REPORT TO

THE DEPARTMENT OF PLANNING, INDUSTRY AND ENVIRONMENT – DEVELOPMENT AND TRANSACTIONS

ON

GEOTECHNICAL ASSESSMENT

FOR

PROPOSED DEVELOPMENT

AT

FORMER MANLY HOSPITAL, 150 DARLEY STREET, MANLY, NSW

Date: 9 September 2020
Ref: 31233YJrpt3

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DOCUMENT REVISION RECORD

Report Reference	Report Status	Report Date
31233YJrpt3	Final Report	9 September 2020

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ATTACHMENTS

1 INTRODUCTION

This report presents the results of our geotechnical assessment of the risk of slope instability posed by the site to the proposed development of the former Manly Hospital at 150 Darley Road, Manly, NSW. The location of the site is shown in Figure 1. The assessment was commissioned by Cox Architecture (Cox) in accordance with our fee proposal, Ref: P50758Y, dated 20 November 2020.

We previously carried out a geotechnical investigation at the site (Ref: 31233YJrpt2, dated 22 May 2020), which included the results of our earlier investigation, was carried out in 2018 and provided geotechnical comments and recommendations on geotechnical aspects relevant to the proposed development, as set out in the concept masterplan. This slope risk assessment was one of the recommendations contained in our previous geotechnical report.

We have been provided with the following information:

- Former Manly Hospital Council Presentation document dated April 2020 (23 pages);
- Public Domain Strategy drawings by Tract Consultants (Tract) dated 21 April 2020 (22 pages);
- Annotated Landscape Masterplan received from Cox by email on 29 April 2020; and,
- Survey drawing by LTS Lockley Pty Ltd (Ref: Drawing Number 50261 001D, survey date March 2018).

Based on the above information we understand that the proposed development will comprise demolition of some of the existing buildings and structures on site and construction of 10 new buildings (including a hospice building), new car parks, driveways, soft landscaped areas and internal paved courtyard areas with other associated structures such as retaining walls and stairways. We understand that five heritage buildings will remain and will be upgraded. The proposed new building finished floor levels (FFL's) are shown to range between Reduced Levels (RLs) 55m and RL65m, with some buildings with a stepped FFL's following the gradient of the land. Approximate locations of the proposed buildings and car parks/driveways and buildings to remain have been shown on Figures 2, 3 and 4a to 4f. We anticipate excavation to a maximum depth of about 2m may be required to achieve these proposed levels. Localised excavation will be required for lift pits, services, subsurface drainage, etc., however these details are not available at this stage. Some filling will also be required to achieve final levels. The extent of filling is unknown at this stage as design details for the proposed buildings have not been provided, i.e. whether they are designed as suspended structures or slabs on grade. The above development is proposed to comprise 6 precinct areas, identified as Precincts A to F, which generally include retail (Precinct A), senior living and well-being (Precincts B and C), a hospice (Precinct D), restoration/recreation (Precinct E) and ecology and landscape (Precinct F).

The purpose of this assessment was to assess the risk posed by slope instability to both life and property. Our assessment considered both the existing and proposed development.

2 ASSESSMENT PROCEDURE

2.1 Walkover Survey

Site visits over two partial days were carried out on 2 and 7 July 2020 by our Senior Geotechnical Engineer, Mr Jarett Mones, to carry out the risk assessment.

The assessment was based on a detailed inspection of the topographic, surface drainage and geological conditions of the site and its immediate environs. These features were compared to those of other similar lots in neighbouring locations to provide a comparative basis for assessing the risk of instability. 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 AGS 2007c.

Notable geotechnical features and a cross section (Section A-A) are shown in the attached Figures 4a to 4f and 5. The geotechnical mapping symbols adopted are shown in Figure 6. The geotechnical features shown in the above figures were mapped using a combination of taped measurements from existing features shown on the survey plan prepared by LTS Lockley Pty Ltd and a clinometer. Consequently, where mapping has been completed beyond the site boundaries, such as the area south-west of the car park, the location of the features shown are approximate. Should any of these features be critical to the proposed development, we recommend they be located more accurately using instrument survey techniques. The survey datum, such as that shown on Section A-A (Figure 5), is Australian Height Datum.

2.2 Subsurface Investigation

The fieldwork for our previous geotechnical investigation was carried out between 9 and 18 April 2018 and comprised the following:

- Fifty Four boreholes (BH1 to BH54) drilled using spiral augers with an attached tungsten carbide (TC) bit, generally to refusal depths ranging from 0.7m to 7.3m below existing surface levels. All boreholes were drilled using our track and truck mounted JK205, JK305 and JK350 drill rigs. The bedrock was proved using a 'TC' bit to refusal depths.
- Seven hand auger boreholes (BH55 to BH61) were drilled to refusal depths below existing surface levels ranging between 0.11m and 1.20m. In addition, Dynamic Cone Penetration (DCP) tests (DCP55 to DCP61) were carried out at each of the hand augered borehole locations to depths ranging from 0.25m to 1.3m, which generally represent the DCP refusal depth.
- Slotted PVC standpipes were installed in BH9, BH13, BH19, BH35 and BH44 to allow further groundwater level monitoring during the fieldwork period and a short period after completion of drilling these boreholes (on 17 April 2018).

Investigation locations are shown on Figures 2 and 3. Should further details on the investigation be required reference should be made to our previous geotechnical report. The borehole logs and DCP test results sheets are attached.

3 RESULTS OF ASSESSMENT AND INVESTIGATION

3.1 Site Description

We recommend that this site description be read in conjunction with the attached Figures 4a to 4f and 5, which show relevant geotechnical features, such as sandstone outcrops, retaining walls, sloping ground and cliff-lines. Figure 6 presents the geotechnical mapping symbols used.

The site is located, as shown on attached Figure 1, near the crest of North Head. Although the site does have an overall slope ranging between about 3° and 7° to the south-west, slopes do vary from vertical sandstone faces to gently sloping ground,. Construction of the original hospital and on-going development of the site has resulted in the formation of level building areas by cut and fill earthworks. The hospital complex structures include brick buildings, fibro clad and timber cladded structures that range in height up to five storeys. The more recent brick buildings appeared in good condition, based on a cursory visual inspection. However, the older fibro and timber clad buildings appeared in a dilapidated condition. Concrete and asphaltic pavements were interspersed around the hospital buildings and these appeared in good condition upon a visual cursory inspection. The car parks located in the southern and eastern portions of the site were constructed from asphaltic concrete and appeared to be in poor condition with rutting and cracking observed.

The embankment that slopes below the car park areas located to the south-west of the site buildings typically ranged between about 25° to 40°. It should be highlighted that access to the majority of the embankment south-west of the car park areas was not accessible due to the presence of thick vegetation. The available survey did not cover this portion of the site.

Areas that have obviously been filled consisted of the south-western carpark and raised garden and lawns. These were retained by rendered and non-rendered brick, concrete, masonry sandstone and dry stone retaining walls that varied, in places, up to 3m in height. Sandstone bedrock cliff-lines were observed across the developed portion of the site, as well as downslope of the undeveloped portion and the location of the observed cliff-lines has been shown on Figures 4a to 4e. The cliff-lines near driveways, car parks and buildings were up to about 2.5 high, whereas the cliff-lines along the embankment area to the south-west of the car park areas were up to about 6m high. The sandstone bedrock was generally assessed to be moderately weathered and of medium to high strength. Vegetation across the site generally comprised lawns, garden areas and small to medium height trees located around the hospital buildings.

We observed some retaining walls that we assessed to be in poor condition, an area of potential cliff-line instability and a sinkhole. We have provided a summary of these with some photographs and have provided recommendations for remediation in Sections 4 and 5.

The following walls with heights of greater or equal to 0.7m were assessed to be in poor condition:

- Brick retaining wall, 1.2m high with 30mm wide vertical cracking and approximately 2° tilt at north-western end, as shown on Figure 4a and Plate 1 below.

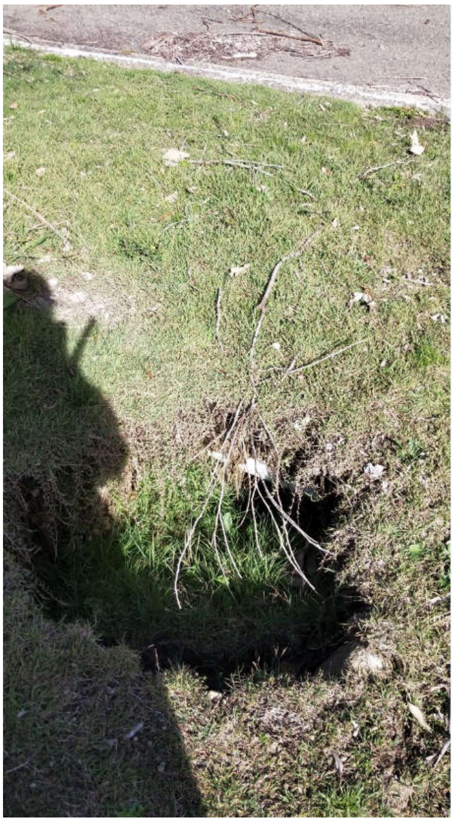
- Brick retaining wall, 0.7m high with 10° tilt over extents of wall (about 7m in length), as shown on Figure 4e and Plate 2 below.

Plate 1: Photograph of 1.2m High Brick Wall Assessed to be in Poor Condition

Plate 2: Photograph of 0.7m High Brick Wall Assessed to be in Poor Condition

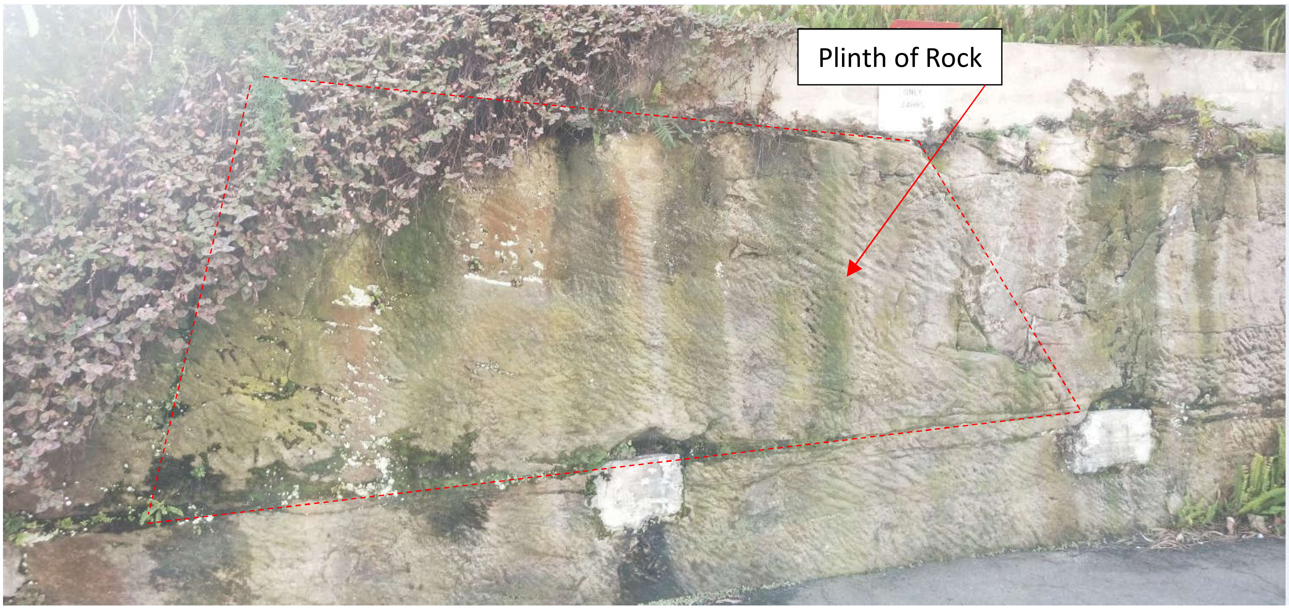
A relatively small sink hole was observed around buried water services to the north of a car park area as shown on Figure 4e and Plate 3 below. The sink hole was about 0.9m diameter and about 0.9m deep.

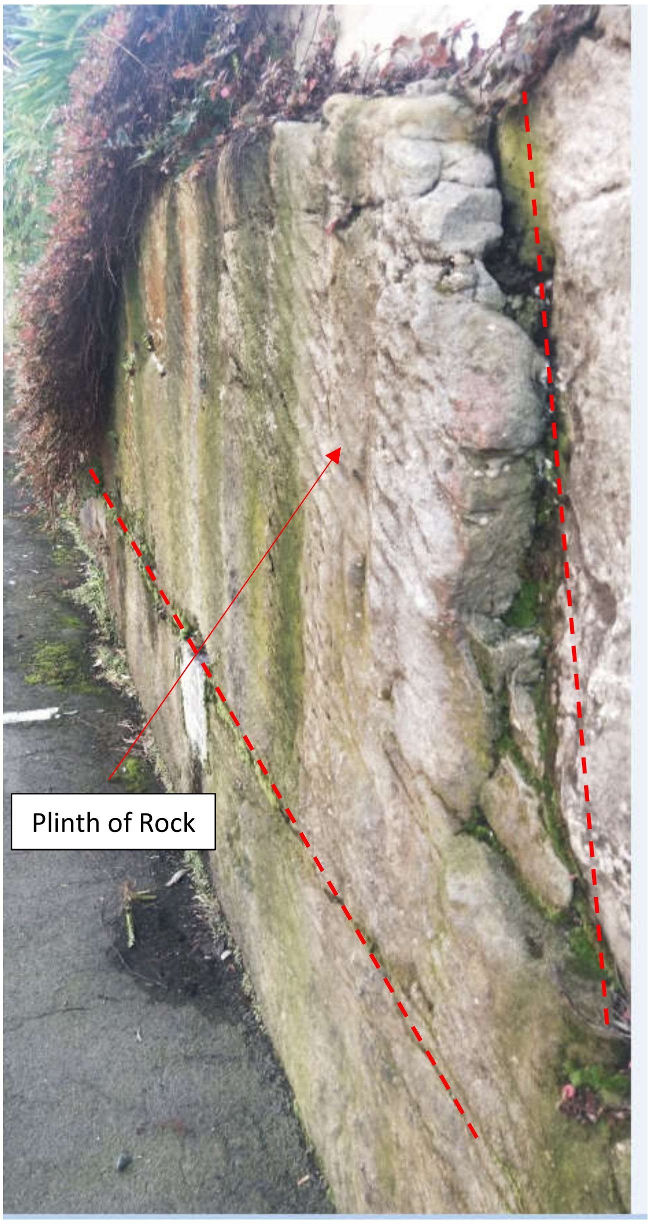
Plate 3: Photograph of Sinkhole



Along a cliff-line at the north-western end of the site near the Darley Road entrance we observed a plinth of bedrock that appears likely to dislodge from the face. The plinth was about 100mm thick over an area of about 1.1m (vertical) x 3.2m (horizontal), as shown in Plate 4.

Plate 4: Photographs of Plinth of Bedrock That May Detach from Cliff-Line





Darley Road bounds the site to the north while to the northeast/east is North Head Scenic Drive. Both roads appeared in good condition based upon a cursory visual inspection. To the southwest, south and southeast of the site is steeply sloping, densely vegetated bushland which falls down to Collins Beach and North Harbour. To the west is St Paul's College which comprises multi-storey masonry buildings.

3.2 Geology and Subsurface Conditions

Reference to the Sydney 1:100,000 Geological Series Sheet indicates that the site is underlain by Hawkesbury Sandstone of the Wianamatta Group. Hawkesbury Sandstone comprises medium to coarse grained quartz sandstone with very minor shale and laminite lenses.

Our previous investigation encountered a generalised subsurface profile consisting of a shallow to moderate depth of granular fill that generally overlies sandstone bedrock. However, in BH3, BH11, BH12, BH21, BH25 and BH27 residual silty and sandy clays and Quaternary aged Aeolian sand were encountered between the base of the fill and the top of the sandstone bedrock. The weathered sandstone bedrock was encountered in the majority of the boreholes at highly variable depths ranging from 0.2m to 5.4m below existing surface levels. Some of the more pertinent subsurface observations are discussed below. For specific details of the materials encountered at a particular location, reference should be made to the attached borehole logs and DCP test result sheet. Figures 3 indicates the approximate top of rock contour levels across the site based on the results of the investigation.

Pavements

With the exception of BH3, BH5, BH15, BH16, BH25 to BH28, BH32, BH35 to BH38, BH42, BH43, BH47 and BH55 to BH61 either asphaltic concrete (AC) or concrete pavements were encountered in all remaining boreholes. AC pavements were encountered at the majority of the locations and ranged in thickness from 20mm to 50mm. Concrete pavements were encountered in BH18, BH19, BH29 and BH30 and ranged in thickness of 100mm to 150mm.

Fill

Fill was encountered either from the surface or immediately underlying the pavements. The fill typically extended to depths ranging from 0.2m to 1.7m, although moderately to deep fill was encountered in a number of boreholes as can be seen in the following table which summarises fill depths exceeding 1.7m. The deepest fill depths, i.e. at BH28, BH39 and BH45 were highlighted in bold.

Borehole Number	Fill Depth (m)
BH12	3.6
BH13	2.5
BH14	3.0
BH16	2.8
BH19	2.7
BH28	**7.3**
BH39	**5.4**
BH40	2.8
BH45	**4.1**
BH46	2.6
BH48	3.0

The fill generally comprised gravelly sand, silty sand, sandy gravel and clayey sand and was of variable compaction and assessed to range from poorly to well compacted. The fill contained various gravel inclusions and varying fractions of brick, ash, glass, igneous gravel, tile, timber and concrete. We consider that the fill would be classed as uncontrolled fill.

Natural Soils

Natural soils encountered in the boreholes consisted of Quaternary aged Aeolian sands and residual silty and sandy clays. The Quaternary aged sands Aeolian deposited sands were encountered in BH3, BH8 and BH25 beneath the fill at depths ranging between 0.4m and 1.4m and ranged in thickness of 0.9m to 1.4m. The silty sand was assessed to be of loose relative density. The residual silty and sandy clays were encountered in

BH11, BH21 and BH27 and extended to depths between 1.3m and 2.4m. The silty and sandy clays were assessed to be of low to medium plasticity and of stiff to very stiff strength.

Sandstone Bedrock

As discussed in our site description, sandstone bedrock was outcropping in many areas of the site (Ref: Figure 4a to 4d) and was assessed to be moderately weathered and of medium to high strength.

With the exception of BH32, where a band of claystone was found to be overlying the better quality sandstone bedrock and extended from a depth of 1.2m to 2.5m, sandstone bedrock was encountered or inferred in all other boreholes below the soils. The depth to sandstone bedrock in the test locations varied across the site with the bedrock generally deeper in the lower southwestern portions of the site. Sandstone bedrock was encountered from approximately RL65.1m (depth of 0.5m) in BH51 on the eastern (upper end) of the site, to about RL44.4m (depth of 1.9m) in BH42 on the western (lower end) of the site.

Typically, the sandstone bedrock was assessed to be of medium to high strength or better when first encountered. The rock either maintained the same strength or increased in strength with depth, although there were some exceptions. In BH8 to BH10, BH30 to BH32, BH35, BH38, BH40 and BH47, the bedrock was assessed to be extremely weathered and was encountered at depths ranging between 0.2m and 2.8m and varied in thickness from 0.1m (BH10) to 1.3m (BH9).

'TC' auger bit refusal within sandstone bedrock was encountered in most boreholes with the exception of BH12 and BH41. At BH12 the borehole was terminated within sandstone bedrock or a sandstone floater due to the augers kicking off and the hole being unable to be maintained vertical. BH41 refused on a 'floater' in the fill. BH28 is likely to have refused on sandstone bedrock although no rock cuttings were returned on the auger and we were unable to confirm the presence of sandstone bedrock. Consequently, there is some degree of uncertainty on whether this borehole has refused on sandstone bedrock. High auger resistance and 'TC' bit refusal within the sandstone bedrock generally indicates medium to high or greater strength bedrock.

The attached Figure 3 presents a plan showing the approximate reduced surface levels for the sandstone bedrock. We note that the contours are based on interpolation between the known rock depths at the borehole locations and rock outcrops and as a result should be treated as approximate only. Figures 4a to 4d include the mapped cliff-lines at the site. Generally, where bedrock was outcropping it was assessed to be moderately weathered and of medium to high strength.

The refusal depth of the DCP tests (BH55 to BH61) are generally considered to approximate the depth to sandstone bedrock. However, as these tests neither penetrate nor prove the underlying bedrock it is possible that premature refusal may have occurred on inclusions within the fill or other harder layers in the soils. Notwithstanding this, based on our observation of the site and sandstone outcrops, we consider that it is likely that the depth of refusal of the DCP tests indicates the approximate depth to the top of bedrock.

Groundwater

With the exception of BH7, BH19 and BH28, all boreholes were dry during and on the completion of drilling. Groundwater seepage during augering was encountered at depths of 1.2m (BH7), 1.6m (BH19) and 7.0m (BH28). Slotted PVC standpipes were installed in BH9, BH13, BH19, BH35 and BH44 to allow longer term groundwater monitoring to be completed. Groundwater levels in the standpipes were measured on 17 April 2018. At that time all the standpipes were dry with the exception of BH9, which had a measured groundwater level at a depth of 2.08m below ground surface.

4 RISK ASSESSMENT

4.1 Landslide Risk Assessment Criteria

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

The assessment has been made on a semi-quantitative basis with quantitative values assigned to qualitative assessments. The qualitative assessments are based on judgements made in the field by the geotechnical engineer and in this regard are subjective and formed in part by the engineers' previous experiences. The range of annual probabilities assigned to the likelihood of events occurring, the recommended vulnerability values and the qualitative risk analysis matrix are presented in Appendix A.

Since the existing site is currently closed the duration of use (temporarily probability) of persons above and below the hazards assumed the site is in use. We recommend that the risk assessment is reviewed at the following two stages:

- Stage 1 - Once the design drawings are finalised to confirm hazards for the proposed development, and
- Stage 2 - During construction to confirm that the risk posed by those hazards identified and requiring remedial works now pose an acceptable risk.

It should be highlighted that access to the majority of the embankment south-west of the car park areas was not accessible due to thick vegetation. Similarly the survey did not cover this portion of the site. We

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[1] Journal and News of the Australian Geomechanics Society, Volume 37, No 2, May 2002

recommend that a geotechnical inspection of the inaccessible areas be carried out once access is possible i.e. following thinning or clearing of vegetation.

4.1.1 Hazards

Reference should be made to the attached Figures 4a to 4f, which indicate the approximate location of the potential hazards posed by this site. As there were numerous existing retaining walls (about 35), cliff-lines and slopes the hazards have been grouped together to simplify the assessment. The following hazards were identified:

- **Hazard A** – Failure of retaining walls. To review the risk of each wall this hazard was sub-divided into the following groups:
    - AA-Concrete (full height) assessed to be in good condition.
    - AB-Brick, Masonry Sandstone Block and Concrete (partial height above cliff-lines/walls) assessed to be in good condition.
    - AC-Brick assessed to be poor condition and Dry Stone (irregular sandstone block).
    - AD-New Engineered. Since design drawings were not available at the time of our assessment we have assumed their total length to be the equivalent to 20% of the length of the new buildings.

  Landscape retaining walls less than 0.4m high were excluded from this assessment. The risk posed by these walls is not material
- **Hazard B** – Instability of cliff-lines. To review the risk posed by the cliff-line this hazard was sub-divided into the following groups:
    - BA-Near car parks and access roads. Hazard BA3 includes a plinth of rock that appears likely to detach.
    - BB-Near buildings.
    - BC-Embankment below car park.
- **Hazard C -** Instability of sloping ground. To review the risk of each slope this hazard was sub-divided into the following groups:
    - AA-Slopes >20°<25°.
    - AB- Slopes >25°.

  Sloping ground less than 20° was generally ignored for this assessment.
- **Hazard D** – Sinkhole.

4.1.2 Risk Analysis

The attached Table A summarises our qualitative assessment of each potential landslide hazard and of the consequences to the property should the landslide hazard occur. Use has been made of the data presented in MacGregor *et al* (2007) to assist with our assessment of the likelihood of a potential hazard occurring. 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 is Low, which would be considered acceptable in accordance with the criteria given in Reference 1. The risk can be reduced to Very Low following remediation of the sink hole.

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 1×10^{-5}. This would be considered to be acceptable in relation to the criteria given in Reference 1. However, we note that if plinth of rock (Hazard BA, as shown in Plate 4) is removed, the risk for the person most at risk would be reduced to about 5×10^{-7}. This risk can be further improved by replacing the walls that were observed to be poor condition and reinstating the sink hole.

4.2 Risk Assessment

The design project life for this project has been taken as 50 years. This provides the context within which the geotechnical risk assessment should be made. The required 50 years baseline broadly reflects the expectations of the community for the anticipated life of a residential structure and hence the timeframe to be considered when undertaking the geotechnical risk assessment and making recommendations as to the appropriateness of a development, and its design and remedial measures that should be taken to control risk. It is recognised that in a 50 year period external factors that cannot reasonably be foreseen may affect the geotechnical risks associated with a site. Hence, the geotechnical engineer does not warrant the development for a 50 year period, rather provides a professional opinion that foreseeable geotechnical risks to which the development may be subjected in that timeframe have been reasonably considered.

Our assessment of the probability of failure of existing structural elements such as retaining walls (where applicable) is based upon a visual appraisal of their type and condition at the time of our inspection. Where existing structural elements such as retaining walls will not be replaced as part of the proposed development, where appropriate we identify the time period at which reassessment of their longevity seems warranted.

In our assessment we have made the following assumptions:

- The proposed development works will be carried out in accordance with our comments and recommendations in our geotechnical investigation report (Ref: 31233YJrpt2, dated 22 May 2020).
- The sinkhole area will be backfilled as set-out in the recommendations below.
- The walls assessed to be in poor condition identified above will be replaced with new engineered retaining walls or supported.
- All new retaining walls will be engineered retaining walls designed in accordance with our recommendations (Ref: 31233YJrpt2, dated 22 May 2020) and in accordance with relevant Australian Standards/design codes.
- The area of potential cliff-line instability will be addressed during construction as discussed in Section 5.
- That no activities on surrounding land which may affect the risk on the subject site would be carried out.

- That all Council's buried services are, and will be regularly maintained to remain, in good condition.

Provided the assumptions above are correct and the recommendations below are followed, we consider that our risk analysis has shown that the site and existing and proposed development can achieve the 'Acceptable Risk Management' criteria. However, we recommend that the stability assessment be reviewed at the stages discussed in Section 4.1.

5 COMMENTS AND RECOMMENDATIONS IN REGARDS TO THE RISK ASSESSMENT

5.1 Remediation of Identified Hazards

As identified in our site description, two walls are in a state of failure, there is an area of potential rock instability along the cliff-line and there is an existing sink hole. To achieve an acceptable level of risk for the site, both in its current condition and for the proposed development we recommend that:

- All recommendations set out in our previous report (Ref: 31233YJrpt2, dated 22 May 2020) be closely followed. While reference should be made to our previous report for a complete set of recommendations, for ease we have provided recommendations on excavation, retention and the placement of engineered fill for the backfilling of the sinkhole or behind newly constructed retaining walls. These recommendations are provided below in Sections 5.2 and 5.3.
- The identified retaining walls are to be replaced with new engineered walls.
- The thin plinth of rock along the cliff-line should be removed during construction. Until removed an exclusion zone that extends a perpendicular distance of 4m out from the cliff line and for the full length of the plinth, plus an additional 1.5m at either end, should be formed. The geotechnical engineer should indicate to the builder, prior to them establishing to site, the required extent of the exclusion zone. During removal of the plinth we recommend that a geotechnical engineer be present to provide advice on the required extent of removal. Care must be taken to avoid damaging the retaining wall (brick rendered) above the cliff-line that is about 0.4m high. Some support or underpinning of this wall may be required. Alternatively, consideration could be given to providing long term support to the plinth of rock, which may include the installation of permanent rock bolts, shotcrete and mesh. General recommendations regarding inspections of cut faces during construction are provided in Section 5.2.
- The sinkhole has likely developed due to the existing buried water service pipe leaking. We recommend that the following works be completed in this area:
    - The buried services should be pressure checked for leaks. Any leaky services should be repaired.
    - The area should be backfilled with engineered fill as recommended below in Section 5.3. If no buried services are found to be leaking and the cause of the sinkhole cannot be determined further advice should be sought from this office.

5.2 Retention

Sandstone bedrock of better than low strength may be cut vertically and left unsupported provided it contains no adverse defects such as joints, clay seams bedding partings etc. Where adversely orientated defects are present, such as the identified plinth of rock, remedial measures such as rock bolts, drainage, shotcrete and mesh will be required to provide support to the excavated bedrock. Alternatively, the plinth may be removed but the geotechnical engineer must reinspect the plinth to confirm the extent of removal required and that its removal will not destabilise other structures. In this regard, the geotechnical engineer may request that part, or all of the plinth be removed whilst they are on site.

Where vertical unsupported excavation through sandstone bedrock of greater than low strength is completed we recommend that a geotechnical engineer inspect the cut faces every 1.5m of vertical cut so that where adverse defects are present, these may be identified and remedial measures adopted. Most weathered sandstone will fret when exposed and even though the cut faces will be essentially stable, protection with shotcrete should be considered to avoid drains becoming silted up and requiring regular maintenance.

Our assessment of site conditions is based on information available from the site investigation and is limited to interpolation between borehole locations (some of which were hand augered boreholes and did not penetrate the rock) and observation of the sandstone outcrops. We therefore recommend that a geotechnical engineer progressively inspect the rock faces as discussed above during excavation to confirm site conditions and identify any features, which require stabilisation. Some provision for rock bolting, drainage and shotcrete with mesh should be included in the contract documents.

Where existing walls are required to be replaced or remediated, as discussed above, we anticipate the walls will be demolished and the soils behind temporarily battered. We anticipate that adequate space will generally exist for the formation of temporary and permanent batters. Temporary batters through granular soils such as the fill may be formed at no steeper than 1 Vertical (V):1.5 Horizontal (H), but can be increased to 1V:1H in residual clayey soils of at least very stiff strength or in extremely weathered bedrock. Surcharge loads should be kept well away from the edges of the temporary batters. Flatter batters and additional shoring would be required should groundwater be encountered. We expect that battered slopes would be backfilled upon completion of construction of retaining walls. Where excavations are carried out close to heritage buildings (which will remain), following demolition we recommend a series of test pits be carried out to review these buildings' footing details.

Where permanent batters are adopted they may be formed through granular soils at no steeper than 1V:3H and through residual clayey soils of at least very stiff strength or extremely weathered rock at no steeper than 1V:2H. Where permanent batters are adopted they should be protected from erosion by vegetation, shotcrete and mesh or equivalent. A geotechnical engineer should inspect permanent batters during construction.

Where free-standing retaining walls up to 3m high are required they may be designed for a triangular earth pressure distribution, a coefficient of active lateral earth pressure, k_a, of at least 0.35 and a bulk unit weight of 20kN/m^3 for soil (including extremely weathered bedrock) and highly weathered bedrock, assuming an level backfill surface. Appropriate surcharge and hydrostatic loads should be added to the above pressures. For propped or anchored walls (including permanent walls that are propped by the floor slabs) or to limit deflections of the wall an earth pressure coefficient of at least 0.5 should be adopted.

A lateral restraint of 300kPa may be adopted for that part of the wall embedded in the underlying sandstone bedrock of at least very low strength. This assumes that full passive restraint can be mobilised in the rock and that features such as excavations in front of the wall do not reduce the available capacity. In this regard we recommend that all retaining wall designs be reviewed by a geotechnical engineer prior to construction to confirm that appropriate design values have been adopted. A geotechnical engineer should inspect the retaining wall footing excavations.

Since some of the existing buildings may be below ground surface, the existing building walls may be acting as retaining walls. It may be possible to re-use some of the walls for retention, although it is likely that this will require additional lateral support (where floor slabs are removed during demolition). However, if this is considered a review of the existing buildings as-built drawings showing existing floor levels, lower ground/basement footprints, etc. would need to be reviewed by the structural engineer to confirm whether additional support is required. Test pit excavations may also be required to confirm footing details and ground conditions.

5.3 Engineered Fill

The existing fill encountered in the boreholes is considered suitable for reuse as engineered fill on condition that it is free from organic matter, other deleterious materials, and contaminants and has a maximum particle size not exceeding 75mm. If material is imported to raise site levels we recommend that a well graded granular fill material (e.g. crushed/ripped sandstone) be sourced, as such materials will form a better quality fill material than clayey soils.

Engineered fill comprising well graded granular material (e.g. crushed/ripped bedrock) should be compacted in typically 200mm loose thickness layers, although layer thicknesses may be varied depending on the size of the compaction equipment used provided the required density ratio is achieved over the full thickness of the layer. Well graded granular material may be compacted to a density ratio of at least 98% of SMDD. In soft landscaped areas this compaction specification can be reduced to a density ratio of at least 96% of SMDD.

Engineered fill comprising clayey soils should be compacted in approximately 200mm thick loose layers to a density ratio strictly between 98% and 102% of SMDD at a moisture content within 2% of Standard Optimum Moisture Content (SOMC). In soft landscaped areas (and not for backfilling around structures such as retaining walls) this compaction specification can be reduced to a density ratio of at least 96% (i.e. no upper bound restriction). We note that moisture conditioning of such clays may be required in order to conform to the above moisture specification.

6 OVERVIEW

Provided those hazards requiring remediation and identified above are remediated and new structures are constructed in accordance with our recommendations, we consider that the site poses an acceptable risk in both its existing condition and for the proposed development.

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 reported in 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.

Reference 2: MacGregor, P, Walker, B, Fell, R, and Leventhal, A (2007) *'Assessment of Landslide Likelihood in the Pittwater Local Government Area'*, Australian Geomechanics, Vol 42, No 1, March 2007, pp183-196.

TABLE A

SUMMARY OF RISK ASSESSMENT TO PROPERTY

POTENTIAL LANDSLIDE HAZARD	**A - Instability of Retaining Walls**				**B - Instability of Cliff-Lines**			**C- Land instability (Sloping Ground)**		**D - Sink Hole Extending (i.e. Collapsing Further)**
	(AA) Concrete	**(AB) Brick, Masonry Sandstone Block and Concrete above crest-lines**	**(AC) Brick Poor Condition and Irregular Dry Stone**	**(AD) New Engineered Walls**	**Near Driveway and Parking Areas (BA)**	**(BB) Near Buildings**	**(BC) Embankment Area**	**(CA) Slope angle >=20°<25°**	**(CB) Slope Angle >=25**	**Approximately 0.9m Diameter by 0.9m Depth**
Assessed Likelihood	Rare	Unlikely	Possible	Barely Credible	Unlikely (BA1 and BA2) / Almost Certain (BA3)	Rare	Barely Credible	Unlikely	Possible	Likely
Assessed Consequence	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
Risk	Very Low				*Low (BA3) / Very Low (BA1, BA2, BB and BC)			Very Low		Low
Comments	Walls assessed to be in poor condition should be remediated during construction as recommended. Above should be review during construction				Above should be reviewed during construction. *Plinth of rock (Hazard BA3) is to be removed during construction and the risk will be reduced to Very Low			Inaccessible areas on embankment to be inspected to review the above if vegetation is cleared		This area can be remediated during construction to eliminate the risk

TABLE B

SUMMARY OF RISK ASSESSMENT TO LIFE

POTENTIAL LANDSLIDE HAZARD	**A - Instability of Retaining Walls**				**B - Instability of Cliff-Lines**			**C- Land instability (Sloping Ground)**		**D - Sink Hole Extending (i.e. Collapsing Further)**
	(AA) Concrete	**(AB) Brick, Masonry Sandstone Block and Concrete above crest-lines**	**(AC) Brick Failing and Irregular Dry Stone**	**(AD) New Engineered Walls**	**(BA) Near Driveway and Parking Areas**	**(BB) Near Buildings**	**(BC) Embankment Area**	**(CA) Slope angle >=20°<25°**	**(CB) Slope Angle >=25°<=40°**	**Approximately 0.9m Diameter by 0.9m Depth**
Assessed Likelihood	Rare	Unlikely	Possible	Barely Credible	Unlikely $^{(BA1\ and\ BA2)}$ / Almost Certain $_{(BA3)}$	Rare	Barely Credible	Unlikely	Possible	Likely
Indicative Annual Probability	10^{-5}	10^{-4}	10^{-3}	10^{-6}	10^{-4} / 10^{-1}	10^{-5}	10^{-6}	10^{-4}	10^{-3}	10^{-2}
Duration of Use of Area Affected (Temporal Probability)	(i) On top of wall, varies from 1min/month (2.3 x 10-5) to 2min/day (1.3 x 10-3) (ii) Below wall, varies from 1min/month (2.3 x 10-5) to 2min/day (1.3 x 10-3)	(i) On top of wall, varies from 1 min/year (1.90 x 10-6) to 5min/day (3.47 x 10-3) (ii) Below wall, varies from 1 min/year (1.90 x 10-6) to 5min/day (3.47 x 10-3)	(i) On top of wall, varies from 1 min/year (1.90 x 10-6) to 5min/day (3.47 x 10-3) (ii) Below wall, varies from 1 min/year (1.90 x 10-6) to 2min/day (1.39 x 10-3)	(i) On top of wall, 5min/day (9.51 x 10-6) (ii) Below wall, 4hrs/day (1.67 x 10-1)	(i) On top of cliff-line, 1 min/month (2.28 x 10-5) (ii) Below cliff-line, varies from 1 min/day (6.94 x 10-4) to 2 min/day, 1.39 x 10-3)	(i) On top of cliff-line, 1 minute/year (1.90 x 10-6) (ii) Below cliff-line, varies from 1min/month (2.28 x 10-5) to 1 min/day (6.94 x 10-4)	(i) On top of cliff-line, 1 minute/month (2.28 x 10-5) (ii) Below cliff-line, 1 minute/month (2.28 x 10-5)	(i) On the slide, 1min/month (2.28 x 10-5) (ii) Below the slide, varies from 30 sec/day (3.47 x 10-4) to 1min/day (6.94 x 10-4)	(i) On the slide, varies from 1min/year (1.92 x 10-6) to 10 min/day (6.94 x 10-3) (ii) Below the slide, varies from 1min/year (1.92 x 10-6) to 1 min/day (6.94 x 10-4)	(i) Above, 1 min/day (6.94 x 10-3) (ii) Inside, 1 min/month (2.28 x 10-5)
Probability of not Evacuating Area Affected	(i) 1.0 (ii) 0.8	(i) 1.0 (ii) 0.8	(i) 1.0 (ii) 0.8	(i) 1.0 (ii) 1.0	(i) 1.0 (ii) varies, 0.8 to 1.0	(i) 1.0 (ii) 0.8	(i) 1.0 (ii) 0.8	(i, ii) 0.1	(i, ii) 0.1	(i, ii) 0.01
Spatial Probability	(i, ii) varies, from 0.08 to 0.5	(I, ii) varies, from 0.026 to 1.0	(i, ii) varies, from 0.033 to 0.5	(i, ii) 0.018	(i, ii) varies, from 0.088 to 0.23	(i, ii) varies from 0.15 to 0.26	(i, ii) 0.13	(i, ii) varies from 0.1 to 0.33	(i, ii) varies from 0.03 to 0.33	(i, ii) 1.0
Vulnerability to Life if Failure Occurs Whilst Person Present	(i, ii) varies, from 0.1 to 1.0	(i, ii) varies, from 0.001 to 1.0	(i, ii) varies, from 0.1 to 1.0	(i, ii) 1.0	(i, ii) varies 0.1 to 1.0	(i, ii) 0.1	(i) 0.1	(i, ii) 0.1	(i, ii) varies, from 0.01 to 0.1	(i, ii) 0.001
Risk for Person most at Risk	(i) sum = 6.5 x 10-10 (ii) sum = 4.7 x 10-9	(i) sum = 7.1 x 10-9 (ii) sum = 7.9 x 10-8	(i) sum = 5.6 x 10-8 (ii) sum = 2.9 x 10-7	(i) 1.4 x 10-14 (ii) 3.0 x 10-9	(i) sum = 2.0x10-8 (ii) sum = 1.2x10-5	(i) sum = 7.8x10-13 (ii) sum = 8.6 x 10-11	(i) 3.0 x 10-13 (ii) 2.4 x 10-13	(i) 2.3 x 10-12 (ii) sum = 1.8 x 10-10	(i) sum = 6.4 x 10-9 (ii) sum = 7.4 x 10-10	(i) 6.9 x 10-10 (ii) 2.3 x 10-12
Combined Total Risk for Person most at Risk	**1.3 x 10-5 (If Hazard BA3 is removed, i.e. thin plinth of rock is removed; the combined total risk would be 4.5 x 10-7)**									

BOREHOLE LOG

Borehole No.
1
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Method: SPIRAL AUGER
JK350
R.L. Surface: ≈ 56.1m
Date: 9/4/18
Datum: AHD
Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION	■					0	■	-	ASPHALTIC C0NCRETE: 30mm.t.	M			
	■			■	N >10 5,10/50mm		▨		FILL: Clayey sand, fine to medium grained, grey.				
						1	⁝	-	SANDSTONE: fine to medium grained, orange brown and grey.	DW	M-H		MEDIUM TO HIGH 'TC' BIT RESISTANCE
									END OF BOREHOLE AT 1.5m				'TC' BIT REFUSAL
						2							
						3							
						4							
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
2
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 9/4/18
Method: SPIRAL AUGER
JK350
R.L. Surface: ≈ 56.3m
Datum: AHD
Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION						0	■	-	ASPHALTIC CONCRETE: 30mm.t.	M			APPEARS WELL COMPACTED
							▨		FILL: Sand, fine to coarse grained, grey and brown, trace of fine to coarse grained sandstone gravel.				
	■				N = 25 9,13,12		▨		FILL: Silty sand, fine to coarse grained, dark brown, trace of coarse grained sandstone gravel .				
						1	▨						
	■						⁞	-	SANDSTONE: fine to coarse grained, grey.	DW	M-H		HIGH 'TC' BIT RESISTANCE
						2			END OF BOREHOLE AT 2.0m				'TC' BIT REFUSAL
						3							
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
3
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 9/4/18
Method: SPIRAL AUGER JK350
R.L. Surface: ≈ 56.4m
Datum: AHD
Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■			■	N = 9 3,4,5	0	▨		FILL: Silty sand, fine to coarse grained, dark grey and dark brown, trace fine grained sandstone gravel and fragment of glass.	M			APPEARS MODERATELY COMPACTED
	■			■		1	░	SM	Silty SAND: fine to coarse grained, yellow brown.	M	(L)		AEOLIAN SAND
				■		2	⁝	-	SANDSTONE: fine to coarse grained, grey and orange orange brown.	MW	M-H		MODERATE TO HIGH 'TC' BIT RESISTANCE HIGH RESISTANCE
						3			END OF BOREHOLE AT 3.0m				'TC' BIT REFUSAL
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
4
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY

Method: SPIRAL AUGER
JK350

R.L. Surface: ≈ 54.3m

Date: 9/4/18

Datum: AHD

Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■					0		-	ASPHALTIC CONCRETE: 30mm.t.	M			APPEARS WELL COMPACTED
									FILL: Silty sand, fine to coarse grained, grey, trace fine to coarse grained sandstone gravel.				
	■				N > 15 15/50mm				FILL: Silty sand, fine to coarse grained, brown grey brown, trace of fine to medium grained sandstone gravel.				
	■					1		-	SANDSTONE: fine to medium grained, orange brown and grey.	SW	M-H		HIGH 'TC' BIT RESISTANCE
									END OF BOREHOLE AT 1.5m				'TC' BIT REFUSAL
						2							
						3							
						4							
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
5
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 9/4/18
Method: SPIRAL AUGER
JK350
R.L. Surface: ≈ 52.3m
Datum: AHD
Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■					0			FILL: Silty sand, fine to medium grained, brown, with root fibres.	M			GRASS COVER
					N >10 2,10/50mm								APPEARS MODERATELY COMPACTED
						1		-	SANDSTONE: fine to medium grained, grey and orange brown.	DW	L		
				■						MW	M-H		MODERATE TO HIGH 'TC' BIT RESISTANCE
									END OF BOREHOLE AT 1.5m				'TC' BIT REFUSAL
						2							
						3							
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
6
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY

Date: 9/4/18

Method: SPIRAL AUGER
JK350

R.L. Surface: ≈ 52.8m

Datum: AHD

Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■					0		-	ASPHALTIC CONCRETE: 30mm.t.	M			APPEARS POORLY COMPACTED
									FILL: Sand, fine to coarse grained, brown and grey, with fine to coarse grained sandstone gravel.				
	■			■	N = 7 3,3,4				FILL: Clayey sand, fine to coarse grained, dark grey.				
						1							
	■			■				-	SANDSTONE: fine to coarse grained, grey.	MW	H		HIGH 'TC' BIT RESISTANCE
						2			END OF BOREHOLE AT 2.0m				'TC' BIT REFUSAL
						3							
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
7
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 9/4/18
Method: SPIRAL AUGER
JK350
Logged/Checked by: T.C./W.T.
R.L. Surface: ≈ 54.4m
Datum: AHD

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
						0		-	ASPHALTIC CONCRETE: 30mm.t.	M			APPEARS WELL COMPACTED
									FILL: Silty sand, fine to coarse grained, dark grey and brown.				
	■				N = 23 5,11,12								HYDROCARBON ODOUR
						1			as above, but brown.				
▼				■				-	SANDSTONE: fine to medium grained, grey and orange brown.	MW	M-H		MODERATE TO HIGH 'TC' BIT RESISTANCE
						2			END OF BOREHOLE AT 2.0m				'TC' BIT REFUSAL
						3							
						4							
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
8
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Method: SPIRAL AUGER JK350
R.L. Surface: ≈ 52.2m
Date: 10/4/18
Datum: AHD
Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES				Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
	ES	U50	DB	DS									
DRY ON COMPL -ETION	■					0		-	ASPHALTIC CONCRETE: 40mm.t	M			APPEARS WELL COMPACTED
									FILL: Sand, fine to coarse grained, brown and grey, with coarse grained igneous gravel.				
	■			■	N = 15 6,8,7	1			FILL: Sand, fine to coarse grained, brown and yellow brown.				
	■							SM	Silty SAND: fine to coarse grained, yellow brown.	M	(L)		MARINE SAND
					N > 10 10/50mm			-	Extremely Weathered sandstone: Silty SAND, fine to coarse grained, grey and orange brown.	XW	D		LOW 'TC' BIT RESISTANCE
				■		2			SANDSTONE: fine to medium grained, grey.	MW	M-H		HIGH RESISTANCE
						3 4 5 6 7			END OF BOREHOLE AT 2.7m				'TC' BIT REFUSAL

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BOREHOLE LOG

Borehole No.
9
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY

Method: SPIRAL AUGER
JK350

R.L. Surface: ≈ 52.4m

Date: 10/4/18

Datum: AHD

Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES				Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
	ES	U50	DB	DS									
DRY ON COMPL -ETION AND AFTER 7 DAYS	■					0		-	ASPHALTIC CONCRETE: 40mm.t.	M			APPEARS WELL COMPACTED
									FILL: Gravelly sand, fine to coarse grained, grey and brown, fine to coarse grained igneous.				
	■				N > 22 5,22/50mm				FILL: Sand, fine to coarse grained, orange brown and grey, with fine to coarse grained sandstone gravel.				
	■					1		-	Extremely Weathered sandstone: Silty SAND, fine to coarse grained, orange brown.	XW	D		VERY LOW 'TC' BIT RESISTANCE
				■	N = 33 9,13,20								
				■		2			SANDSTONE: fine to medium grained, orange brown and grey.	MW	L-M		LOW TO MODERATE 'TC' BIT RESISTANCE
				■							M-H		MODERATE TO HIGH RESISTANCE
						3 4 5 6 7			END OF BOREHOLE AT 2.70m				Groundwater monitoring well installed to 2.70m. Class 18 machine slotted 50mm dia. PVC standpipe 1.70m to 2.70m. Casing 0.0m to 1.70m. 2mm sand filter pack 1.5m to 2. 70m. Bentonite seal 0.0m to 1. 5m. Completed with a concreted gatic cover

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BOREHOLE LOG

Borehole No.
10
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY

Date: 10/4/18

Method: SPIRAL AUGER
JK350

Logged/Checked by: T.C./W.T.

R.L. Surface: ≈ 55.2m

Datum: AHD

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■					0		-	ASPHATIC CONCRETE: 30mm.t.	M			APPEARS WELL COMPACTED
							▨		FILL: Gravelly sand, fine to coarse grained, grey and brown, fine to coarse grained igneous gravel.				
	■			■	N = 18 6,8,10		▨		FILL: Silty sand, fine to medium grained, dark grey.				
						1	▨						
								-	Extremely Weathered sandstone: Silty SAND, fine to coarse grained, orange brown, with sub rounded quartz inclusions.	XW	D		
				■					SANDSTONE: fine to medium grained, orange brown.	MW	M-H		MODERATE TO HIGH 'TC' BIT RESISTANCE
						2							HIGH RESISTANCE
									END OF BOREHOLE AT 2.50m				'TC' BIT REFUSAL
						3							
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
11
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 10/4/18
Method: SPIRAL AUGER JK350
Logged/Checked by: T.C./W.T.
R.L. Surface: ≈ 57.5m
Datum: AHD

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION						0		-	ASPHALTIC CONCRETE: 40mm.t.				APPEARS POORLY COMPACTED
									FILL: Gravelly sand, fine to coarse grained, dark grey.	M			
					N = 1 0,1,0				FILL: Sand, fine to coarse grained, orange brown and grey, with clay and fine to coarse grained sandstone gravel.	M			
						1							
					N = 11 7,3,8			CL-CH	Silty CLAY: medium plasticity, grey.	W≈PL	VSt	250 350	RESIDUAL
						2							
								-	SANDSTONE: fine to medium grained, grey and orange brown.	MW	M-H		MODERATE TO HIGH 'TC' BIT RESISTANCE
						3							
									END OF BOREHOLE AT 3.50m				'TC' BIT REFUSAL
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
12Rev1
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 10/4/18
Method: SPIRAL AUGER JK350
Logged/Checked by: T.C./W.T.
R.L. Surface: ≈ 51.2m
Datum: AHD

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■					0		-	ASPHALTIC CONCRETE: 40mm.t.	M			
									FILL: Silty sand, fine to medium grained, grey with fine to medium grained igneous gravel.				APPEARS WELL COMPACTED
	■			■	N = 37 13,17,20				FILL: Silty sand, fine to coarse grained, brown and grey, with fine to coarse grained sandstone gravel.				
						1							
	■			■	N >15 5,15/50mm								
						2							
					N = 5 2,2,3	3			FILL: Sand, fine to coarse grained, orange brown.	M			
								-	SANDSTONE: fine to coarse grained, orange brown, possible bedrock or floater.	MW	L-M		HIGH 'TC' BIT RESISTANCE
						4			END OF BOREHOLE AT 4.0m				POSSIBLE FLOATER DUE TO OBJECTS IN THE FILL THE BOREHOLE COULD NOT BE KEPT STRAIGHT WHILST AUGERING. BOREHOLE TERMINATED AT 4.0m
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
13
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 10/4/18
Method: SPIRAL AUGER
JK350
Logged/Checked by: T.C./W.T.
R.L. Surface: ≈ 50.8m
Datum: AHD

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION AND AFTER 7 DAYS	■					0	■	-	ASPHALTIC CONCRETE: 40mm.t.	M			
							▨		FILL: Gravelly sand, fine to coarse grained, grey, fine to coarse grained igneous gravel.				
	■			■	N = 12 5,5,7	1	▨		FILL: Silty sand, fine to coarse grained, orange brown, with fine to coarse grained sandstone gravel.				APPEARS MODERATELY COMPACTED
	■			■	N = 6 2,3,3	2	▨		FILL: Gravelly sand, fine to coarse grained, orange brown, fine to coarse grained sandstone gravel.				APPEARS POORLY COMPACTED
				■			⁝	-	SANDSTONE: fine to coarse grained, orange brown.	MW	M-H		LOW 'TC' BIT RESISTANCE
						3 4 5 6 7			END OF BOREHOLE AT 2.70m				'TC' BIT REFUSAL Groundwater monitoring well installed to 2.70m. Class 18 machine slotted 50mm dia. PVC standpipe 1.70m to 2.70m. Casing 0.0m to 1.70m. 2mm sand filter pack 1.5m to 2. 70m. Bentonite seal 0.0m to 1.5m. Completed with a concreted gatic cover

BOREHOLE LOG

Borehole No.
14
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY

Date: 10/4/18

Method: SPIRAL AUGER
JK350

R.L. Surface: ≈ 51.3m

Datum: AHD

Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■					0	■	-	ASPHALTIC CONCRETE: 40mm.t.				APPEARS POORLY COMPACTED
							▨		FILL: Gravelly sand, fine to coarse grained, dark brown and orange brown, fine to coarse grained sandstone gravel.	M			
	■				N = 7 3,4,3		▨		FILL: Silty sand, fine to coarse grained, yellow brown.	M			
						1							
	■				N = 6 2,3,3		▨		FILL: Sand, fine to coarse grained, orange brown, red brown and grey, with brick fragments.				
						2							
				■		3	⁞	-	SANDSTONE: fine to medium grained, grey.	SW	M-H		MODERATE TO HIGH 'TC' BIT RESISTANCE
									END OF BOREHOLE AT 3.40m				'TC'BIT REFUSAL
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
15
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Method: SPIRAL AUGER
JK350
R.L. Surface: ≈ 51.9m
Date: 10/4/18
Datum: AHD
Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■					0	▨		FILL: Sandy gravel, fine to coarse grained, grey brown igneous and sandstone.	M			
							▨		FILL: Sand, fine to coarse grained, grey, trace of coarse grained sandstone gravel.	M			APPEARS MODERATELY COMPACTED
	■				N = 10 8,6,4		▨						
						1	▨						
				■			⋮	-	SANDSTONE: fine to coarse grained, grey and orange brown.	DW	M-H		HIGH 'TC' BIT RESISTANCE
				■		2	⋮						
									END OF BOREHOLE AT 2.50m				'TC' BIT REFUSAL
						3							
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
16
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY

Date: 10/4/18

Method: SPIRAL AUGER
JK350

R.L. Surface: ≈ 51.2m

Datum: AHD

Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES				Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
	ES	U50	DB	DS									
DRY ON COMPL -ETION	■					0	▨		FILL: Silty sand, fine to coarse grained, brown, trace of fine to coarse grained sandstone gravel.	M			
	■			■	N = 13 6,7,6	1	▨						APPEARS MODERATELY TO WELL COMPACTED
							▨		FILL: Gravelly sand, fine to coarse grained, brown and grey, fine to coarse grained sandstone gravel.				
	■			■	N = 11 6,6,5	2	▨						
						3	⁝	-	SANDSTONE: fine to coarse grained, orange brown and grey.	SW	M-H		HIGH 'TC' BIT RESISTANCE
						4 5 6 7			END OF BOREHOLE AT 3.20m				'TC' BIT REFUSAL

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BOREHOLE LOG

Borehole No.
17
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 11/4/18
Method: SPIRAL AUGER JK350
R.L. Surface: ≈ 52.1m
Datum: AHD
Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■					0	■	-	ASPHALTIC CONCRETE: 40mm.t.	M			APPEARS MODERATELY TO WELL COMPACTED
							▨		FILL: Silty gravel, fine grained, dark grey, trace of silt and igneous.				
	■			■	N = 14 3,4,10	1	▨		FILL: Clayey sand, fine to coarse grained, grey and brown, trace fine to coarse grained sandstone gravel.				
				■			⁝	-	SANDSTONE: fine to coarse grained, orange brown and grey.	DW	M-H		MODERATE 'TC' BIT RESISTANCE
						2			END OF BOREHOLE AT 1.80m				'TC' BIT REFUSAL
						3							
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
18
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY

Date: 11/4/18

Method: SPIRAL AUGER
JK350

R.L. Surface: ≈ 53.0m

Datum: AHD

Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION						0			CONCRETE: 100mm.t.				
	■						▨	-	FILL: Silty sand, fine to coarse grained, brown, trace fine to coarse grained igneous gravel.	M			
	■				N = 7 11,6,1	1	▨		FILL: Silty sand, fine to coarse grained, grey and brown, trace of fine to coarse grained sandstone cobble.				APPEARS POORLY COMPACTED
						2		-	SANDSTONE: fine to medium grained, grey and orange brown.	DW	M-H		MODERATE TO HIGH 'TC' BIT RESISTANCE
						3 4 5 6 7			END OF BOREHOLE AT 2.20m				'TC'BIT REFUSAL

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BOREHOLE LOG

Borehole No.
19
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 11/4/18

Method: SPIRAL AUGER
JK350

R.L. Surface: ≈ 54.0m
Datum: AHD

Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON 17/4/18						0			CONCRETE: 110mm.t.				NO OBSERVED REINFORCEMENT
	■							-	FILL: Silty sand, fine to coarse grained, brown and grey, with fine to coarse grained sandstone gravel.	M			APPEARS POORLY COMPACTED
	■			■	N = 4 2,2,2								
						1							
▼	■				N >10 2,10/50mm				FILL: Clayey sand, fine to coarse grained, dark grey.	W			
						2							
								-	SANDSTONE: fine to coarse grained, grey and orange brown.	DW	M-H		MODERATE TO HIGH RESISTANCE
						3							
									END OF BOREHOLE AT 3.1m				'TC'BIT REFUSAL Groundwater monitoring well installed to 3.20m. Class 18 machine slotted 50mm dia. PVC standpipe 2.20m to 3.20m. Casing 0.0m to 2.20m. 2mm sand filter pack 2.0m to 3.20m. Bentonite seal 0.0m to 2.0m. Completed with a concreted gatic cover
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
20
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Method: SPIRAL AUGER JK350
R.L. Surface: ≈ 55.9m
Date: 11/4/18
Datum: AHD
Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION						0	■		ASPHALTIC CONCRETE: 40mm.t.				
							▨	-	FILL: Gravelly sand, fine to medium grained, grey and brown, fine to medium grained sandstone.	M			
				■			⁝	-	SANDSTONE: fine to medium grained, orange and grey.	DW	L-M		LOW TO MODERATE 'TC' BIT RESISTANCE
						1	⁝						
				■			⁝				M-H		MODERATE TO HIGH RESISTANCE
									END OF BOREHOLE AT 1.50m				'TC' BIT REFUSAL
						2							
						3							
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
21
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 11/4/18
Method: SPIRAL AUGER
JK350
Logged/Checked by: T.C./W.T.
R.L. Surface: ≈ 56.8m
Datum: AHD

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■					0			ASPHALTIC CONCRETE: 50mm.t.				
								-	FILL: Sandy gravel, fine to medium grained, grey igneous, trace of silt.	M			
	■			■	N = 6 3,2,4	1		CL-CH	Silty CLAY: medium plasticity, grey.	W≈PL	VSt		RESIDUAL
				■				-	SANDSTONE: fine to coarse grained, orange brown and grey.	DW	M-H		MODERATE TO HIGH 'TC' BIT RESISTANCE
						2			END OF BOREHOLE AT 1.70m				'TC' BIT REFUSAL

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BOREHOLE LOG

Borehole No.
22
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 11/4/18
Method: SPIRAL AUGER
JK350
Logged/Checked by: T.C./W.T.
R.L. Surface: ≈ 52.8m
Datum: AHD

Groundwater Record	SAMPLES				Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
	ES	U50	DB	DS									
DRY ON COMPL -ETION	■					0			ASPHALTIC CONCRETE: 50mm.t.				
								-	FILL: Sandy gravel, fine to medium grained, dark grey igneous trace of silt.	M			
	■			■				-	SANDSTONE: fine to coarse grained, orange brown and grey.	DW	L-M		LOW TO MODERATE 'TC' BIT RESISTANCE
				■		1					M		MODERATE RESISTANCE
											H		
									END OF BOREHOLE AT 1.50m				'TC' BIT REFUSAL
						2							
						3							
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
23
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Method: SPIRAL AUGER
JK350
R.L. Surface: ≈ 53.9m

Date: 11/4/18
Datum: AHD

Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■					0	▬	-	ASPHALTIC CONCRETE: 30mm.t.	M			APPEARS MODERATELY COMPACTED
	■				N = 11 20,11,0		▨		FILL: Silty sand, fine to medium grained, brown, with fine to medium grained igneous gravel.				
						1	▨		FILL: Silty sand, fine to coarse grained, orange brown and brown and dark grey, with fine to coarse grained sandstone gravel.				
	■			■	N > 10 10,10/ 50mm		▨						
				■		2	⁝	-	SANDSTONE: fine to coarse grained, grey and orange brown.	DW	M-H		MODERATE TO HIGH 'TC'BIT RESISTANCE
									END OF BOREHOLE AT 2.10m				'TC' BIT REFUSAL
						3							
						4							
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
24
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY

Method: SPIRAL AUGER
JK350

R.L. Surface: ≈ 53.3m

Date: 11/4/18

Datum: AHD

Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■					0		-	ASPHALTIC CONCRETE: 20mm.t.				
									FILL: Sandy gravel, fine to medium grained, grey, trace of igneous and clay.	M			
				■ ■				-	SANDSTONE: fine to medium grained, orange brown.	DW	M		MODERATE TO HIGH 'TC'BIT RESISTANCE
						1			END OF BOREHOLE AT 1.0m				'TC'BIT REFUSAL
						2							
						3							
						4							
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
25
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 11/4/18
Method: SPIRAL AUGER JK350
R.L. Surface: ≈ 50.1m
Datum: AHD
Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■					0			FILL: Sandy gravel, fine to coarse grained, grey and brown igneous.	M			
	■				N = 9 3,4,5				FILL: Sandy gravel, fine to coarse grained, orange brown, sandstone with sandstone cobbles.	M			APPEARS MODERATELY COMPACTED
	■			■		1		SM	SILTY SAND: fine to medium grained, dark grey.	M	L		AEOLIAN
				■		2		-	SANDSTONE: fine to medium grained, grey and orange brown.	DW	M-H		HIGH 'TC'BIT RESISTANCE
						3 4 5 6 7			END OF BOREHOLE AT 2.2m				'TC' BIT REFUSAL

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BOREHOLE LOG

Borehole No.
26
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 12/4/18
Method: SPIRAL AUGER
JK305
R.L. Surface: ≈ 61.5m
Datum: AHD
Logged/Checked by: J.B.J./W.T.

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■			■		0	▨		FILL: Silty sand, fine to medium grained, dark brown, trace sandstone gravel and root fibres.	M			GRASS COVER
	■						⋮	-	SANDSTONE: fine to medium grained, orange brown.	DW	L		LOW 'TC' BIT RESISTANCE
				■		1	⋮						
							⋮				L-M		LOW TO MODERATE RESISTANCE
				■			⋮				H		HIGH RESISTANCE
						2			END OF BOREHOLE AT 2.0m				'TC' BIT REFUSAL
						3							
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
27
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 12/4/18
Method: SPIRAL AUGER JK305
R.L. Surface: ≈ 61.7m
Datum: AHD
Logged/Checked by: J.B.J./W.T.

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	●					0			FILL: Silty sand, fine to medium grained, dark brown, trace roots and root fibres.	M			GRASS COVER
	●			●	N = 7 4,3,4	1		CL	Sandy CLAY: low plasticity, grey and orange brown banding.	W≈PL	St	150 150 100	RESIDUAL
				●		2		-	SANDSTONE: fine to coarse grained, light grey.	DW	VL		VERY LOW 'TC' BIT RESISTANCE
	●								as above, but with coarse grained quartz.		L-M M-H		LOW RESISTANCE WITH MEDIUM BANDS HIGH RESISTANCE
						3 4 5 6 7			END OF BOREHOLE AT 2.5m				'TC' BIT REFUSAL

BOREHOLE LOG

Borehole No.
28
1/2

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 12/4/18
Method: SPIRAL AUGER
JK305
R.L. Surface: ≈ 51.1m
Datum: AHD
Logged/Checked by: J.B.J./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
	■					0	▨		FILL: Silty sand, fine to medium grained, yellow orange, trace of roots and fibres.	M			GRASS COVER
	■			■	N = 6 2,3,3		▨						
						1	▨						APPEARS POORLY COMPACTED
	■			■	N = 1 1,0,1		▨						
						2	▨						
	■			■	N = 9 4,4,5	3	▨		as above, but with fragments of glass, brick and sandstone cobbles.				
⊂						4	▨						NOTE: SPT COULD BE SEATED DUE TO BOREHOLE COLLAPSE
	■						▨						
						5	▨						
						6	▨						NOTE:SPT COULD BE SEATED DUE TO BOREHOLE COLLAPSE
						7	▨						

BOREHOLE LOG

Borehole No.
28
2/2

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Method: SPIRAL AUGER JK305
R.L. Surface: ≈ 51.1m
Date: 12/4/18
Datum: AHD
Logged/Checked by: J.B.J./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
◀	■						▨		FILL: Clayey sand, dark brown and red brown, trace glass and brick.	W			
									END OF BOREHOLE AT 7.3m				'TC' BIT REFUSAL POSSIBLE SANDSTONE BEDROCK
						8							
						9							
						10							
						11							
						12							
						13							
						14							

BOREHOLE LOG

Borehole No.
29
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY

Method: SPIRAL AUGER
JK305

R.L. Surface: ≈ 55.7m

Date: 12/4/18

Datum: AHD

Logged/Checked by: J.B.J./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION						0			CONCRETE: 100mm.t.				10mm.t DIAMETER REINFORCEMENT 70mm.t TOP COVER
	■ ■			■	N >11 5,11/50mm			-	FILL: Silty sand, fine to medium grained, dark brown and red brown, trace sandstone cobbles.	M			
				■				-	SANDSTONE: fine to medium grained, orange grey.	DW	H		HIGH 'TC' BIT RESISTANCE
						1			END OF BOREHOLE AT 1.0m				'TC' BIT REFUSAL
						2							
						3							
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
30
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 12/4/18
Method: SPIRAL AUGER
JK305
R.L. Surface: ≈ 53.3m
Datum: AHD
Logged/Checked by: J.B.J./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION	■					0			CONCRETE: 140mm.t.				NO OBSERVED REINFORCEMENT
								-	FILL: Silty sand, fine to coarse grained, dark brown, trace sandstone.	M			SPT COULD NOT BE SEATED DUE TO FLOATER IN FILL
						1			FILL: Silty sand, fine to coarse grained, orange brown.				
	■			■	N = 12 9,5,7			-	Extremely Weathered sandstone: Sandy CLAY, medium plasticity, grey.	XW	Hd		
						2							
				■					SANDSTONE: fine to medium grained, grey.	DW	L		LOW 'TC' BIT RESISTANCE
				■		3					H		HIGH RESISTANCE
									END OF BOREHOLE AT 3.2m				'TC'BIT REFUSAL
						4							
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
31
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 12/4/18
Method: SPIRAL AUGER JK305
R.L. Surface: ≈ 56.8m
Datum: AHD
Logged/Checked by: J.B.J./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION	■					0		-	ASPHALTIC CONCRETE: 40mm.t.				APPEARS WELL COMPACTED
									FILL: Silty sand, fine to medium grained, brown.	M			
	■				N = 22 6,8,14								
						1		-	Extremely Weathered sandstone: Silty SAND, fine to coarse grained, orange brown.	XW	MD		
	■				N >14 7,14/50mm								
				■		2			SANDSTONE: fine to coarse grained, light grey orange, iron indurated bands.	DW	H		HIGH 'TC' BIT RESISTANCE
									END OF BOREHOLE AT 2.2m				'TC'BIT REFUSAL
						3							
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
32
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 12/4/18
Method: SPIRAL AUGER JK305
R.L. Surface: ≈ 57.7m
Datum: AHD
Logged/Checked by: J.B.J./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■					0	▨		FILL: Silty sand, fine to medium grained, dark grey, glass and tile fragments present.	M			GRASS COVER
						1	▨		FILL: Sandy gravel, fine to medium grained, red brown, sandstone trace of brick fragments.				
				■	N = 18 16,8,10	2	☰	-	Extremely Weathered claystone: Silty CLAY, medium plasticity, grey, trace fine grained sandstone.	XW	Hd		LOW 'TC' BIT RESISTANCE
				■			⁙	-	SANDSTONE: fine to coarse grained, orange brown grey.	DW	L		LOW RESISTANCE
						3 4 5 6 7			END OF BOREHOLE AT 2.7m				'TC' BIT REFUSAL

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BOREHOLE LOG

Borehole No.
33
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY

Date: 13/4/18

Method: SPIRAL AUGER
JK205

R.L. Surface: ≈ 65.4m

Datum: AHD

Logged/Checked by: J.B.J./W.T.

Groundwater Record	SAMPLES				Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
	ES	U50	DB	DS									
DRY ON COMPL -ETION	■					0		-	ASPHALTIC CONCRETE: 40mm.t FILL: Silty sand, fine to medium grained, dark brown, igneous gravel.	M			
				■				-	SANDSTONE: fine to coarse grained, orange grey, grey.	DW	M-H		MODERATE TO HIGH 'TC' BIT RESISTANCE
											L		LOW RESISTANCE
				■		1			as above, but light grey yellow.		M		MODERATE RESISTANCE
				■							H		HIGH RESISTANCE
						2			END OF BOREHOLE AT 1.7m				'TC' BIT REFUSAL
						3							
						4							
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
34
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 13/4/18
Method: SPIRAL AUGER
JK205
Logged/Checked by: J.B.J./W.T.
R.L. Surface: ≈ 65.1m
Datum: AHD

Groundwater Record	SAMPLES				Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
	ES	U50	DB	DS									
DRY ON COMPLETION	■					0		-	ASPHALTIC CONCRETE: 30mm.t FILL: Silty sand, fine to coarse grained, dark brown, with igneous gravel.	M			
				■				-	SANDSTONE: fine to coarse grained, orange grey.	DW	L		LOW 'TC' BIT RESISTANCE
											H		HIGH RESISTANCE
									END OF BOREHOLE AT 0.7m				'TC' BIT REFUSAL
						1							
						2							
						3							
						4							
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
35
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY

Date: 13/4/18

Method: SPIRAL AUGER
JK205

R.L. Surface: ≈ 63.3m

Datum: AHD

Logged/Checked by: J.B.J./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION AND AFTER 4 DAYS	■					0			FILL: Silty sand, fine to medium grained, dark brown, with sandstone gravel.	M			GRASS COVER
								-	Extremely Weathered sandstone: Clayey SAND, fine to coarse grained, orange grey, trace root fibres.	XW	D		
	■			■	N = 15 9,7,8								
						1							
				■					SANDSTONE: fine to coarse grained, orange brown and light grey.	DW	M-H		MODERATE TO HIGH 'TC' BIT RESISTANCE
						2							
									END OF BOREHOLE AT 2.2m				'TC' BIT REFUSAL Groundwater monitoring well installed to 2.2m. Class 18 machine slotted PVC standpipe 0.12m to 2.2m. Casing 0m to 0. 12m. 2mm sand filter pack 2.2m to 0.12m. Bentonite seal 0.0m to 0.12m. Completed with a concreted gatic cover
						3							
						4							
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
36
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY

Date: 13/4/18

Method: SPIRAL AUGER
JK205

R.L. Surface: ≈ 54.7m

Datum: AHD

Logged/Checked by: J.B.J./W.T.

Groundwater Record	SAMPLES				Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
	ES	U50	DB	DS									
DRY ON COMPL -ETION	■					0	▨		FILL: Silty sand, fine to medium grained, dark brown, with root fibres.	M			GRASS COVER
	■			■	N >3 3,3/50mm		▨		as above, but light grey.				
				■		1	⁙	-	SANDSTONE: fine to coarse grained, orange and light grey.	DW	M-H		MODERATE TO HIGH 'TC' BIT RESISTANCE
						2 3 4 5 6 7			END OF BOREHOLE AT 1.4m				'TC' BIT REFUSAL

BOREHOLE LOG

Borehole No.
37
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY

Date: 13/4/18

Method: SPIRAL AUGER
JK205

R.L. Surface: ≈ 57.5m

Datum: AHD

Logged/Checked by: J.B.J./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■					0	▨		FILL: Silty sand, fine to medium grained, dark grey, trace roots and fibres.	M			GRASS COVER
	■			■	N >13 3,4,9/50mm REFUSAL		▨		FILL: Gravelly sand, fine to medium grained, light grey.				APPEARS MODERATELY COMPACTED
				■		1	⁞	-	SANDSTONE: fine to coarse grained, orange and light grey, quartz gravel, rounded inclusions.	DW	M-H		MODERATE TO HIGH 'TC' BIT RESISTANCE
						2			END OF BOREHOLE AT 2.0m				'TC' BIT REFUSAL
						3							
						4							
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
38
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Method: SPIRAL AUGER
JK205
R.L. Surface: ≈ 57.8m
Date: 13/4/18
Datum: AHD
Logged/Checked by: J.B.J./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■		■			0			FILL: Silty sand, fine to medium grained, light grey brown, trace grass roots and fibres, brick and cobble fragments.	M			GRASS COVER
	■			■	N = 11 3,5,6			-	Extremely Weathered sandstone: Sandy CLAY, medium plasticity, light grey brown.	XW	St/ VSt	150 150 200	
				■		1			SANDSTONE: fine to coarse grained, orange grey.	DW	M-H		MODERATE TO HIGH 'TC' BIT RESISTANCE
						2			END OF BOREHOLE AT 2.0m				'TC'BIT REFUSAL
						3							
						4							
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
39
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Method: SPIRAL AUGER
JK205
R.L. Surface: ≈ 55.0m
Date: 13/4/18
Datum: AHD
Logged/Checked by: J.B.J./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■					0	▨	-	ASPHALTIC CONCRETE: 40mm.t	M			
							▨		FILL: Gravelly sand, fine to coarse grained, brown and light grey, fine to coarse grained sandstone gravel, trace of brick fragments.				
	■			■	N = 12 8,8,4		▨						
						1	▨						
	■				N = 11 6,6,5		▨						APPEARS MODERATELY COMPACTED
						2	▨						
							▨		FILL: Sand, fine to medium grained, trace igneous gravel.				
	■			■	N = 8 5,5,3	3	▨						
						4	▨						
						5	▨						
				■			⁙	-	SANDSTONE: fine to coarse grained, orange light grey.	MW	M-H		MODERATE TO HIGH 'TC' BIT RESISTANCE
									END OF BOREHOLE AT 5.6m				'TC' BIT REFUSAL
						6							
						7							

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BOREHOLE LOG

Borehole No.
40
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Method: SPIRAL AUGER JK205
R.L. Surface: ≈ 55.10,
Date: 13/4/18
Datum: AHD
Logged/Checked by: J.B.J./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■					0	■	-	ASPHALIC CONCRETE: 40mm.t	M			
							▨		FILL: Silty sand, fine to medium grained, light orange brown, with fine to coarse grained igneous gravel.				
	■			■	N = 9 4,3,6		▨		FILL: Gravelly sand, fine to coarse grained, light grey, fine to coarse grained sandstone gravel.				APPEARS MODERATELY COMPACTED
						1	▨						
	■			■	N = 13 2,4,9		▨						
						2	▨						
							⋮	-	Extremely Weathered sandstone: Gravelly SAND, fine to coarse grained, light grey orange brown.	XW	D		VERY LOW 'TG BIT RESISTANCE
				■	N = 16 8,7,9	3	⋮						
				■		4	⋮		SANDSTONE:fine to coarse grained, grey and orange brown.	MW	M-H		MODERATE TO HIGH 'TC' BIT RESISTANCE
									END OF BOREHOLE AT 4.4m				'TC' BIT REFUSAL
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
41
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Method: SPIRAL AUGER JK205
R.L. Surface: ≈ 53.0m
Date: 13/4/18
Datum: AHD
Logged/Checked by: J.B.J./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■					0	■		ASPHALTIC CONCRETE: 40mm.t				
							▨	-	FILL: Silty sand, fine to medium grained, light grey, fine to medium grained sandstone gravel and brick fragments.	M			
				■			⁞	-	SANDSTONE: fine to coarse grained, light grey.	DW	M-H		HIGH 'TC'BIT RESISTANCE
						1			END OF BOREHOLE AT 0.8m				'TC' BIT REFUSALON SANDSTONE BOULDER
						2							
						3							
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
42
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 16/4/18
Method: SPIRAL AUGER JK205
Logged/Checked by: T.C./W.T.
R.L. Surface: ≈ 46.3m
Datum: AHD

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■					0	▨		FILL: Silty sand, fine to medium grained, dark brown, with fine to coarse grained sandstone gravel trace of roots.	M			APPEARS POORLY COMPACTED
	■				N = 2 0,1,1		▨		FILL: Sandy gravel, fine to coarse grained, orange brown, sandstone.				
						1	▨		FILL: Clayey sand, fine to coarse grained, dark grey and orange brown.				
				■	N = 1 1,0,1		▨						
						2	⁝	-	SANDSTONE: fine to medium grained, grey.	MW	M-H		HIGH 'TC' BIT RESISTANCE
									END OF BOREHOLE AT 2.20m				'TC' BIT REFUSAL
						3							
						4							
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
43
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY

Method: SPIRAL AUGER
JK205

R.L. Surface: ≈ 45.8m

Date: 16/4/18

Datum: AHD

Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■					0			FILL: Silty sand, fine to medium grained, dark brown, trace root fibres.	M			
				■				-	SANDSTONE: fine to medium grained, grey.	MW	M-H		MODERATE TO HIGH 'TC' BIT RESISTANCE
									END OF BOREHOLE AT 0.8m				'TC' BIT REFUSAL
						1							
						2							
						3							
						4							
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
44
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 16/4/18
Method: SPIRAL AUGER JK205
R.L. Surface: ≈ 51.7m
Datum: AHD
Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION AND AFTER 1 DAY	■ ■			■	N >15 12,15/ 50mm	0 1	▨	-	ASPHALTIC CONCRETE: 40mm.t FILL: Gravelly sand, fine to coarse grained, orange brown and grey, fine to coarse grained sandstone gravel, trace of silt.	M			APPEARS WELL COMPACTED
				■ ■		2	⁚	-	SANDSTONE: fine to medium grained, grey.	MW	M-H		HIGH 'TC' BIT RESISTANCE
						3 4 5 6 7			END OF BOREHOLE AT 2.2m				'TC' BIT REFUSAL Monitoring well installed to 2.20m. Class 18 machine slotted PVC standpipe 1.20m to 2.20m. Casing 0.0m to 1.20m. 2mm sand filter pack 1.0m to 2. 20m. Bentonite seal 0.0m to 1. 0m. Completed with a concreted gatic cover

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BOREHOLE LOG

Borehole No.
45
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY

Method: SPIRAL AUGER
JK205

R.L. Surface: ≈ 53.5m

Date: 16/4/18

Datum: AHD

Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION						0		-	ASPHALTIC CONCRETE: 40mm.t	M			APPEARS MODERATELY COMPACTED
									FILL: Gravelly sand, fine to coarse grained, brown, fine to coarse grained sandstone gravel.				
					N = 19 9,8,11				FILL: Silty sand, fine to coarse grained, grey, trace coarse grained sandstone gravel.				
						1							APPEARS WELL COMPACTED
					N > 10 6,10/50mm								
						2							
					N > 10 10/50mm	3							
						4		-	SANDSTONE: fine to coarse grained, grey.	MW	M-H		HIGH 'TC' BIT RESISTANCE
						5			END OF BOREHOLE AT 5.0m				'TC' BIT REFUSAL
						6							
						7							

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BOREHOLE LOG

Borehole No.
46
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Method: SPIRAL AUGER
JK205
R.L. Surface: ≈ 53.4m

Date: 16/4/18
Datum: AHD

Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES				Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
	ES	U50	DB	DS									
DRY ON COMPL -ETION	■					0		-	ASPHALTIC CONCRETE: 40mm.t				
									FILL: Silty sand, fine to medium grained, brown and grey, with fine to medium grained sandstone gravel.	M			
	■			■	N = 20 9,12,8								
						1							APPEARS WELL COMPACTED
				■	N > 10 3,10/50mm								
						2							
				■				-	SANDSTONE: fine to medium grained, grey.	MW	M-H		HIGH 'TC' BIT RESISTANCE
						3			END OF BOREHOLE AT 3.0m				'TC' BIT REFUSAL
						4							
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
47
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY

Method: SPIRAL AUGER
JK205

R.L. Surface: ≈ 53.3m

Date: 16/4/18

Datum: AHD

Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES				Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
	ES	U50	DB	DS									
DRY ON COMPL -ETION						0	▨		FILL: Silty sand, fine to medium grained, dark grey, trace of roots.	M			GRASS COVER
	■				N > 10 4,10/50mm		▨		FILL: Sandy gravel, fine to coarse grained, orange brown and yellow brown.				APPEARS WELL COMPACTED
		■				1	⁙	-	Extremely Weathered sandstone: Silty SAND, fine to coarse grained, grey with fine to coarse grained iron indurated bands.	XW	(D)		VERY LOW TO LOW 'TC' BIT RESISTANCE
				■			⁙		SANDSTONE: fine to coarse grained, grey.	MW	M-H		HIGH 'TC' BIT RESISTANCE
						2			END OF BOREHOLE AT 2.0m				'TC' BIT REFUSAL
						3							
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
48
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY

Method: SPIRAL AUGER
JK205

R.L. Surface: ≈ 52.9m

Date: 16/4/18

Datum: AHD

Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES				Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
	ES	U50	DB	DS									
						0	■	-	ASPHALTIC CONCRETE: 40mm.t	M			
							▨		FILL: Gravelly sand, fine to medium grained, dark grey, fine to medium grained igneous gravel, trace of silt and slag.				
	■			■	N = 5 3,2,3		▨		FILL: Silty sand, fine to coarse grained, dark grey, trace of coarse grained sandstone gravel.				APPEARS POORLY COMPACTED
						1	▨						
	■			■	N = 3 1,1,2		▨		as above, but dark grey and orange brown.				
						2	▨						
▼						3	⁚	-	SANDSTONE: fine to medium grained, grey and orange brown.	MW	M-H		HIGH 'TC' BIT RESISTANCE
					BOUNCE				END OF BOREHOLE AT 3.50m				'TC' BIT REFUSAL
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
49
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 17/4/18
Method: SPIRAL AUGER JK305
R.L. Surface: ≈ 64.7m
Datum: AHD
Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■					0			ASPHALTIC CONCRETE: 50mm.t				
								-	FILL: Silty sand, fine to medium grained, dark grey, trace of igneous gravel.	M			
				■ ■		1		-	SANDSTONE: fine to medium grained, grey and orange brown.	MW	M-H		HIGH 'TC' BIT RESISTANCE
						2 3 4 5 6 7			END OF BOREHOLE AT 1.50m				'TC' BIT REFUSAL

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BOREHOLE LOG

Borehole No.
50
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 17/4/18
Method: SPIRAL AUGER
JK305
Logged/Checked by: T.C./W.T.
R.L. Surface: ≈ 65.1m
Datum: AHD

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■					0	■		ASPHALTIC CONCRETE: 50mm.t				
							▩	-	FILL: Silty sand, fine to coarse grained, brown, with fine to medium grained, sandstone and igneous gravel.	M			
							⁝	-	SANDSTONE: fine to medium grained, grey and orange brown.	MW	M-H		MODERATE TO HIGH 'TC'BIT RESISTANCE
				■		1	⁝						
				■			⁝						HIGH RESISTANCE
						2			END OF BOREHOLE AT 2.0m				'TC' BIT REFUSAL
						3							
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
51
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY

Method: SPIRAL AUGER
JK305

R.L. Surface: ≈ 65.6m

Date: 17/4/18

Datum: AHD

Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■					0	■		ASPHALTIC CONCRETE: 50mm.t				
							▨	-	FILL: Silty sand, fine to coarse grained, brown, trace fine to medium grained sandstone gravel.	M			
				■			⁘	-	SANDSTONE: fine to medium grained, grey and orange brown.	MW	M-H		HIGH 'TC' BIT RESISTANCE
						1			END OF BOREHOLE AT 1.0m				'TC' BIT REFUSAL
						2							
						3							
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
52
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 17/4/18
Method: SPIRAL AUGER
JK305
R.L. Surface: ≈ 60.6m
Datum: AHD
Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■					0	■	-	ASPHALTIC CONCRETE: 50mm.t				
							⊠		FILL: Silty sand, fine to coarse grained, brown, trace fine to coarse grained sandstone gravel.	M			
				■			⁞	-	SANDSTONE: fine to coarse grained, grey and orange brown.	MW	M-H		MODERATE TO HIGH 'TC' BIT RESISTANCE
						1	⁞						
							⁞				L		LOW RESISTANCE
				■			⁞				H		HIGH RESISTANCE
						2	⁞						
									END OF BOREHOLE AT 2.30m				'TC' BIT REFUSAL
						3							
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
53
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Method: SPIRAL AUGER
JK305
R.L. Surface: ≈ 59.8m

Date: 17/4/18
Datum: AHD

Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■					0		-	ASPHALTIC CONCRETE: 50mm.t				
								-	CONCRETE: 100mm.t				
									FILL: Silty sand, fine to coarse grained, brown, with sandstone cobbles.	M			SPT NOT ATTEMPTED BECAUSE OF HIGH 'TC' BIT RESISTANCE
				■		1		-	SANDSTONE: fine to coarse grained, orange brown.	MW	M-H		MODERATE TO HIGH 'TC' BIT RESISTANCE
									END OF BOREHOLE AT 1.5m				'TC' BIT REFUSAL
						2							
						3							
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
54
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Date: 17/4/18
Method: SPIRAL AUGER
JK305
R.L. Surface: ≈ 59.6m
Datum: AHD
Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES				Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
	ES	U50	DB	DS									
DRY ON COMPL -ETION	■					0		-	ASPHALTIC CONCRETE: 50mm.t FILL: Silty sand, fine to coarse grained, brown, with fine to medium grained sandstone gravel.	M			
				■				-	SANDSTONE: fine to coarse grained, grey and orange brown.	MW	M-H		MODERATE 'TC' BIT RESISTANCE
						1							
				■									HIGH RESISTANCE
									END OF BOREHOLE AT 1.7m				'TC' BIT REFUSAL
						2							
						3							
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No.
55
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY

Method: HAND AUGER

R.L. Surface: ≈ 54.1m

Date: 18/4/18

Datum: AHD

Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES				Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
	ES	U50	DB	DS									
DRY ON COMPL -ETION						0	▨		FILL: Silty sand, fine to coarse grained, dark grey, with fine grained sandstone gravel.	M			
									END OF BOREHOLE AT 0.25m				HAND AUGER REFUSAL
						1							
						2							
						3							
						4							
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
56
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Method: HAND AUGER
R.L. Surface: ≈ 55.5m
Date: 18/4/18
Datum: AHD
Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL -ETION	■ ■ ■				REFER TO DCP TEST RESULTS SHEET	0	▨		FILL: Silty sand, fine to medium grained, dark grey and grey, with coarse grained sandstone gravel, trace of timber fragments and ash.	M W			HYDROCARBON ODOUR APPEARS POORLY COMPACTED
						1			END OF BOREHOLE AT 1.0m				HAND AUGER REFUSAL
						2							
						3							
						4							
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
57
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Method: HAND AUGER
R.L. Surface: ≈ 56.8m
Date: 18/4/18
Datum: AHD
Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES				Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
	ES	U50	DB	DS									
DRY ON COMPL -ETION	■				REFER TO DCP TEST RESULTS SHEET	0	▨		FILL: Clayey sand, fine to medium grained, brown and grey, trace fine grained sandstone gravel.	M			APPEARS POORLY COMPACTED
									END OF BOREHOLE AT 0.50m				HAND AUGER REFUSAL
						1							
						2							
						3							
						4							
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
58
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY

Method: HAND AUGER

R.L. Surface: ≈ 47.6m

Date: 18/4/18

Datum: AHD

Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES				Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
	ES	U50	DB	DS									
DRY ON COMPL -ETION					REFER TO DCP TEST RESULTS SHEET	0 1	▨		FILL: Silty gravelly sand, fine to coarse grained, grey and brown, coarse grained sandstone gravel and concrete fragments.	M			APPEARS POORLY COMPACTED
						2 3 4 5 6 7			END OF BOREHOLE AT 1.20m				HAND AUGER REFUSAL

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BOREHOLE LOG

Borehole No.
59
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Method: HAND AUGER
R.L. Surface: ≈ 49.0m
Date: 18/4/18
Datum: AHD
Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPL-ETION					REFER TO DCP TEST RESULTS	0			FILL: Gravely sand, fine to coarse grained, brown and grey, with brick and concrete fragments.	M			APPEARS POORLY COMPACTED
									END OF BOREHOLE AT 0.11m				HAND AUGER REFUSAL
						1							
						2							
						3							
						4							
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
60
1/1

Client: NSW HEALTH INFRASTRUCTURE

Project: DUE DILIGENCE

Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY **Method:** HAND AUGER **R.L. Surface:** ≈ 49.2m

Date: 18/4/18 **Datum:** AHD

Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES				Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
	ES	U50	DB	DS									
DRY ON COMPL -ETION					REFER TO DCP TEST RESULTS	0	▨		FILL: Gravely sand, fine to coarse grained, brown and grey, fine to medium grained sandstone gravel with brick and timber fragments.	M			APPEARS POORLY COMPACTED
									END OF BOREHOLE AT 0.5m				HAND AUGER REFUSAL
						1							
						2							
						3							
						4							
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
61
1/1

Client: NSW HEALTH INFRASTRUCTURE
Project: DUE DILIGENCE
Location: MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No. 31233VY
Method: HAND AUGER
R.L. Surface: ≈ 49.0m
Date: 18/4/18
Datum: AHD
Logged/Checked by: T.C./W.T.

Groundwater Record	SAMPLES				Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
	ES	U50	DB	DS									
DRY ON COMPL -ETION					REFER TO DCP TEST RESULTS	0	▨		FILL: Silty sand, fine to coarse grained, brown and grey, with brick and timber fragments.	M			APPEARS POORLY COMPACTED
									END OF BOREHOLE AT 0.5m				HAND AUGER REFUSAL
						1							
						2							
						3							
						4							
						5							
						6							
						7							

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DYNAMIC CONE PENETRATION TEST RESULTS

Client:	NSW HEALTH INFRASTRUCTURE
Project:	DUE DILIGENCE
Location:	MANLY HOSPITAL, 150 DARLEY ROAD, MANLY, NSW

Job No.	31233VY	Hammer Weight & Drop: 9kg/510mm
Date:	18-4-18	Rod Diameter: 16mm
Tested By:	T.C.	Point Diameter: 20mm

Number of Blows per 100mm Penetration

Test Location Depth (mm)	**55**	**56**	**57**	**58**	**58**	**60**	**61**
0 - 100	↓	7	3	1	1	3	2
100 - 200	7	3	2	3	↓	1	2
200 - 300	18/50mm	1	2	↓	↓	↓	1
300 - 400	END	↓	3	↓	1	↓	↓
400 - 500		↓	5	2	REFUSAL	↓	REFUSAL
500 - 600		↓	14	2		REFUSAL	
600 - 700		↓	END	↓			
700 - 800		1		↓			
800 - 900		1		4			
900 - 1000		↓		5			
1000 - 1100		4		5			
1100 - 1200		5		REFUSAL			
1200 - 1300		21					
1300 - 1400		END					
1400 - 1500							
1500 - 1600							
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 similar to that described in AS1289.6.3.2-1997, Method 6.3.2.
2. Usually 8 blows per 20mm is taken as refusal

SOURCE: http://www.whereis.com/

AERIAL IMAGE SOURCE: MAPS.AU.NEARMAP.COM

Title:
SITE LOCATION PLAN

Location:
150 DARLEY ROAD
MANLY, NSW

Report No: 31233SYJrpt3

Figure No: 1

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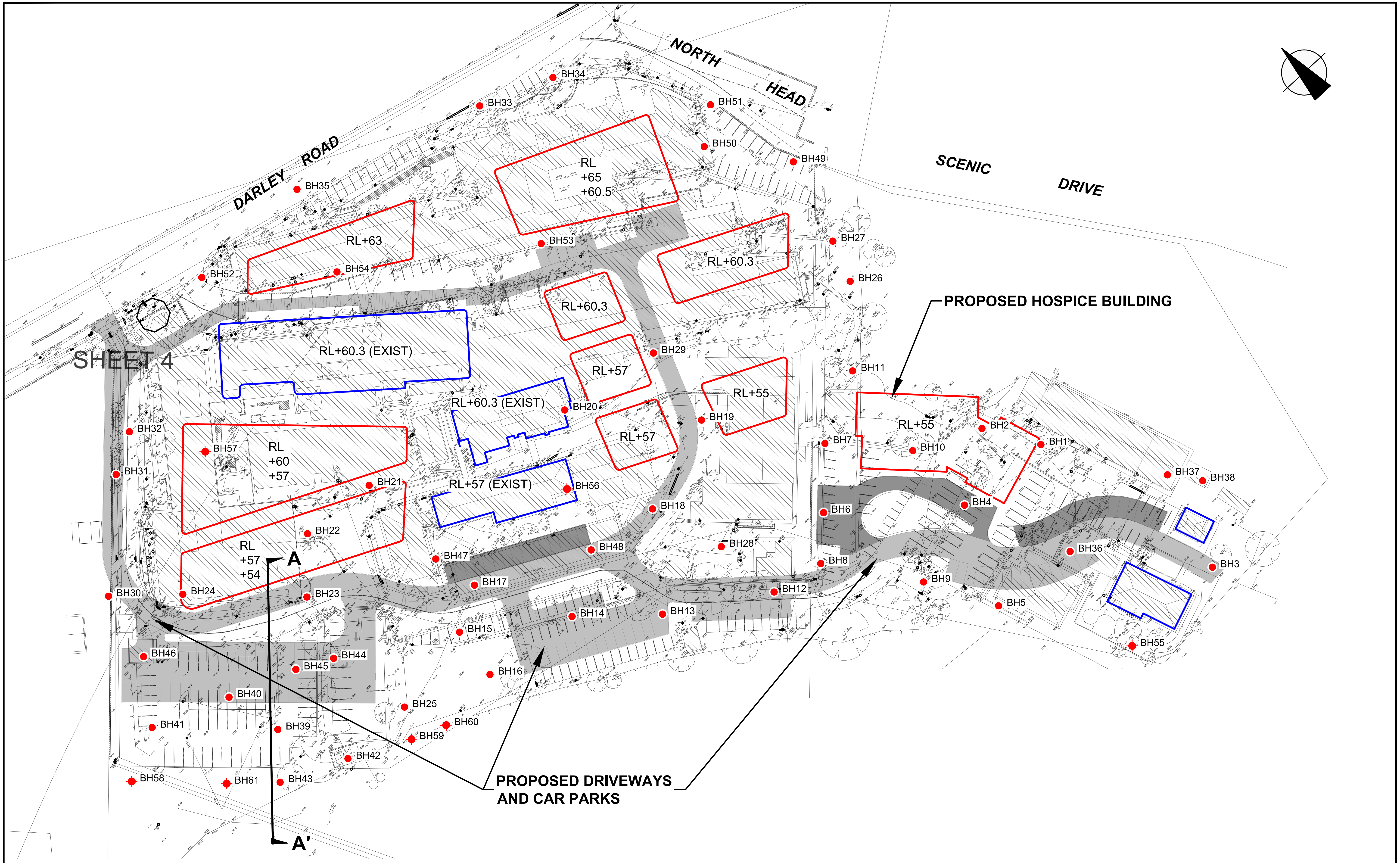
This plan should be read in conjunction with the JK Geotechnics report.

PLOT DATE: 9/09/2020 8:49:54 AM DWG FILE: Z:\6 GEOTECHNICAL\6F GEOTECHNICAL JOBS\31000'S\31233SY MANLY\CAD\31233SYJRPT2\31233SYJRPT3.DWG



LEGEND

●	BOREHOLE
⊕	BOREHOLE AND DCP TEST
RL+	PROPOSED APPROXIMATE FFL RL (m) FOR PROPOSED BUILDINGS OR EXISTING FFL RL (m) FOR EXISTING BUILDINGS
🟥	APPROXIMATE OUTLINE OF PROPOSED BUILDINGS
🟦	APPROXIMATE OUTLINE OF EXISTING HERITAGE BUILDINGS

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

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

Title:
BOREHOLE LOCATION PLAN

Location:
150 DARLEY ROAD
MANLY, NSW

Report No: 31233YJrpt3

Figure No: 2

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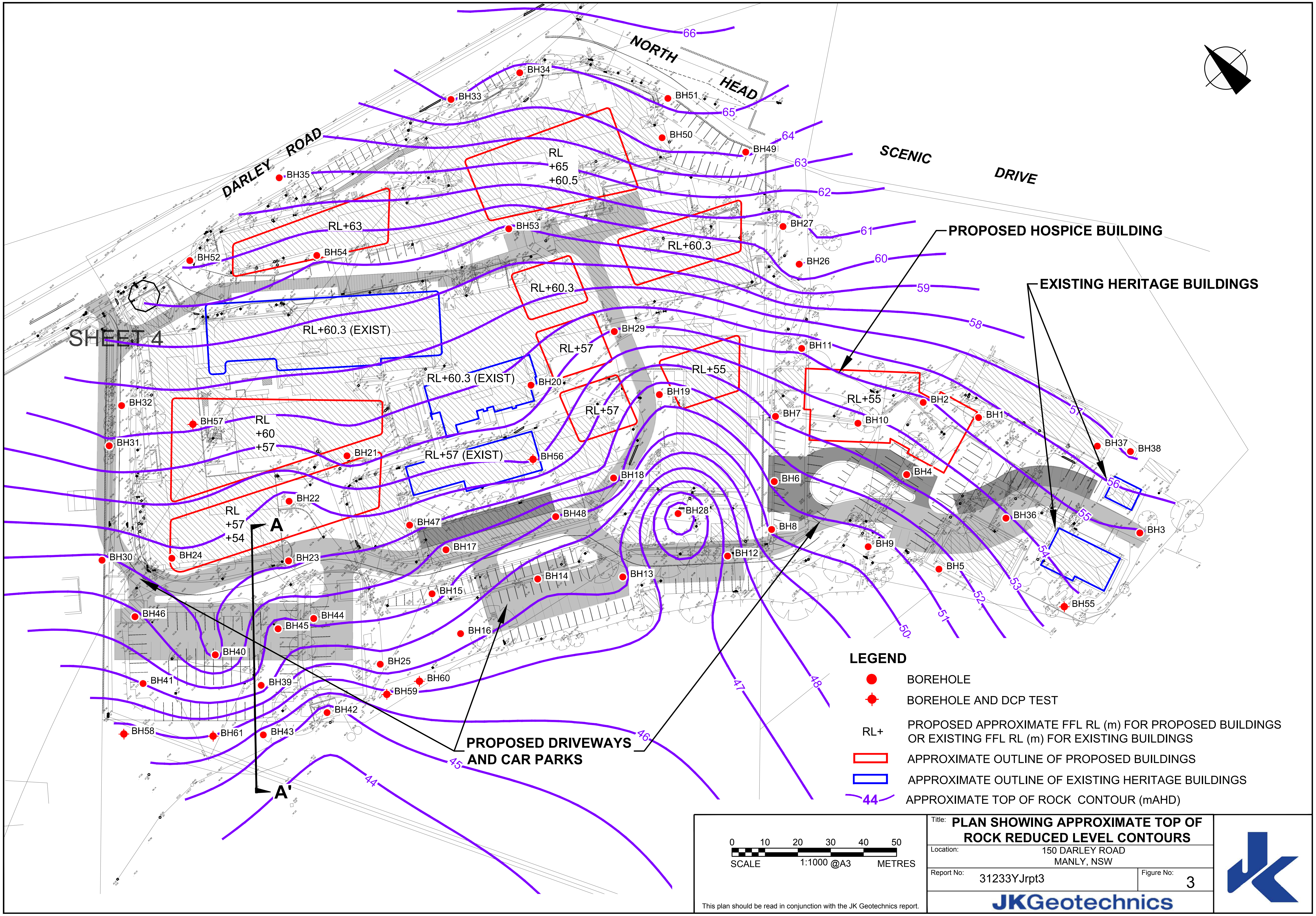
PLOT DATE: 1/09/2020 1:22:47 PM DWG FILE: Z:\6 GEOTECHNICAL\6F GEOTECHNICAL JOBS\31000'S\31233VY MANLY\CAD\31233YJRPT2\31233YJRPT3.DWG



LEGEND

● BOREHOLE

⌖ BOREHOLE AND DCP TEST

RL+ PROPOSED APPROXIMATE FFL RL (m) FOR PROPOSED BUILDINGS OR EXISTING FFL RL (m) FOR EXISTING BUILDINGS

🟥 APPROXIMATE OUTLINE OF PROPOSED BUILDINGS

🟦 APPROXIMATE OUTLINE OF EXISTING HERITAGE BUILDINGS

44 APPROXIMATE TOP OF ROCK CONTOUR (mAHD)

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

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

Title: **PLAN SHOWING APPROXIMATE TOP OF ROCK REDUCED LEVEL CONTOURS**

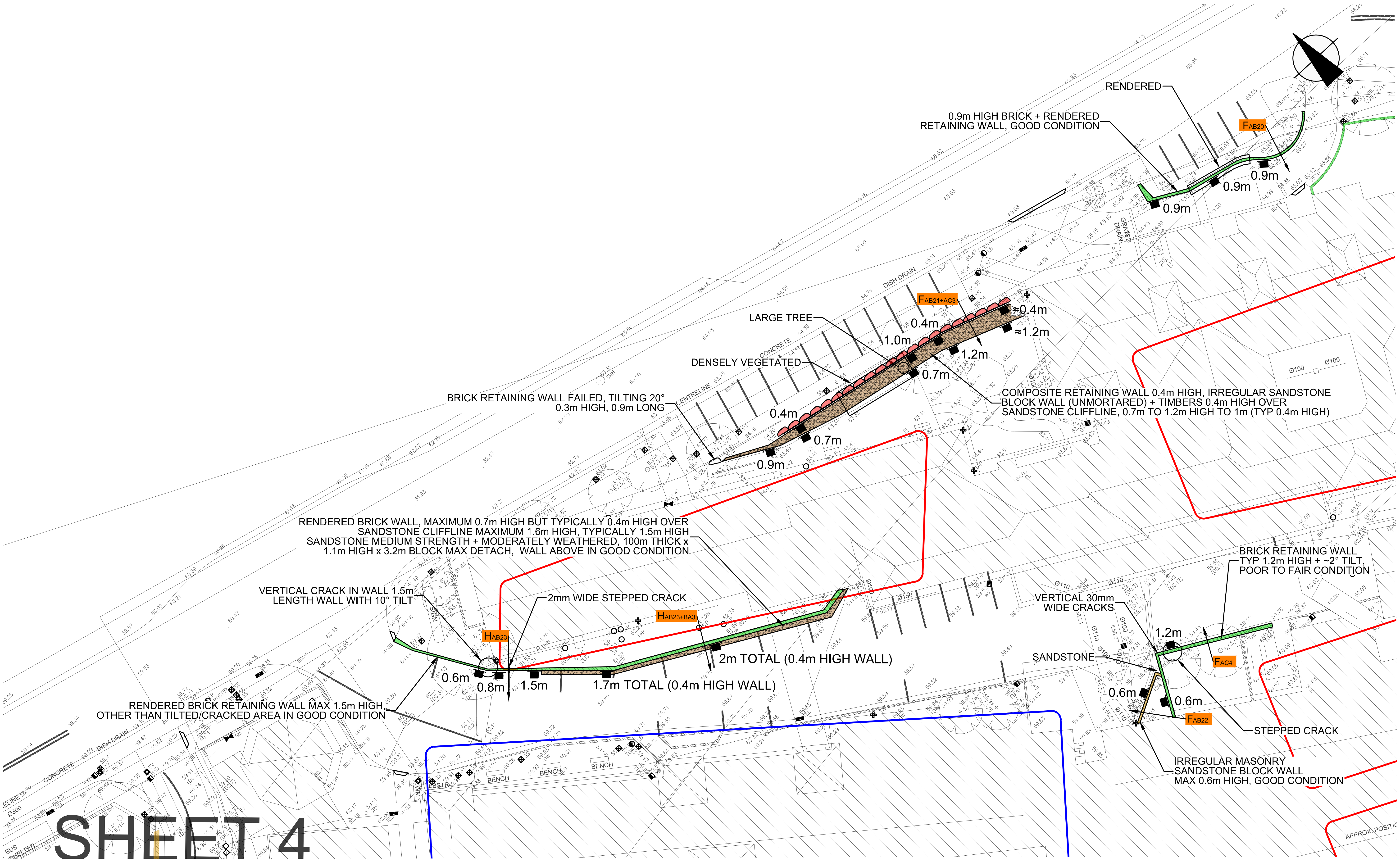
Location: 150 DARLEY ROAD
MANLY, NSW

Report No: 31233YJrpt3

Figure No: 3

JKGeotechnics

PLOT DATE: 1/09/2020 1:23:13 PM DWG FILE: Z:\6 GEOTECHNICAL\6F GEOTECHNICAL JOBS\31000'S\31233YY MANLY\CAD\31233YJRPT\31233YJRPT3.DWG



LEGEND

HAB23 →	GEOTECHNICAL HAZARD	🟪	COMPOSITE RETAINING WALL (BRICK, CONCRETE, MORTARED SANDSTONE BLOCKS)
🟩	BRICK RETAINING WALL	🟦	TIMBER RETAINING WALL
🟨	MASONRY SANDSTONE BLOCK RETAINING WALL	▨	SANDSTONE CLIFF-LINE
🟦	CONCRETE WALL	□	APPROXIMATE OUTLINE OF PROPOSED BUILDINGS
🟥	UNMORTARED ('DRY STONE') SANDSTONE BLOCK RETAINING WALL	□	APPROXIMATE OUTLINE OF EXISTING HERITAGE BUILDINGS

0 4 8 12 16 20
SCALE 1:400 @A3 METRES

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

Title: **GEOTECHNICAL HAZARD PLAN (1 OF 6)**

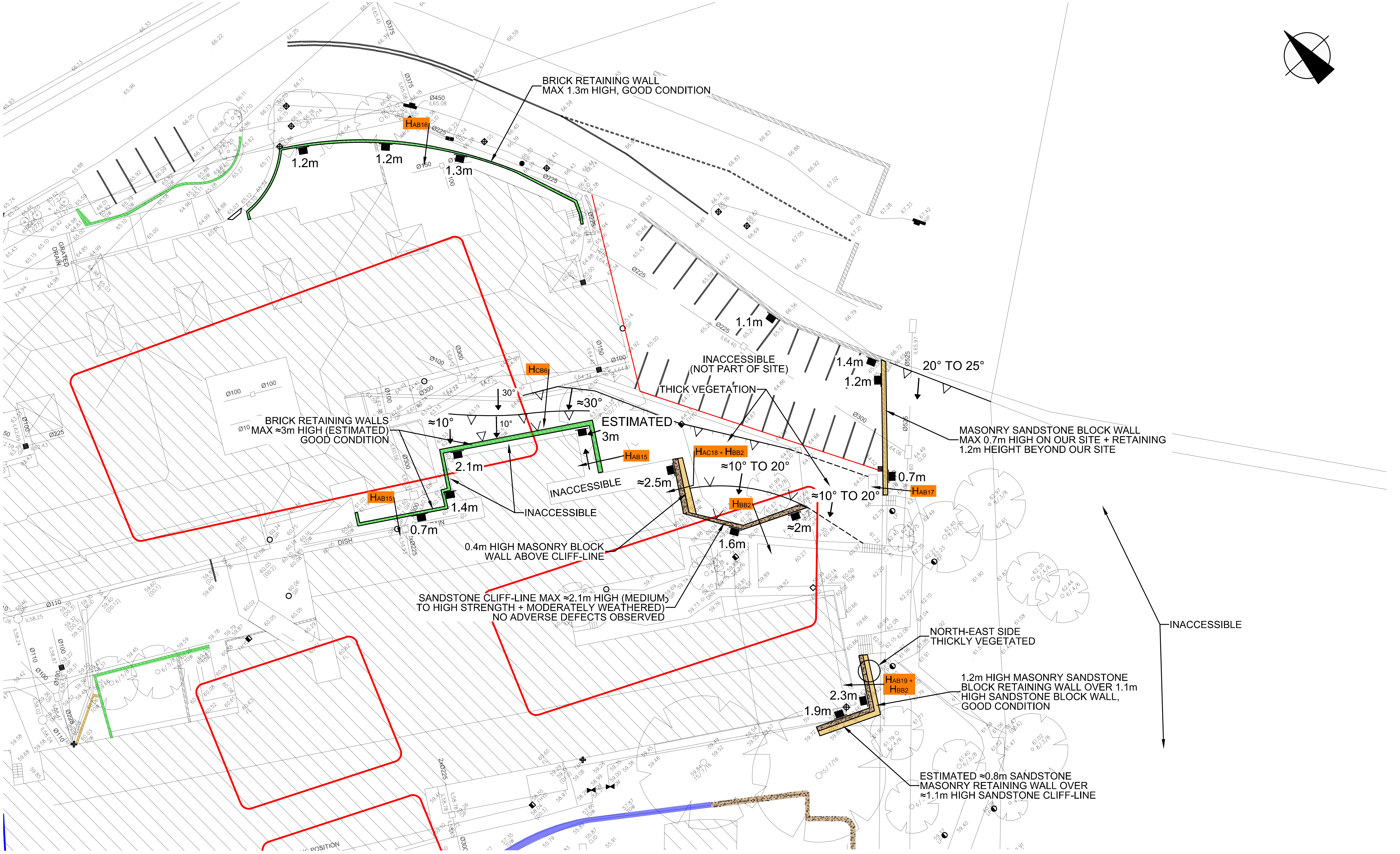
Location: 150 DARLEY ROAD
MANLY, NSW

Report No: 31233YJrpt3

Figure No: 4a

JKGeotechnics

PLOT DATE: 28/08/2020 11:00:48 AM DWG FILE: Z:\6 GEOTECHNICAL\6F GEOTECHNICAL JOBS\31000'S\31233VY MANLY\CAD\31233YJRPT2\31233YJRPT3.DWG



LEGEND

🟧 HAB23 →	GEOTECHNICAL HAZARD	🟪	COMPOSITE RETAINING WALL (BRICK, CONCRETE, MORTARED SANDSTONE BLOCKS)
🟩	BRICK RETAINING WALL	🟦	TIMBER RETAINING WALL
🟨	MASONRY SANDSTONE BLOCK RETAINING WALL	🟫	SANDSTONE CLIFF-LINE
🟦	CONCRETE WALL	▭	APPROXIMATE OUTLINE OF PROPOSED BUILDINGS
🟥	UNMORTARED ('DRY STONE') SANDSTONE BLOCK RETAINING WALL	▭	APPROXIMATE OUTLINE OF EXISTING HERITAGE BUILDINGS

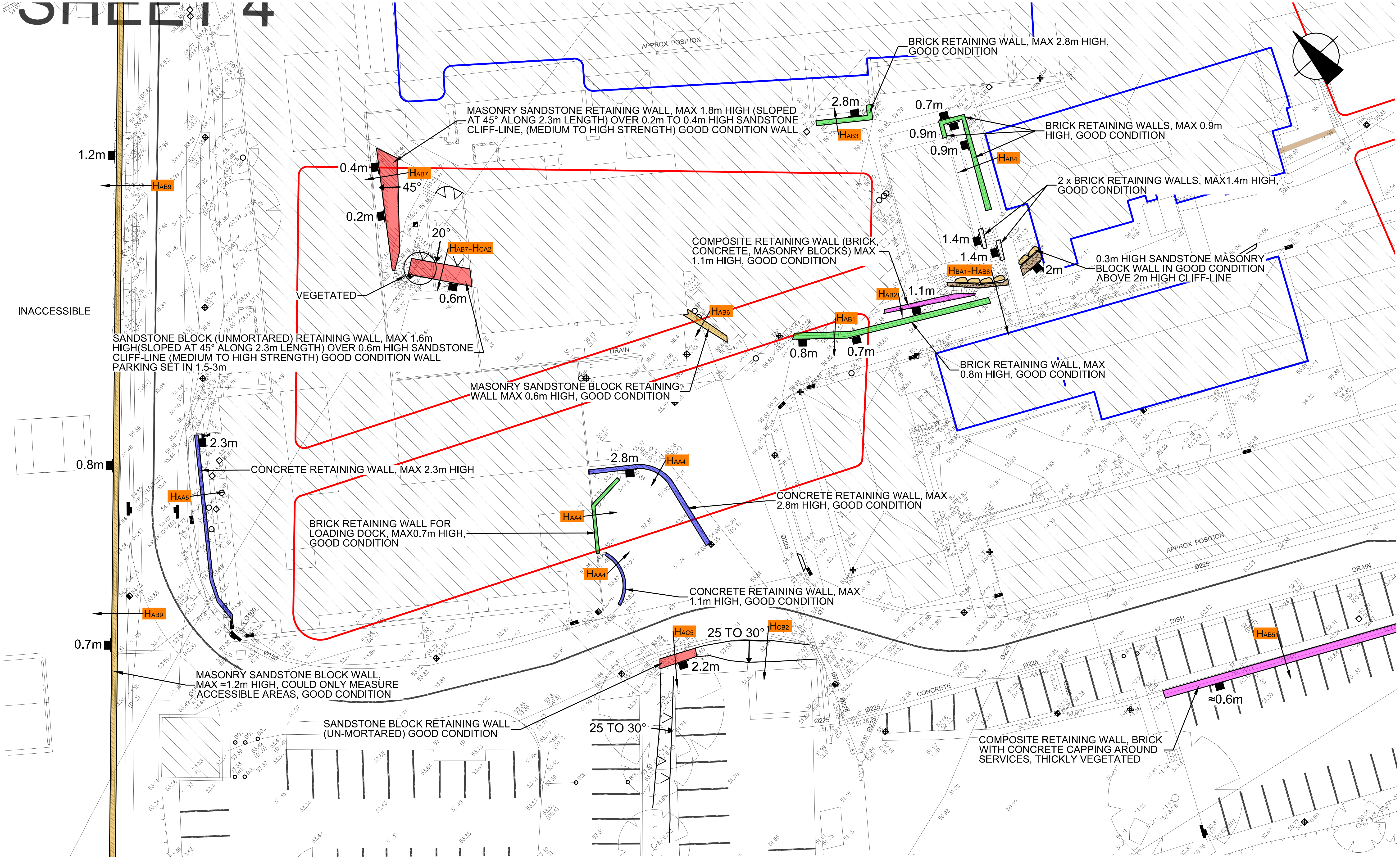
0 4 8 12 16 20
SCALE 1:400 @A3 METRES

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

Title: **GEOTECHNICAL HAZARD PLAN (2 OF 6)**
Location: 150 DARLEY ROAD
MANLY, NSW
Report No: 31233YJrpt3
Figure No: 4b

JKGeotechnics

PLOT DATE: 1/09/2020 1:25:23 PM DWG FILE: Z:\6 GEOTECHNICAL\6F GEOTECHNICAL JOBS\31000'S\31233YY MANLY\CAD\31233YJRPT2\31233YJRPT3.DWG



LEGEND

HAB23 ➝ GEOTECHNICAL HAZARD

🟩 BRICK RETAINING WALL

🟨 MASONRY SANDSTONE BLOCK RETAINING WALL

🟦 CONCRETE WALL

🟥 UNMORTARED ('DRY STONE') SANDSTONE BLOCK RETAINING WALL

🟪 COMPOSITE RETAINING WALL (BRICK, CONCRETE, MORTARED SANDSTONE BLOCKS)

▭ TIMBER RETAINING WALL

▨ SANDSTONE CLIFF-LINE

▭ APPROXIMATE OUTLINE OF PROPOSED BUILDINGS

▭ APPROXIMATE OUTLINE OF EXISTING HERITAGE BUILDINGS

0 4 8 12 16 20

SCALE 1:400 @A3 METRES

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

Title: **GEOTECHNICAL HAZARD PLAN**
(3 OF 6)

Location: 150 DARLEY ROAD
MANLY, NSW

Report No: 31233YJrpt3

Figure No: 4c

JKGeotechnics

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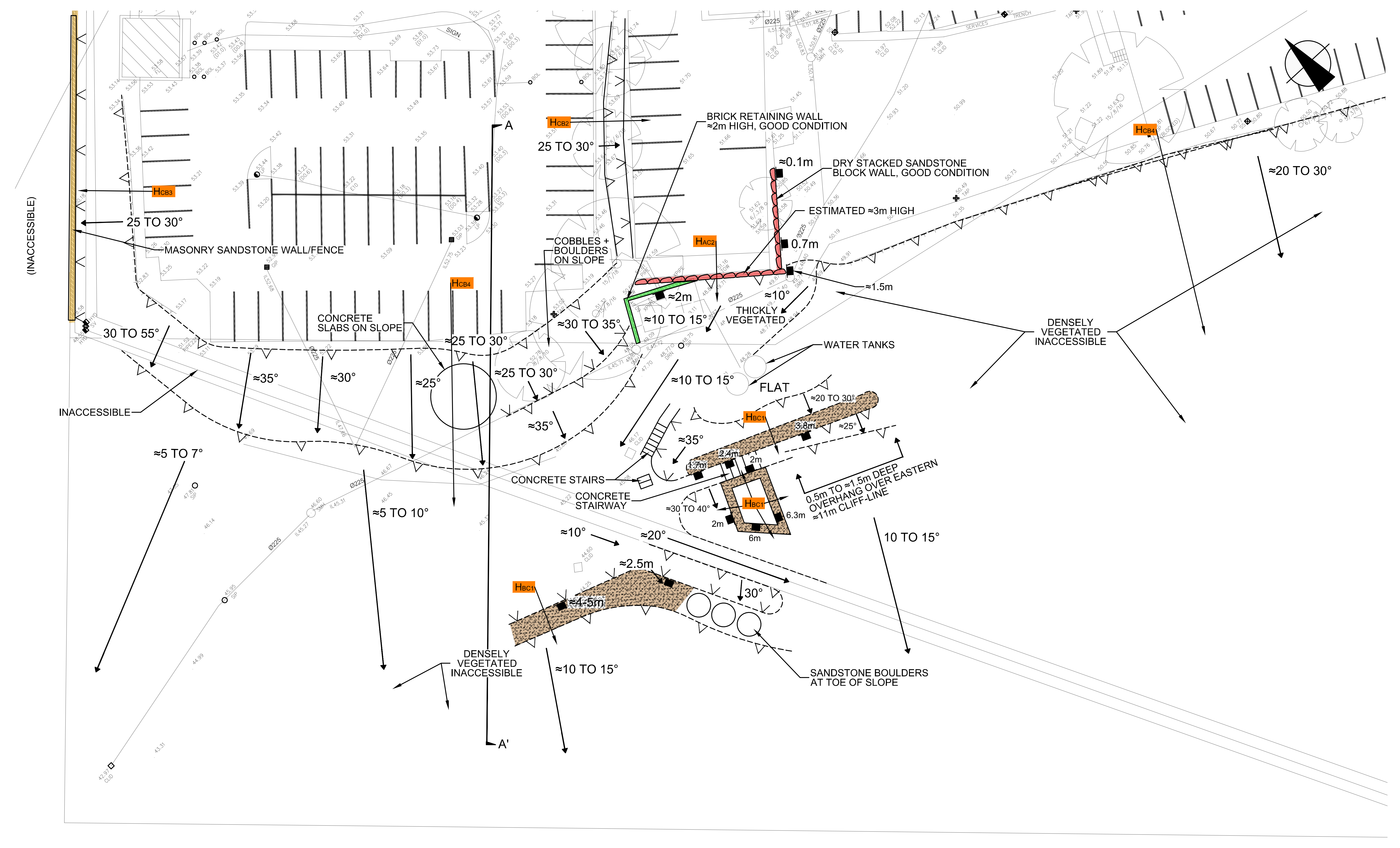

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LEGEND

HAB23 →	GEOTECHNICAL HAZARD	🟪	COMPOSITE RETAINING WALL (BRICK, CONCRETE, MORTARED SANDSTONE BLOCKS)
🟩	BRICK RETAINING WALL	🟦	TIMBER RETAINING WALL
🟨	MASONRY SANDSTONE BLOCK RETAINING WALL	▨	SANDSTONE CLIFF-LINE
🟦	CONCRETE WALL	▭	APPROXIMATE OUTLINE OF PROPOSED BUILDINGS
🟥	UNMORTARED ('DRY STONE') SANDSTONE BLOCK RETAINING WALL	▭	APPROXIMATE OUTLINE OF EXISTING HERITAGE BUILDINGS

0 4 8 12 16 20
SCALE 1:400 @A3 METRES

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

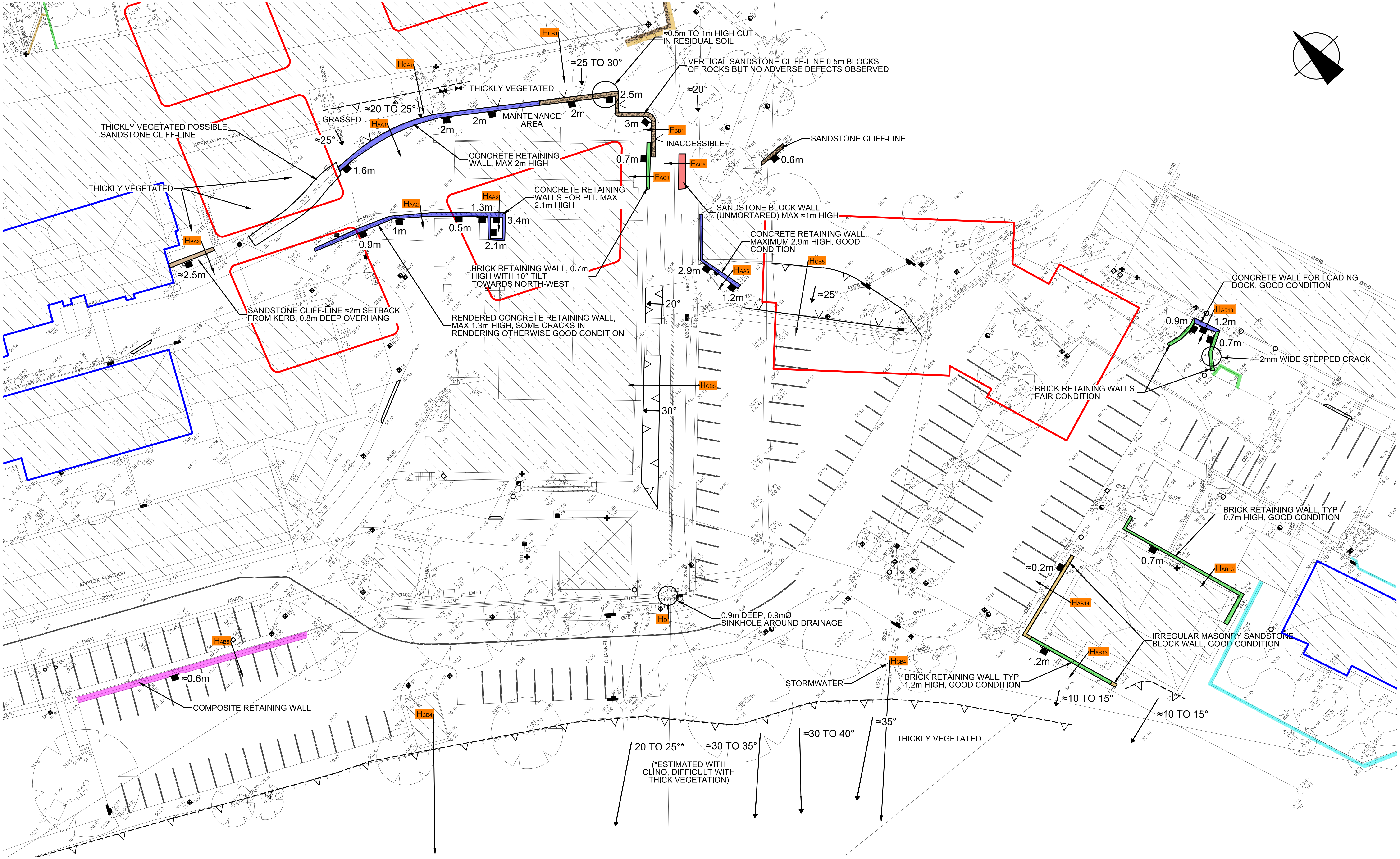
Title: **GEOTECHNICAL HAZARD PLAN (4 OF 6)**

Location: 150 DARLEY ROAD
MANLY, NSW

Report No: 31233YJrpt3

Figure No: 4d

JKGeotechnics



LEGEND

HAB23 ➝	GEOTECHNICAL HAZARD	🟪	COMPOSITE RETAINING WALL (BRICK, CONCRETE, MORTARED SANDSTONE BLOCKS)
🟩	BRICK RETAINING WALL	🟦	TIMBER RETAINING WALL
🟨	MASONRY SANDSTONE BLOCK RETAINING WALL	▨	SANDSTONE CLIFF-LINE
🟦	CONCRETE WALL	☐	APPROXIMATE OUTLINE OF PROPOSED BUILDINGS
🟥	UNMORTARED ('DRY STONE') SANDSTONE BLOCK RETAINING WALL	☐	APPROXIMATE OUTLINE OF EXISTING HERITAGE BUILDINGS

0 5 10 15 20 25

SCALE 1:500 @A3 METRES

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

Title:
GEOTECHNICAL HAZARD PLAN
(5 OF 6)

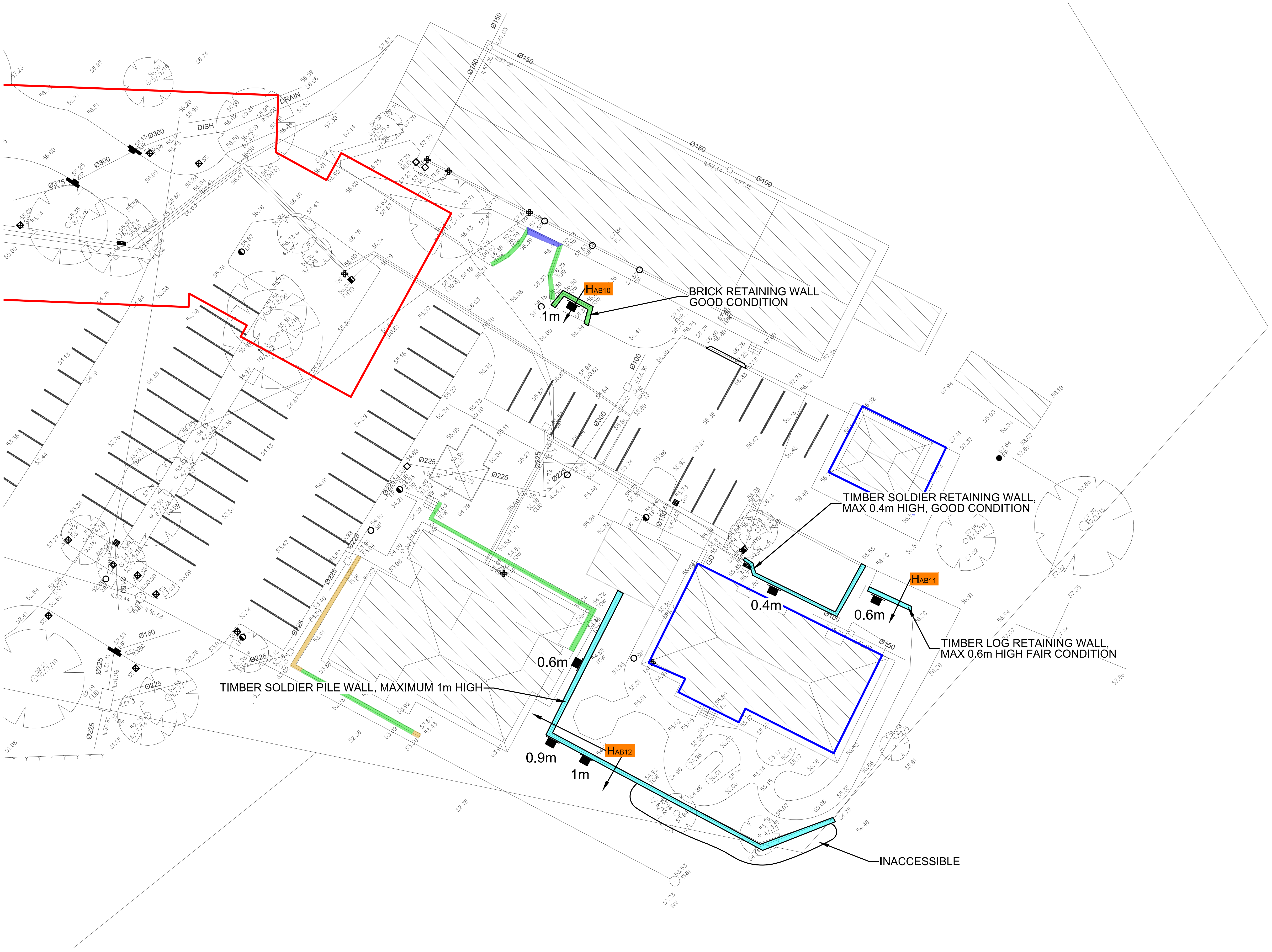
Location: 150 DARLEY ROAD
MANLY, NSW

Report No: 31233YJrpt3

Figure No: 4e

JKGeotechnics

PLOT DATE: 28/08/2020 11:03:16 AM   DWG FILE: Z:\6 GEOTECHNICAL\6F GEOTECHNICAL JOBS\31000'S\31233Y\Y MANLY\CAD\31233YJRPT2\31233YJRPT3.DWG



LEGEND

HAB23 →	GEOTECHNICAL HAZARD
🟩	BRICK RETAINING WALL
🟨	MASONRY SANDSTONE BLOCK RETAINING WALL
🟦	CONCRETE WALL
🟥	UNMORTARED ('DRY STONE') SANDSTONE BLOCK RETAINING WALL
🟪	COMPOSITE RETAINING WALL (BRICK, CONCRETE, MORTARED SANDSTONE BLOCKS)
🟦	TIMBER RETAINING WALL
▨	SANDSTONE CLIFF-LINE
▭	APPROXIMATE OUTLINE OF PROPOSED BUILDINGS
▭	APPROXIMATE OUTLINE OF EXISTING HERITAGE BUILDINGS

0 4 8 12 16 20
SCALE 1:400 @A3 METRES

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

Title: **GEOTECHNICAL HAZARD PLAN**
(6 OF 6)

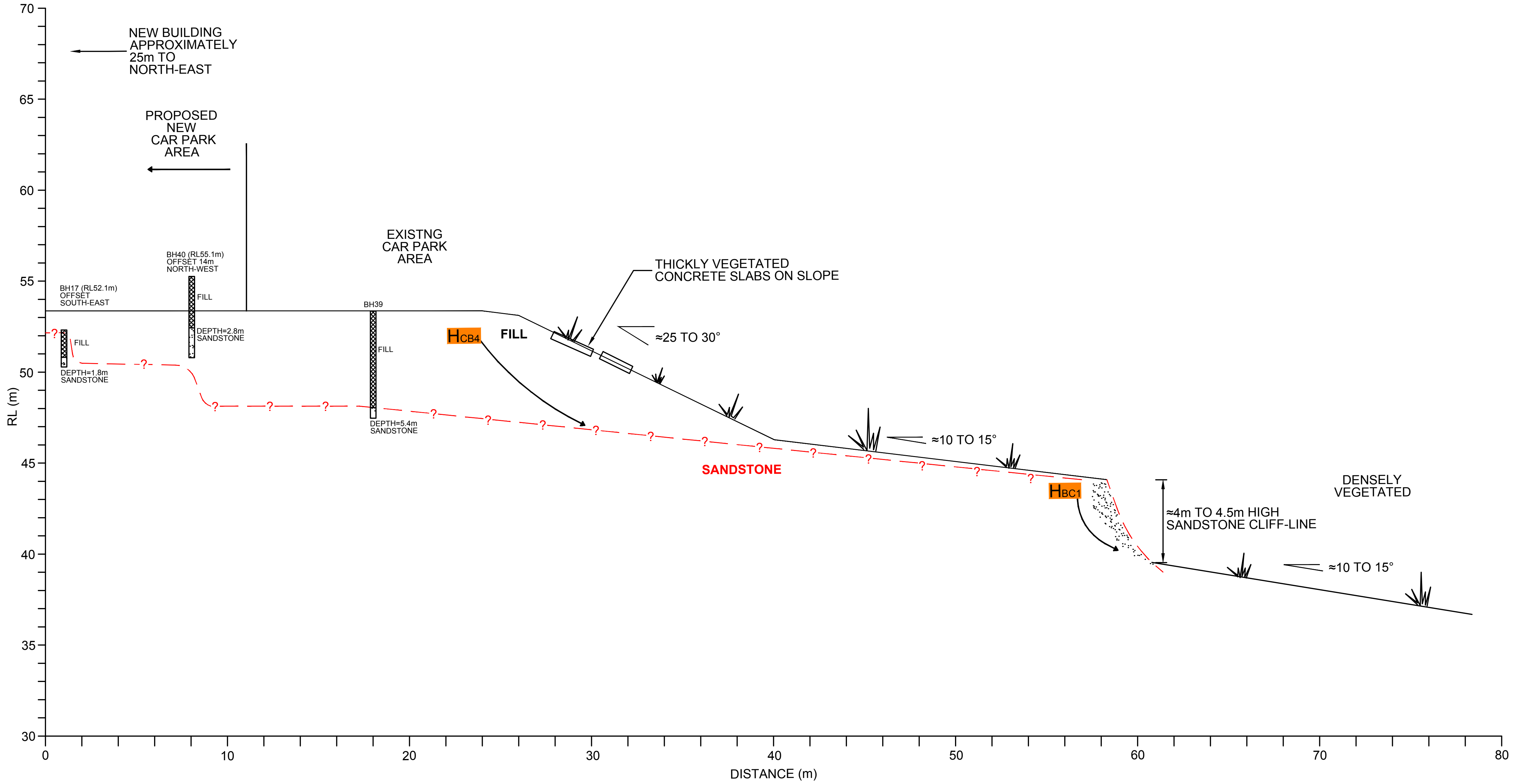
Location: 150 DARLEY ROAD
MANLY, NSW

Report No: 31233YJrpt3

Figure No: 4f

JKGeotechnics

PLOT DATE: 28/08/2020 11:03:29 AM DWG FILE: Z:\6 GEOTECHNICAL\6F GEOTECHNICAL JOBS\31000'S\31233VY MANLY\CAD\31233YJRPT3\31233YJRPT3.DWG



LEGEND

—?—? INFERRED GEOTECHNICAL UNIT BOUNDARY

0 2.5 5 7.5 10 12.5

SCALE 1:250 @A3 METRES

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

Title: **SECTION A-A' SHOWING POTENTIAL LANDSLIDE HAZARDS**

Location: 150 DARLEY ROAD
MANLY, NSW

Report No: 31233YJrpt3

Figure No: 5

JKGeotechnics

PLOT DATE: 1/09/2020 1:29:40 PM DWG FILE: Z:\6 GEOTECHNICAL\6F GEOTECHNICAL JOBS\31000'S\31233VY MANLY\CAD\31233YJRPT2\31233YJRPT3.DWG

TOPOGRAPHY

Symbol *Ground Profile*

convex
concave
} well defined or angular break of slope

convex
concave
} poorly defined or smooth change of slope

breaks of slope
changes of slope
} convex and concave too close together to allow the use of separate symbols

sharp
rounded
} ridge crest

3 Cliff or escarpment or sharp break 40° or more (estimated height in metres)

15 Uniform Slope
10 Concave Slope
8 Convex Slope
} Slope direction and angle (Degrees)

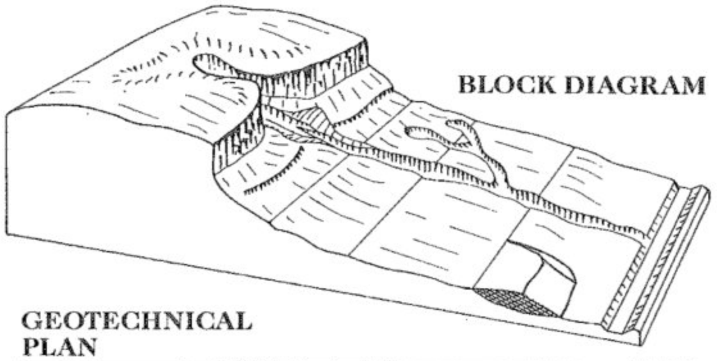
Top
Bottom
} Cut or fill slope, arrows pointing down slope

Hummocky or irregular ground

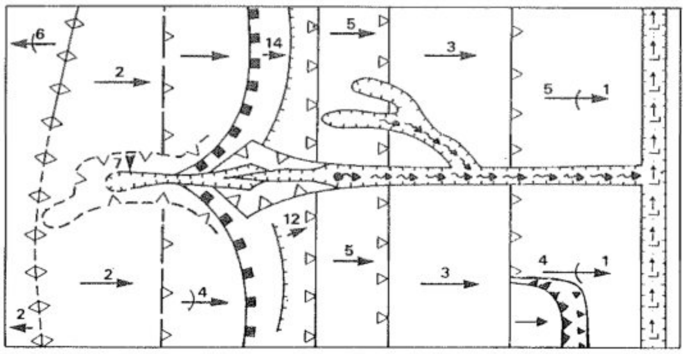
OTHER FEATURES

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

EXAMPLE OF USE OF TOPOGRAPHIC SYMBOLS:


BLOCK DIAGRAM

GEOTECHNICAL PLAN



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

GEOTECHNICAL MAPPING SYMBOLS

JK Geotechnics
GEOTECHNICAL & ENVIRONMENTAL ENGINEERS

Report No. 31233YJrpt3 Figure No. 6

APPENDIX A

LANDSLIDE RISK
MANAGEMENT
TERMINOLOGY

LANDSLIDE RISK MANAGEMENT

Definition of Terms and Landslide Risk

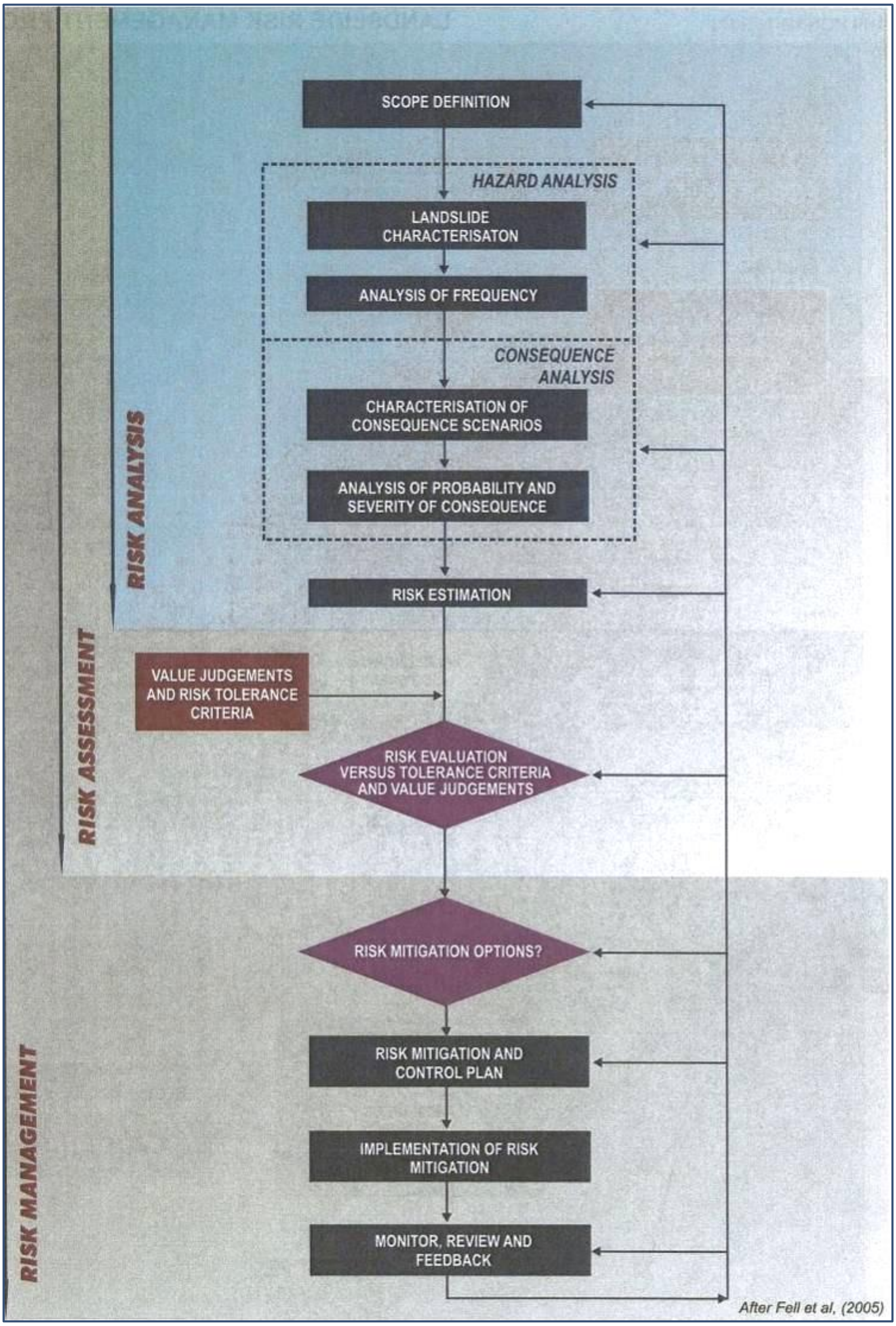
Risk Terminology	Description
Acceptable Risk	A risk for which, for the purposes of life or work, we are prepared to accept as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable.
Annual Exceedance Probability (AEP)	The estimated 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.



After Fell et al, (2005)

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

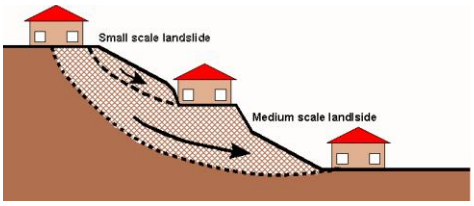


Figure 1

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.

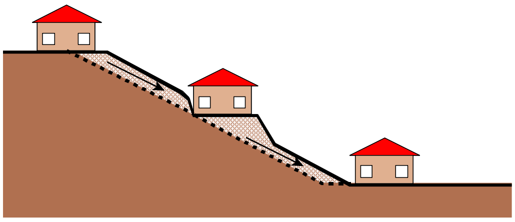


Figure 2

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.

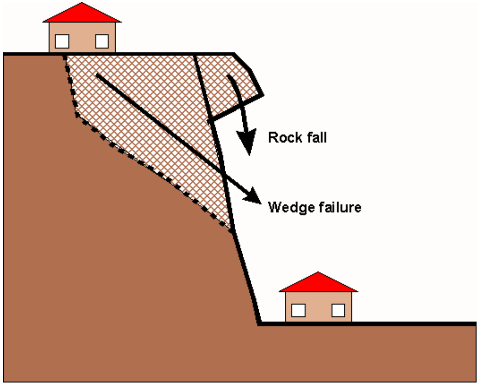


Figure 3

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.

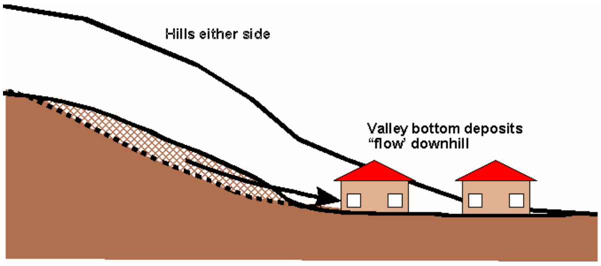


Figure 4

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

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- GeoGuide LR3 - Soil Slopes
- 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

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

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APPENDIX B

SOME GUIDELINES

FOR

HILLSIDE CONSTRUCTION

SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

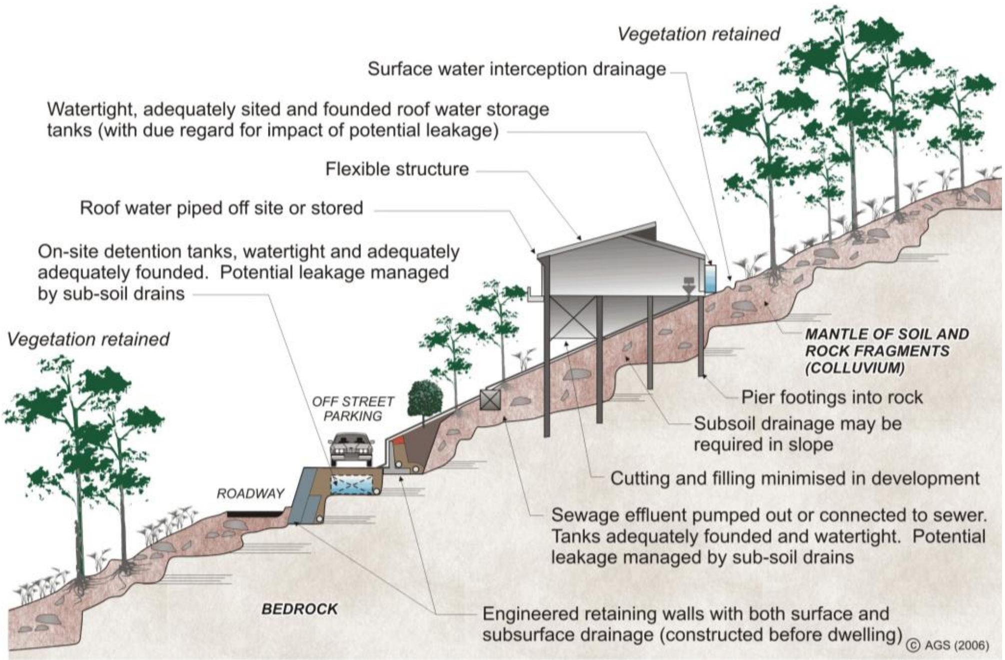
	GOOD ENGINEERING PRACTICE	POOR ENGINEERING PRACTICE
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical consultant at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having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

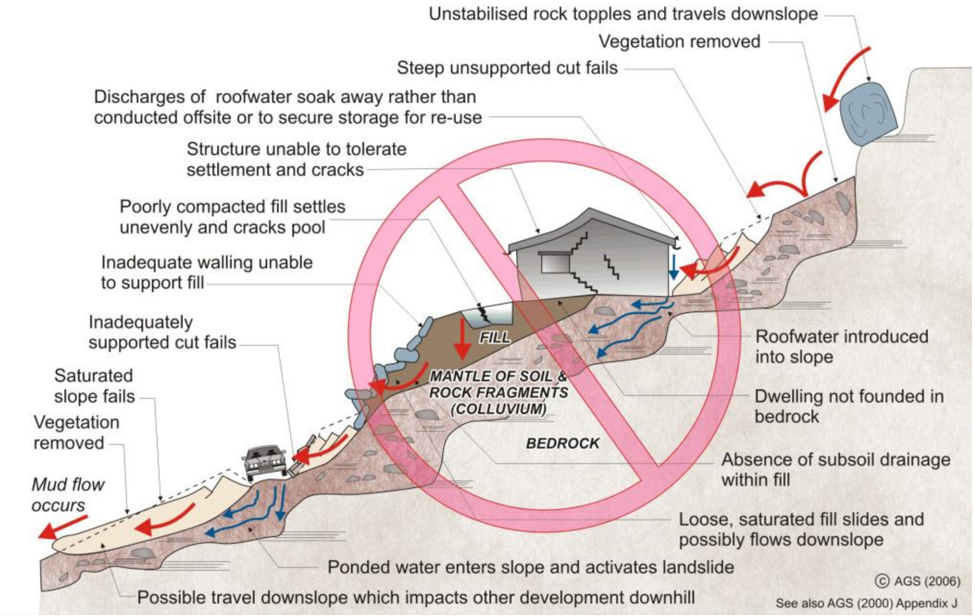
Flexible structures - have been used because they can tolerate a certain amount of movement with minimal signs of distress and maintain their functionality.

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

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REPORT EXPLANATION NOTES

INTRODUCTION

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

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

DESCRIPTION AND CLASSIFICATION METHODS

The methods of description and classification of soils and rocks used in this report are based on Australian Standard 1726:2017 *'Geotechnical Site Investigations'*. In general, descriptions cover the following properties – soil or rock type, colour, structure, strength or density, and inclusions. Identification and classification of soil and rock involves judgement and the Company infers accuracy only to the extent that is common in current geotechnical practice.

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

Soil Classification	Particle Size
Clay	< 0.002mm
Silt	0.002 to 0.075mm
Sand	0.075 to 2.36mm
Gravel	2.36 to 63mm
Cobbles	63 to 200mm
Boulders	> 200mm

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

Relative Density	SPT 'N' Value (blows/300mm)
Very loose (VL)	< 4
Loose (L)	4 to 10
Medium dense (MD)	10 to 30
Dense (D)	30 to 50
Very Dense (VD)	> 50

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

Classification	Unconfined Compressive Strength (kPa)	Indicative Undrained Shear Strength (kPa)
Very Soft (VS)	≤ 25	≤ 12
Soft (S)	> 25 and ≤ 50	> 12 and ≤ 25
Firm (F)	> 50 and ≤ 100	> 25 and ≤ 50
Stiff (St)	> 100 and ≤ 200	> 50 and ≤ 100
Very Stiff (VSt)	> 200 and ≤ 400	> 100 and ≤ 200
Hard (Hd)	> 400	> 200
Friable (Fr)	Strength not attainable – soil crumbles	

Rock types are classified by their geological names, together with descriptive terms regarding weathering, strength, defects, etc. Where relevant, further information regarding rock classification is given in the text of the report. In the Sydney Basin, 'shale' is used to describe fissile mudstone, with a weakness parallel to bedding. Rocks with alternating inter-laminations of different grain size (eg. siltstone/claystone and siltstone/fine grained sandstone) is referred to as 'laminite'.

SAMPLING

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

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

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

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

INVESTIGATION METHODS

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

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

Hand Auger Drilling: A borehole of 50mm to 100mm diameter is advanced by manually operated equipment. Refusal of the hand auger can occur on a variety of materials such as obstructions within any fill, tree roots, hard clay, gravel or ironstone, cobbles and boulders, and does not necessarily indicate rock level.

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

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

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

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

Continuous Core Drilling: A continuous core sample is obtained using a diamond tipped core barrel. Provided full core recovery is achieved (which is not always possible in very low strength rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation. In rocks, NMLC or HQ triple tube core barrels, which give a core of about 50mm and 61mm diameter, respectively, is usually used with water flush. The length of core recovered is compared to the length drilled and any length not recovered is shown as NO CORE. The location of NO CORE recovery is determined on site by the supervising engineer; where the location is uncertain, the loss is placed at the bottom of the drill run.

Standard Penetration Tests: Standard Penetration Tests (SPT) are used mainly in non-cohesive soils, but can also be used in cohesive soils, as a means of indicating density or strength and also of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289.6.3.1–2004 (R2016) *'Methods of Testing Soils for Engineering Purposes, Soil Strength and Consolidation Tests – Determination of the Penetration Resistance of a Soil – Standard Penetration Test (SPT)'*.

The test is carried out in a borehole by driving a 50mm diameter split sample tube with a tapered shoe, under the impact of a 63.5kg hammer with a free fall of 760mm. It is normal for the tube to be driven in three successive 150mm increments and the 'N' value is taken as the number of blows for the last 300mm. In dense sands, very hard clays or weak rock, the full 450mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form:

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

  N = 13
  4, 6, 7

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

  N > 30
  15, 30/40mm

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

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

Cone Penetrometer Testing (CPT) and Interpretation: The cone penetrometer is sometimes referred to as a Dutch Cone. The test is described in Australian Standard 1289.6.5.1–1999 (R2013) *'Methods of Testing Soils for Engineering Purposes, Soil Strength and Consolidation Tests – Determination of the Static Cone Penetration Resistance of a Soil – Field Test using a Mechanical and Electrical Cone or Friction-Cone Penetrometer'*.

In the tests, a 35mm or 44mm diameter rod with a conical tip is pushed continuously into the soil, the reaction being provided by a specially designed truck or rig which is fitted with a hydraulic ram system. Measurements are made of the end bearing resistance on the cone and the frictional resistance on a separate 134mm or 165mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are electrically connected by wires passing through the centre of the push rods to an amplifier and recorder unit mounted on the control truck. The CPT does not provide soil sample recovery.

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

The information provided on the charts comprise:

- Cone resistance – the actual end bearing force divided by the cross sectional area of the cone – expressed in MPa. There are two scales presented for the cone resistance. The lower scale has a range of 0 to 5MPa and the main scale has a range of 0 to 50MPa. For cone resistance values less than 5MPa, the plot will appear on both scales.
- Sleeve friction – the frictional force on the sleeve divided by the surface area – expressed in kPa.
- Friction ratio – the ratio of sleeve friction to cone resistance, expressed as a percentage.

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

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

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

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

There are limitations when using the CPT in that it may not penetrate obstructions within any fill, thick layers of hard clay and very dense sand, gravel and weathered bedrock. Normally a 'dummy' cone is pushed through fill to protect the equipment. No information is recorded by the 'dummy' probe.

Flat Dilatometer Test: The flat dilatometer (DMT), also known as the Marchetti Dilometer comprises a stainless steel blade having a flat, circular steel membrane mounted flush on one side.

The blade is connected to a control unit at ground surface by a pneumatic-electrical tube running through the insertion rods. A gas tank, connected to the control unit by a pneumatic cable, supplies the gas pressure required to expand the membrane. The control unit is equipped with a pressure regulator, pressure gauges, an audio-visual signal and vent valves.

The blade is advanced into the ground using our CPT rig or one of our drilling rigs, and can be driven into the ground using an SPT hammer. As soon as the blade is in place, the membrane is inflated, and the pressure required to lift the membrane (approximately 0.1mm) is recorded. The pressure then required to lift the centre of the membrane by an additional 1mm is recorded. The membrane is then deflated before pushing to the next depth increment, usually 200mm down. The pressure readings are corrected for membrane stiffness.

The DMT is used to measure material index (I_D), horizontal stress index (K_D), and dilatometer modulus (E_D). Using established correlations, the DMT results can also be used to assess the 'at rest' earth pressure coefficient (K_o), over-consolidation ratio (OCR), undrained shear strength (C_u), friction angle (ϕ), coefficient of consolidation (C_h), coefficient of permeability (K_h), unit weight (γ), and vertical drained constrained modulus (M).

The seismic dilatometer (SDMT) is the combination of the DMT with an add-on seismic module for the measurement of shear wave velocity (V_s). Using established correlations, the SDMT results can also be used to assess the small strain modulus (G_o).

Portable Dynamic Cone Penetrometers: Portable Dynamic Cone Penetrometer (DCP) tests are carried out by driving a 16mm diameter rod with a 20mm diameter cone end with a 9kg hammer dropping 510mm. The test is described in Australian Standard 1289.6.3.2–1997 (R2013) *'Methods of Testing Soils for Engineering Purposes, Soil Strength and Consolidation Tests – Determination of the Penetration Resistance of a Soil – 9kg Dynamic Cone Penetrometer Test'*.

The results are used to assess the relative compaction of fill, the relative density of granular soils, and the strength of cohesive soils. Using established correlations, the DCP test results can also be used to assess California Bearing Ratio (CBR).

Refusal of the DCP can occur on a variety of materials such as obstructions within any fill, tree roots, hard clay, gravel or ironstone, cobbles and boulders, and does not necessarily indicate rock level.

Vane Shear Test: The vane shear test is used to measure the undrained shear strength (C_u) of typically very soft to firm fine grained cohesive soils. The vane shear is normally performed in the bottom of a borehole, but can be completed from surface level, the bottom and sides of test pits, and on recovered undisturbed tube samples (when using a hand vane).

The vane comprises four rectangular blades arranged in the form of a cross on the end of a thin rod, which is coupled to the bottom of a drill rod string when used in a borehole. The size of the vane is dependent on the strength of the fine grained cohesive soils; that is, larger vanes are normally used for very low strength soils. For borehole testing, the size of the vane can be limited by the size of the casing that is used.

For testing inside a borehole, a device is used at the top of the casing, which suspends the vane and rods so that they do not sink under self-weight into the 'soft' soils beyond the depth at which the test is to be carried out. A calibrated torque head is used to rotate the rods and vane and to measure the resistance of the vane to rotation.

With the vane in position, torque is applied to cause rotation of the vane at a constant rate. A rate of 6° per minute is the common rotation rate. Rotation is continued until the soil is sheared and the maximum torque has been recorded. This value is then used to calculate the undrained shear strength. The vane is then rotated rapidly a number of times and the operation repeated until a constant torque reading is obtained. This torque value is used to calculate the remoulded shear strength. Where appropriate, friction on the vane rods is measured and taken into account in the shear strength calculation.

LOGS

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

The terms and symbols used in preparation of the logs are defined in the following pages.

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

GROUNDWATER

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

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

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

FILL

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

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

LABORATORY TESTING

Laboratory testing is normally carried out in accordance with Australian Standard 1289 *'Methods of Testing Soils for Engineering Purposes'* or appropriate NSW Government Roads & Maritime Services (RMS) test methods. Details of the test procedure used are given on the individual report forms.

ENGINEERING REPORTS

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

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

- Unexpected variations in ground conditions – the potential for this will be partially dependent on borehole spacing and sampling frequency as well as investigation technique.
- Changes in policy or interpretation of policy by statutory authorities.
- The actions of persons or contractors responding to commercial pressures.
- Details of the development that the Company could not reasonably be expected to anticipate.

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

SITE ANOMALIES

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

REPRODUCTION OF INFORMATION FOR CONTRACTUAL PURPOSES

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

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

REVIEW OF DESIGN

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

SITE INSPECTION

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

Requirements could range from:

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

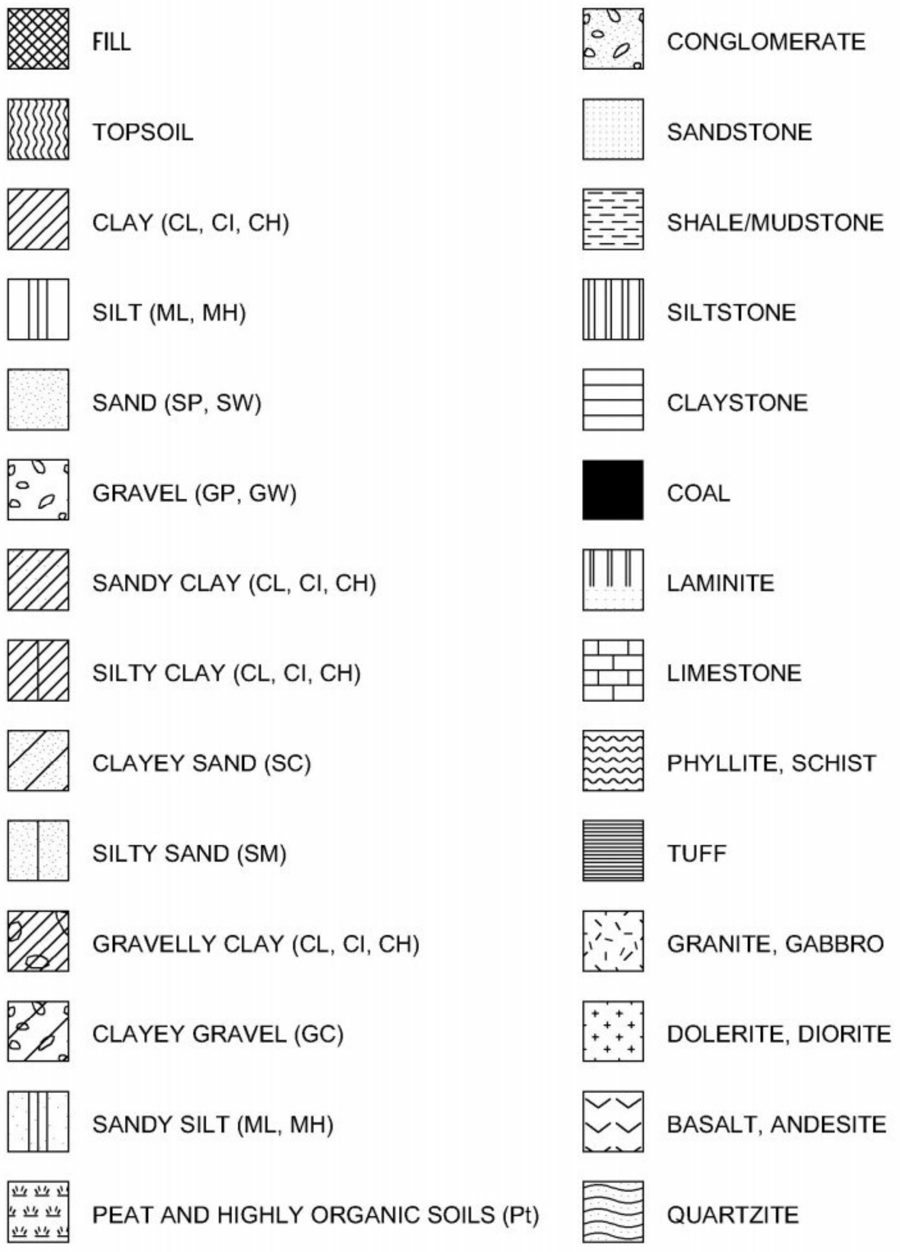
ii) a visit to assist the contractor or other site personnel in identifying various soil/rock types and appropriate footing or pile founding depths, or

iii) full time engineering presence on site.

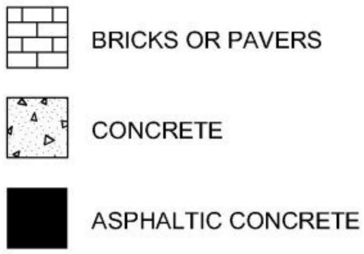
SYMBOL LEGENDS

SOIL

ROCK



OTHER MATERIALS



CLASSIFICATION OF COARSE AND FINE GRAINED SOILS

Major Divisions		Group Symbol	Typical Names	Field Classification of Sand and Gravel	Laboratory Classification	
Coarse grained soil (more than 65% of soil excluding oversize fraction is greater than 0.075mm)	GRAVEL (more than half of coarse fraction is larger than 2.36mm	GW	Gravel and gravel-sand mixtures, little or no fines	Wide range in grain size and substantial amounts of all intermediate sizes, not enough fines to bind coarse grains, no dry strength	≤ 5% fines	$C_u > 4$ $1 < C_c < 3$
		GP	Gravel and gravel-sand mixtures, little or no fines, uniform gravels	Predominantly one size or range of sizes with some intermediate sizes missing, not enough fines to bind coarse grains, no dry strength	≤ 5% fines	Fails to comply with above
		GM	Gravel-silt mixtures and gravel-sand-silt mixtures	'Dirty' materials with excess of non-plastic fines, zero to medium dry strength	≥ 12% fines, fines are silty	Fines behave as silt
		GC	Gravel-clay mixtures and gravel-sand-clay mixtures	'Dirty' materials with excess of plastic fines, medium to high dry strength	≥ 12% fines, fines are clayey	Fines behave as clay
	SAND (more than half of coarse fraction is smaller than 2.36mm)	SW	Sand and gravel-sand mixtures, little or no fines	Wide range in grain size and substantial amounts of all intermediate sizes, not enough fines to bind coarse grains, no dry strength	≤ 5% fines	$C_u > 6$ $1 < C_c < 3$
		SP	Sand and gravel-sand mixtures, little or no fines	Predominantly one size or range of sizes with some intermediate sizes missing, not enough fines to bind coarse grains, no dry strength	≤ 5% fines	Fails to comply with above
		SM	Sand-silt mixtures	'Dirty' materials with excess of non-plastic fines, zero to medium dry strength	≥ 12% fines, fines are silty	N/A
		SC	Sand-clay mixtures	'Dirty' materials with excess of plastic fines, medium to high dry strength	≥ 12% fines, fines are clayey	

Major Divisions		Group Symbol	Typical Names	Field Classification of Silt and Clay			Laboratory Classification
				Dry Strength	Dilatancy	Toughness	% < 0.075mm
ine grained soils (more than 35% of soil excluding oversize fraction is less than 0.075mm)	SILT and CLAY (low to medium plasticity)	ML	Inorganic silt and very fine sand, rock flour, silty or clayey fine sand or silt with low plasticity	None to low	Slow to rapid	Low	Below A line
		CL, CI	Inorganic clay of low to medium plasticity, gravelly clay, sandy clay	Medium to high	None to slow	Medium	Above A line
		OL	Organic silt	Low to medium	Slow	Low	Below A line
	SILT and CLAY (high plasticity)	MH	Inorganic silt	Low to medium	None to slow	Low to medium	Below A line
		CH	Inorganic clay of high plasticity	High to very high	None	High	Above A line
		OH	Organic clay of medium to high plasticity, organic silt	Medium to high	None to very slow	Low to medium	Below A line
	Highly organic soil	Pt	Peat, highly organic soil	–	–	–	–

Laboratory **Classification** Criteria

A well graded coarse grained soil is one for which the coefficient of uniformity $Cu > 4$ and the coefficient of curvature $1 < C_c < 3$. Otherwise, the soil is poorly graded. These coefficients are given by:

$$C_U = \frac{D_{60}}{D_{10}} \quad and \quad C_C = \frac{(D_{30})^2}{D_{10}\,D_{60}}$$

Where D_{10}, D_{30} and D_{60} are those grain sizes for which 10%, 30% and 60% of the soil grains, respectively, are smaller.

NOTES:

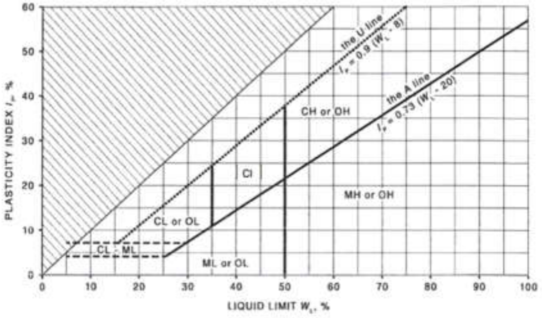
1 For a coarse grained soil with a fines content between 5% and 12%, the soil is given a dual classification comprising the two group symbols separated by a dash; for example, for a poorly graded gravel with between 5% and 12% silt fines, the classification is GP-GM.

2 Where the grading is determined from laboratory tests, it is defined by coefficients of curvature (C_c) and uniformity (C_u) derived from the particle size distribution curve.

3 Clay soils with liquid limits > 35% and ≤ 50% may be classified as being of medium plasticity.

4 The U line on the Modified Casagrande Chart is an approximate upper bound for most natural soils.

Modified Casagrande Chart for Classifying Silts and Clays according to their Behaviour



LOG SYMBOLS

Log Column	Symbol	Definition		
Groundwater Record	—▼—	Standing water level. Time delay following completion of drilling/excavation may be shown.		
	—C—	Extent of borehole/test pit collapse shortly after drilling/excavation.		
	▶—	Groundwater seepage into borehole or test pit noted during drilling or excavation.		
Samples	ES	Sample taken over depth indicated, for environmental analysis.		
	U50	Undisturbed 50mm diameter tube sample taken over depth indicated.		
	DB	Bulk disturbed sample taken over depth indicated.		
	DS	Small disturbed bag sample taken over depth indicated.		
	ASB	Soil sample taken over depth indicated, for asbestos analysis.		
	ASS	Soil sample taken over depth indicated, for acid sulfate soil analysis.		
	SAL	Soil sample taken over depth indicated, for salinity analysis.		
Field Tests	N = 17 4, 7, 10	Standard Penetration Test (SPT) performed between depths indicated by lines. Individual figures show blows per 150mm penetration. 'Refusal' refers to apparent hammer refusal within the corresponding 150mm depth increment.		
	N_c = 5 7 3R	Solid Cone Penetration Test (SCPT) performed between depths indicated by lines. Individual figures show blows per 150mm penetration for 60° solid cone driven by SPT hammer. 'R' refers to apparent hammer refusal within the corresponding 150mm depth increment.		
	VNS = 25	Vane shear reading in kPa of undrained shear strength.		
	PID = 100	Photoionisation detector reading in ppm (soil sample headspace test).		
Moisture Condition (Fine Grained Soils)	w > PL	Moisture content estimated to be greater than plastic limit.		
	w ≈ PL	Moisture content estimated to be approximately equal to plastic limit.		
	w < PL	Moisture content estimated to be less than plastic limit.		
	w ≈ LL	Moisture content estimated to be near liquid limit.		
	w > LL	Moisture content estimated to be wet of liquid limit.		
(Coarse Grained Soils)	D	DRY – runs freely through fingers.		
	M	MOIST – does not run freely but no free water visible on soil surface.		
	W	WET – free water visible on soil surface.		
Strength (Consistency) Cohesive Soils	VS	VERY SOFT – unconfined compressive strength ≤ 25kPa.		
	S	SOFT – unconfined compressive strength > 25kPa and ≤ 50kPa.		
	F	FIRM – unconfined compressive strength > 50kPa and ≤ 100kPa.		
	St	STIFF – unconfined compressive strength > 100kPa and ≤ 200kPa.		
	VSt	VERY STIFF – unconfined compressive strength > 200kPa and ≤ 400kPa.		
	Hd	HARD – unconfined compressive strength > 400kPa.		
	Fr	FRIABLE – strength not attainable, soil crumbles.		
	( )	Bracketed symbol indicates estimated consistency based on tactile examination or other assessment.		
Density Index/ Relative Density (Cohesionless Soils)			**Density Index (I_D) Range (%)**	**SPT 'N' Value Range (Blows/300mm)**
	VL	VERY LOOSE	≤ 15	0 – 4
	L	LOOSE	> 15 and ≤ 35	4 – 10
	MD	MEDIUM DENSE	> 35 and ≤ 65	10 – 30
	D	DENSE	> 65 and ≤ 85	30 – 50
	VD	VERY DENSE	> 85	> 50
	( )	Bracketed symbol indicates estimated density based on ease of drilling or other assessment.		
Hand Penetrometer Readings	300 250	Measures reading in kPa of unconfined compressive strength. Numbers indicate individual test results on representative undisturbed material unless noted otherwise.		

Log Column	Symbol	Definition
Remarks	'V' bit	Hardened steel 'V' shaped bit.
	'TC' bit	Twin pronged tungsten carbide bit.
	T_{60}	Penetration of auger string in mm under static load of rig applied by drill head hydraulics without rotation of augers.
	Soil Origin	The geological origin of the soil can generally be described as:
		RESIDUAL – soil formed directly from insitu weathering of the underlying rock. No visible structure or fabric of the parent rock.
		EXTREMELY WEATHERED – soil formed directly from insitu weathering of the underlying rock. Material is of soil strength but retains the structure and/or fabric of the parent rock.
		ALLUVIAL – soil deposited by creeks and rivers.
		ESTUARINE – soil deposited in coastal estuaries, including sediments caused by inflowing creeks and rivers, and tidal currents.
		MARINE – soil deposited in a marine environment.
		AEOLIAN – soil carried and deposited by wind.
		COLLUVIAL – soil and rock debris transported downslope by gravity, with or without the assistance of flowing water. Colluvium is usually a thick deposit formed from a landslide. The description 'slopewash' is used for thinner surficial deposits.
		LITTORAL – beach deposited soil.

Classification of Material Weathering

Term		Abbreviation		Definition
Residual Soil		RS		Material is weathered to such an extent that it has soil properties. Mass structure and material texture and fabric of original rock are no longer visible, but the soil has not been significantly transported.
Extremely Weathered		XW		Material is weathered to such an extent that it has soil properties. Mass structure and material texture and fabric of original rock are still visible.
Highly Weathered	Distinctly Weathered (Note 1)	HW	DW	The whole of the rock material is discoloured, usually by iron staining or bleaching to the extent that the colour of the original rock is not recognisable. Rock strength is significantly changed by weathering. Some primary minerals have weathered to clay minerals. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores.
Moderately Weathered		MW		The whole of the rock material is discoloured, usually by iron staining or bleaching to the extent that the colour of the original rock is not recognisable, but shows little or no change of strength from fresh rock.
Slightly Weathered		SW		Rock is partially discoloured with staining or bleaching along joints but shows little or no change of strength from fresh rock.
Fresh		FR		Rock shows no sign of decomposition of individual minerals or colour changes.

NOTE 1: The term 'Distinctly Weathered' is used where it is not practicable to distinguish between 'Highly Weathered' and 'Moderately Weathered' rock. 'Distinctly Weathered' is defined as follows: *'Rock strength usually changed by weathering. The rock may be highly discoloured, usually by iron staining. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores'*. There is some change in rock strength.

Rock Material Strength Classification

			Guide to Strength	
Term	**Abbreviation**	**Uniaxial Compressive Strength (MPa)**	**Point Load Strength Index $I_{s(50)}$ (MPa)**	**Field Assessment**
Very Low Strength	VL	0.6 to 2	0.03 to 0.1	Material crumbles under firm blows with sharp end of pick; can be peeled with knife; too hard to cut a triaxial sample by hand. Pieces up to 30mm thick can be broken by finger pressure.
Low Strength	L	2 to 6	0.1 to 0.3	Easily scored with a knife; indentations 1mm to 3mm show in the specimen with firm blows of the pick point; has dull sound under hammer. A piece of core 150mm long by 50mm diameter may be broken by hand. Sharp edges of core may be friable and break during handling.
Medium Strength	M	6 to 20	0.3 to 1	Scored with a knife; a piece of core 150mm long by 50mm diameter can be broken by hand with difficulty.
High Strength	H	20 to 60	1 to 3	A piece of core 150mm long by 50mm diameter cannot be broken by hand but can be broken by a pick with a single firm blow; rock rings under hammer.
Very High Strength	VH	60 to 200	3 to 10	Hand specimen breaks with pick after more than one blow; rock rings under hammer.
Extremely High Strength	EH	> 200	> 10	Specimen requires many blows with geological pick to break through intact material; rock rings under hammer.

Abbreviations Used in Defect Description

Cored Borehole Log Column		Symbol Abbreviation	Description
Point Load Strength Index		• 0.6	Axial point load strength index test result (MPa)
		x 0.6	Diametral point load strength index test result (MPa)
Defect Details	– Type	Be	Parting – bedding or cleavage
		CS	Clay seam
		Cr	Crushed/sheared seam or zone
		J	Joint
		Jh	Healed joint
		Ji	Incipient joint
		XWS	Extremely weathered seam
	– Orientation	Degrees	Defect orientation is measured relative to normal to the core axis (ie. relative to the horizontal for a vertical borehole)
	– Shape	P	Planar
		C	Curved
		Un	Undulating
		St	Stepped
		Ir	Irregular
	– Roughness	Vr	Very rough
		R	Rough
		S	Smooth
		Po	Polished
		Sl	Slickensided
	– Infill Material	Ca	Calcite
		Cb	Carbonaceous
		Clay	Clay
		Fe	Iron
		Qz	Quartz
		Py	Pyrite
	– Coatings	Cn	Clean
		Sn	Stained – no visible coating, surface is discoloured
		Vn	Veneer – visible, too thin to measure, may be patchy
		Ct	Coating ≤ 1mm thick
		Filled	Coating > 1mm thick
	– Thickness	mm.t	Defect thickness measured in millimetres