter PVC fixtures. Indeed, some gully traps are not situated directly under the taps that are installed to charge them, with the result that water from the tap may enter the backfilled trench that houses the sewer piping. If the trench has been poorly backfilled, the water will either pond or flow along the bottom of the trench. As these trenches usually run alongside the footings and can be at a similar depth, it is not hard to see how any water that is thus directed into a trench can easily affect the foundation's ability to support footings or even gain entry to the subfloor area.

GROUND DRAINAGE

In all soils there is the capacity for water to travel on the surface and below it. Surface water flows can be established by inspection during and after heavy or prolonged rain. If necessary, a grated drain system connected to the stormwater collection system is usually an easy solution.

It is, however, sometimes necessary when attempting to prevent water migration that testing be carried out to establish watertable height and subsoil water flows. This subject may be regarded as an area for an expert consultant.

PROTECTION OF THE BUILDING PERIMETER

It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

For this reason, particularly where problems exist or are likely to occur, it is recommended that an apron of paving be installed around as much of the building perimeter as necessary. This paving should extend outwards a minimum of 900 mm (more in highly reactive soil) and should have a minimum fall away from the building of 1:60. The finished paving should be no less than 100 mm below brick vent bases.

It is prudent to relocate drainage pipes away from this paving, if possible, to avoid complications from future leakage. If this is not practical, earthenware pipes should be replaced by PVC and backfilling should be of the same soil type as the surrounding soil and compacted to the same density.

Except in areas where freezing of water is an issue, it is wise to remove taps in the building area and relocate them well away from the building – preferably not uphill.

It may be desirable to install a grated drain at the outside edge of the paving on the uphill side of the building. If subsoil drainage is needed this can be installed under the surface drain.

CONDENSATION

In buildings with a subfloor void, such as where bearers and joists support flooring, insufficient ventilation creates ideal conditions for condensation, particularly where there is little clearance between the floor and the ground. Condensation adds to the moisture already present in the subfloor and significantly slows the process of drying out. Installation of an adequate subfloor ventilation system, either natural or mechanical, is desirable.

TABLE 2. CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS.

Description of typical damage and required repair	Approximate crack width limit	Damage category
Hairline cracks	<0.1 mm	0 – Negligible
Fine cracks which do not need repair	<1 mm	1 – Very Slight
Cracks noticeable but easily filled. Doors and windows stick slightly.	<5 mm	2 – Slight
Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weathertightness often impaired.	5–15 mm (or a number of cracks 3 mm or more in one group)	3 – Moderate
Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window and door frames distort. Walls lean or bulge noticeably, some loss of bearing in beams. Service pipes disrupted.	15–25 mm but also depends on number of cracks	4 – Severe

Warning: Although this Building Technology Resource deals with cracking in buildings, it should be said that subfloor moisture can result in the development of other problems, notably:

- Water that is transmitted into masonry, metal or timber building elements causes damage and/or decay to those elements.
- High subfloor humidity and moisture content create an ideal environment for various pests, including termites and spiders, and mould.
- Where high moisture levels are transmitted to the flooring and walls, an increase in the dust mite count can ensue within the living areas. Dust mites, as well as dampness in general, can be a health hazard to inhabitants, particularly those who are abnormally susceptible to respiratory ailments.

THE GARDEN

The ideal vegetation layout is to have lawn or plants that require only light watering immediately adjacent to the drainage or paving edge, then more demanding plants, shrubs and trees spread out in that order.

Overwatering due to misuse of automatic watering systems is a common cause of saturation and water migration under footings. If it is necessary to use these systems, it is important to remove garden beds to a completely safe distance from buildings.

EXISTING TREES

Where a tree is causing a problem of soil drying or there is the existence or threat of upheaval of footings, if the offending roots are subsidiary and their removal will not significantly damage the tree, they should be severed and a concrete or metal barrier placed vertically in the soil to prevent future root growth in the direction of the building. If it is not possible to remove the relevant roots without damage to the tree, an application to remove the tree should be made to the local authority. A prudent plan is to transplant likely offenders before they become a problem.

INFORMATION ON TREES, PLANTS AND SHRUBS

State departments overseeing agriculture can give information regarding root patterns, volume of water needed and safe distance from buildings of most species. Botanic gardens are also sources of information.

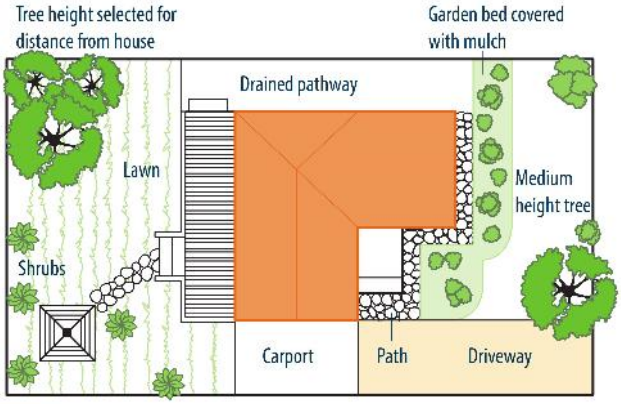

FIGURE 2 Gardens for a reactive site.

EXCAVATION

Excavation around footings must be properly engineered. Soil supporting footings can only be safely excavated at an angle that allows the soil under the footing to remain stable. This angle is called the angle of repose (or friction) and varies significantly between soil types and conditions. Removal of soil within the angle of repose will cause subsidence.

REMEDIATION

Where erosion has occurred that has washed away soil adjacent to footings, soil of the same classification should be introduced and compacted to the same density. Where footings have been undermined, augmentation or other specialist work may be required. Remediation of footings and foundations is generally the realm of a specialist consultant.

Where isolated footings rise and fall because of swell/shrink effect, the home owner may be tempted to alleviate floor bounce by filling the gap that has appeared between the bearer and the pier with blocking. The danger here is that when the next swell segment of the cycle occurs, the extra blocking will push the floor up into an accentuated dome and may also cause local shear failure in the soil. If it is necessary to use blocking, it should be by a pair of fine wedges and monitoring should be carried out fortnightly.

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APPENDIX C: – 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) For 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.

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

APPENDIX C: 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

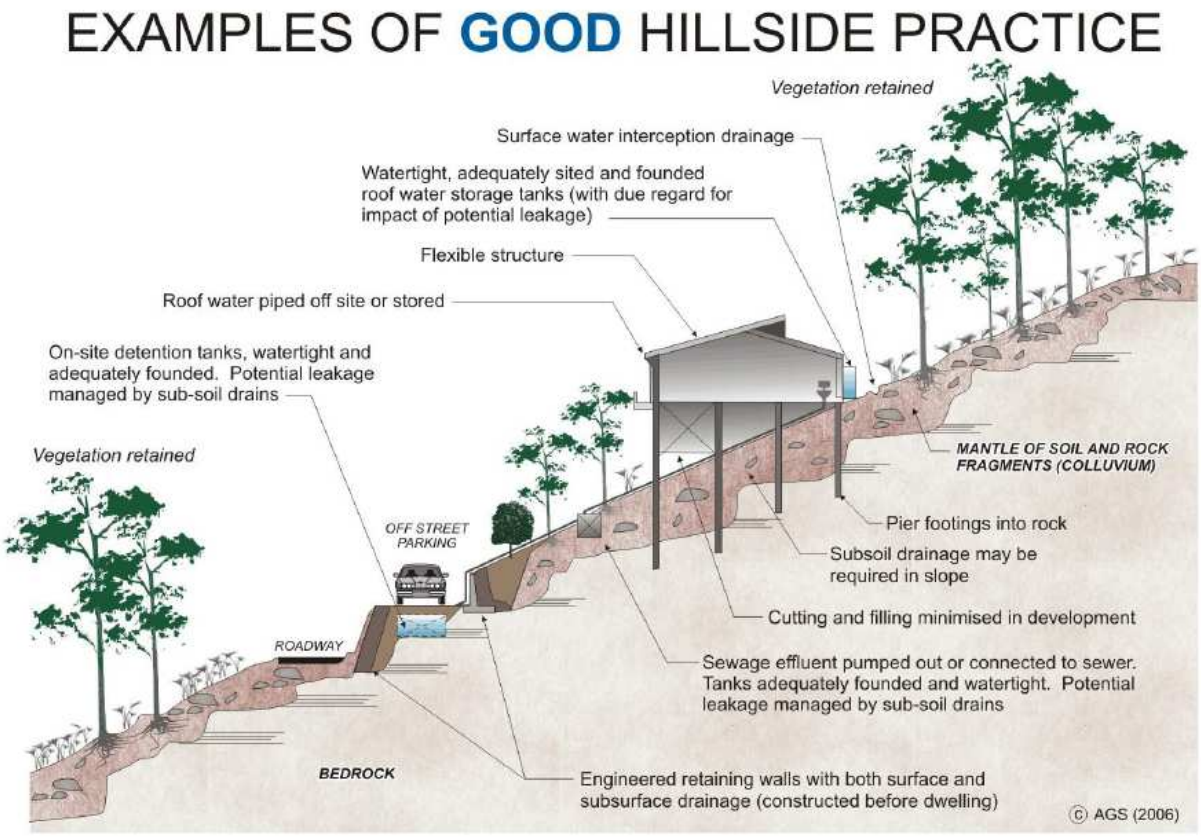
Notes: (2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.

(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

APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	*POOR ENGINEERING PRACTICE*
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical practitioner 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.	Indiscriminatory 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 property 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 rock 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 rock 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 general 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 on 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 roof runoff 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 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 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 see advice. If seepage observed, determine causes or seek advice on consequences.	


EXAMPLES OF GOOD HILLSIDE PRACTICE
Vegetation retained
Surface water interception drainage
Watertight, adequately sited and founded roof water storage tanks (with due regard for impact of potential leakage)
Flexible structure
Roof water piped off site or stored
On-site detention tanks, watertight and adequately founded. Potential leakage managed by sub-soil drains
Vegetation retained
MANTLE OF SOIL AND ROCK FRAGMENTS (COLLUVIUM)
OFF STREET PARKING
Pier footings into rock
Subsoil drainage may be required in slope
Cutting and filling minimised in development
ROADWAY
Sewage effluent pumped out or connected to sewer. Tanks adequately founded and watertight. Potential leakage managed by sub-soil drains
BEDROCK
Engineered retaining walls with both surface and subsurface drainage (constructed before dwelling)
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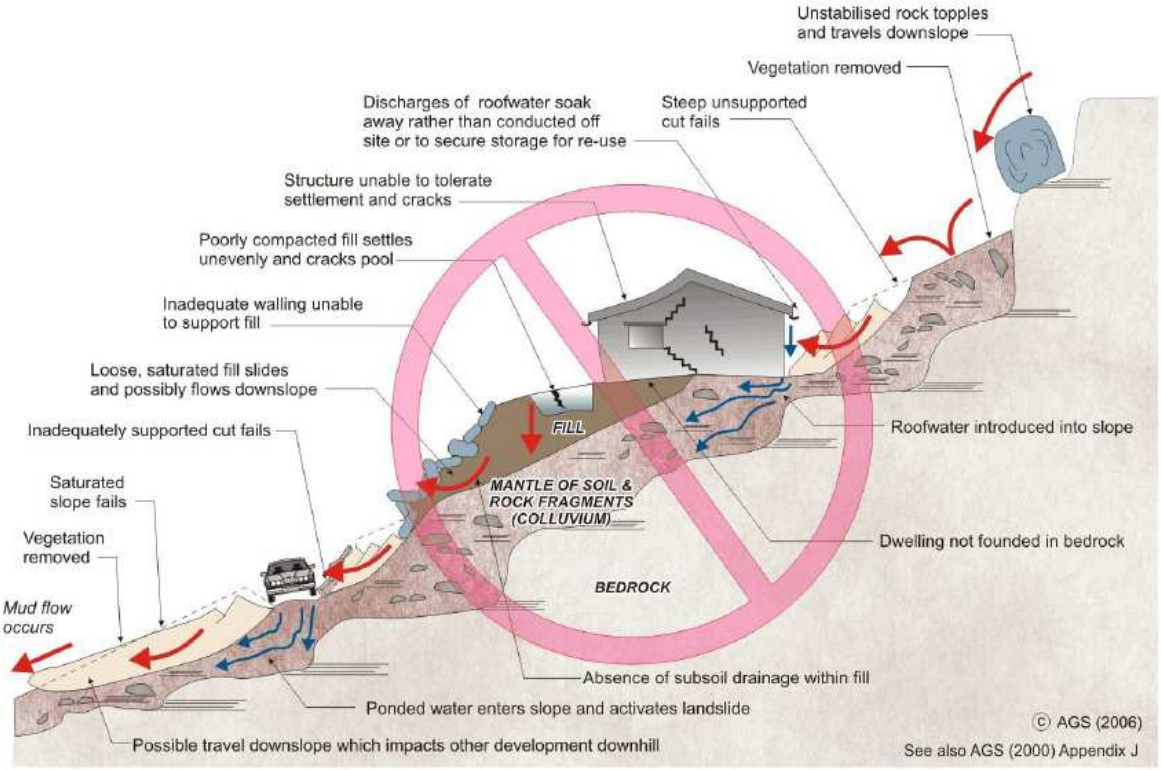
EXAMPLES OF POOR HILLSIDE PRACTICE
Unstabilised rock topples and travels downslope
Vegetation removed
Discharges of roofwater soak away rather than conducted off site or to secure storage for re-use
Steep unsupported cut fails
Structure unable to tolerate settlement and cracks
Poorly compacted fill settles unevenly and cracks pool
Inadequate walling unable to support fill
Loose, saturated fill slides and possibly flows downslope
Inadequately supported cut fails
FILL
Roofwater introduced into slope
Saturated slope fails
MANTLE OF SOIL & ROCK FRAGMENTS (COLLUVIUM)
Vegetation removed
Dwelling not founded in bedrock
BEDROCK
Mud flow occurs
Absence of subsoil drainage within fill
Ponded water enters slope and activates landslide
Possible travel downslope which impacts other development downhill
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See also AGS (2000) Appendix J