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GEOTECHNICAL INVESTIGATION REPORT

for

PROPOSED SUBDIVISION

at

49 BLACKBUTTS ROAD, FRENCHS FOREST

Prepared For

Sekisui House

Project No.: 2023-107

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TABLE OF CONTENTS

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GEOTECHNICAL SITE INVESTIGATION AND ASSESSMENT REPORT
PROPOSED SUBDIVISION
49 BLACKBUTTS ROAD, FRENCHS FOREST

1. INTRODUCTION:

This report details the results of a geotechnical investigation carried out at 49 Blackbutts Road, Frenchs Forest, NSW for a proposed sub-division and re-development of the property. The investigation was undertaken by Crozier Geotechnical Consultants (CGC) at the request of Sekisui house.

It is understood that the site is proposed to be subdivided into 12 dwelling lots with an access road formed adjacent to the western side boundary providing access from Warili Road. The development works appear to involve up to 2.50m depth of excavation and up to 2.50m depth of fill in small areas of the site, with earthworks generally limited to ≤1.00m depth of cut or fill, especially adjacent to the larger development sites property boundaries.

This report includes a description of field work including a site description, plan showing test locations, the results of geotechnical investigation and provides an assessment of potential risk related to excavation and fill placement along with design and construction recommendations.

The site is located within Northern Beaches Council's jurisdiction and is subject to the Warringah LEP 2011 along with the relevant policies. The site is classified under the LEP within Landslip Risk Map – Sheet LSR_007 as being dominantly within risk 'Class A' with the eastern and western edges for the southern half classified as 'Class B'. The site is not considered impacted by Acid Sulfate Soils (Sheet ASS_007).

The site investigation comprised:

a) Drilling of five boreholes using a restricted access drilling rig with Dynamic Cone Penetrometer (DCP) tests adjacent to the boreholes and additional two locations.
b) Site inspection/walkover
c) Onsite mark-out/clearance of test locations by registered service location contractor.

The following plans and drawings were supplied for the proposal, investigation and reporting:

- Design Drawings – Enspire, Drawing No.: 230057-00-DA-C01.01 to 230057-00-DA-C22.01, Revision: 1, Dated: 07 March 2024.
- Civil Engineering and Stormwater Report – Development Application, by Enspire, Revision: 1, Dated: 08 March 2024.
- Survey Drawing – LTS, Reference No.: 51298 – 001DT, Original Issue, Dated: 20-04-2021.

2. SITE FEATURES:

2.1. Description:

The site is located on the southern side of Blacksbutts Road and northern side of Warili Road within a gently south dipping slope. The site is a rectangular shaped block (Lot 1809, DP 752038) and has a boundary length of 162.4018m to its west, 167.724m towards its east, northern front boundary of 60.367m and has an area of 1.02 hectare, as referenced from the supplied survey drawing. An aerial photograph of the site and its surrounds is provided below (Photograph 1), as sourced from NSW Government Six Maps special data system.

Photograph 1: Aerial photo of the site (outlined red)

Blackbutts Road has a bitumen paved surface and is separated from the site by concrete kerb, concrete footpath pavement and vegetation. Blackbutts Road is near level, however Lionel Watts Reserve, which is located on the northern side of the road is gently north dipping indicating Blackbutts Road is located on/adjacent to a ridge crest. The road and concrete pavement were observed with variable cracking and deformations, however there were no indications of large scale or deep seated movement.

The site is occupied by numerous brick building structures scattered throughout the property with bitumen paved driveway and parking areas. Generally low, dry stacked stone walls are scattered throughout the block supporting the terraced landscape of the site as seen in Photograph 2. Furthermore, the site has moderate vegetation within gardens with tall trees predominantly towards the front as seen in Photograph 3. The site's building structures were constructed in early 1970's (approx. 50 years of age) and appeared to be in a good condition without signficant cracks or deformation to indicate large scale or deep-seated instability. However, the pavements within the site and the garden walls contained cracks and deformation, which is considered to be due to age and use.

	
Photograph 2: View of the supporting wall, looking northwest	*Photograph 3: View of the site looking north*

Interpreted sandstone boulders were observed predominantly towards the middle of the site, all appeared to be in a stable condition as seen in Photograph 4.

Photograph 4: View of the interpreted sandstone boulders, looking north

From information provided by an owner of a neighbouring property, it is understood that a pond used to be located towards the front side of the site (in an area currently consisting of moderate to dense vegetation and grass). Historical photos were not able to support the provided information.

The properties towards the west (51 Blackbutts Road, 3 – 11 Malbara Cres) and east (47 Blackbutts Road, 2 – 4 Yanina Place, 2 – 4 Rikara Place) contained of one and two-storey residential dwelling which were separated from the site by metal and timber fences. The properties have similar elevations as the site and the neighbouring properties structures were observed without signs of majors cracks or deformation.

The neighbouring properties towards the south (21, 21A and 23Warili Road) contained one and two-storey residential dwellings within each property surrounded by lawns and gardens and were separated by timber fences. The properties were situated at a lower elevation by approximately 0.50m sites abutting the site, due to being down slope. The neighbouring property structures were observed without signs of major cracks or deformation.

2.2. Geology:

Reference to the Sydney 1:100,000 Geological Series sheet (9130) indicates that the site is located adjacent to a geological boundary and may be underlain a shale subgroup (Rhs) within the Hawkesbury Sandstone (Rh). The upper unit was deposited in the Middle Triassic and comprises shale and laminate with iron rich band along with soft to fine clays and high groundwater flows. The shale bedrock is prone to weather at the surface to clays of medium to high plasticity. Underlying this unit the sandstone comprises medium to coarse grained quartz sandstone with minor lenses of shale and laminite. An extract of the relevant Geology Series Sheet is provided below with the site (in red) indicated.

Extract 1: Extract from the 9030 Geology Series Map.

3. INVESTIGATION:

3.1. Methods:

The field investigation comprised site inspection/mapping and a subsurface investigation which were both undertaken/supervised by a Geotechnical Engineer. The subsurface investigation comprised the drilling of five, solid stem, spiral flight auger boreholes (BH1 to BH5) using a restricted access drilling rig on 2nd June 2023. Prior to commencement of drilling, clearance of test locations by an accredited service locator was undertaken.

DCP testing was carried out from ground surface adjacent to the boreholes and at two additional select locations in accordance with AS1289.6.3.2 – 1997, "Determination of the penetration resistance of a soil – 9kg Dynamic Cone Penetrometer".

Soil samples were recovered from the auger for geotechnical logging purposes which was undertaken in accordance with AS1726:2017 'Geotechnical Site Investigations'. At completion of drilling, the boreholes were backfilled with arisings and surface compacted.

Explanatory notes are included in Appendix: 1. Mapping information are shown on Figure: 1, along with detailed Borehole Log Report and Dynamic Penetrometer Test Sheet in Appendix: 2.

3.2. Ground Conditions:

For a description of the subsurface conditions encountered at individual borehole locations, the Borehole Log Report and Dynamic Penetrometer Test Sheet should be consulted, however a very broad description is provided below.

- **TOPSOIL/FILL** – Topsoil/fill was encountered in all boreholes to a maximum depth of approximately 1.0m (BH2 and BH3) and comprised fine grained sand trace gravels and vegetation.
- **CLAY** – Underlying the topsoil/fill moist, low to medium plasticity clay soil was encountered within BH3 and BH2 (in the south-east corner) at 1.00m depth. The clay was of 'stiff' consistency in both the test locations to its maximum depth of 1.60m below ground surface level.
- **Silty CLAY** - Underlying the topsoil/fill dry, low to medium plasticity silty clay soil was encountered within BH1 and BH5 (at the northern end of the site). The silty clay was encountered as 'soft' from 0.90m depth within BH5 to 1.70m before becoming 'very stiff' and then 'hard' below 2.80m. The silty clay was 'hard' consistency from 0.80m depth within BH1 to a maximum investigated depth of 2.20m.
- **BEDROCK** – Based on the boreholes and DCP test results, bedrock of at least very low strength was encountered at a minimum depth of 0.95m from BH4 (south-west corner) increasing to 2.20m depth at the north-east corner of the site (BH1). Bedrock was not encountered to 4.50m depth within test location BH5/DCP5 at the northern boundary, however, it is anticipated the test location may have been conducted within the historical pond and may not be representative.

A free-standing ground water table was not identified within any of the boreholes. However, minor seepage was encountered within BH3 and BH4 at bedrock interface and is anticipated to increase during wet weather.

4. GEOTECHNICAL DISCUSSION:

4.1. Geotechnical Assessment:

The investigation identified the site is underlain by sandy fill soils that contained no signs of deleterious material to around 1.0m depth underlain by predominately natural/residual clay soils of low to medium plasticity. Beside BH5/DCP5, the natural clay soil was 'generally 'very stiff' to 'hard' consistency within the test locations with very low strength bedrock interpreted from 0.95m depth to 2.20m depth below existing ground surface levels in most of the site. The sandstone bedrock is anticipated to increase to low and then medium strength quickly within intersection whilst boulders which were identified near surface in some locations are also likely to be low to medium strength.

There were no indications of a groundwater table underlying the site within the depth of investigation and it is not anticipated within the depth of proposed works based on site location/topography. However, seepage was encountered within BH3 and BH4 from 1.30m depth (R.L 155.4m) and 0.90m depth (R.L 158.7m) respectively and is expected in numerous locations both overlying residual clay soils and overlying the bedrock surface.

The indicated pond at the northern end of the site was not identified/confirmed during investigation, however this structure could result in increased depths of soils (as seen in BH5), softened clay soils and/or increased volumes of ground water during construction. As such, it is recommended that further investigation into this potential structure is completed to guide design and construction. Further, more detailed investigation is also recommended across the site to guide design and construction of individual retention systems and structures including the access road.

There were no signs of previous or potential landslide hazards within the current site at the time of investigation. The investigation did not identify any significant geotechnical hazards which may impact the proposed sub-division and subsequent construction of residential dwellings.

It is understood that all the existing site structures are proposed to be demolished for a subdivision that will comprise 13 individual lots of land, with 1 used for a new access road and the other 12 used for residential dwelling development.

To facilitate the sub-division and construction of the individual building lots, the site will be cleared, levelled and terraced. The works appear to generally require excavation or filling of ≤ 1.0m depth/height compared to existing ground surface levels however in a small part the excavation will increase up to approximately 2.50m depth whilst filling up to 3.0m depth appears required to create level terraces. No bulk excavation >0.50m depth appears proposed at the larger site's external boundaries, adjacent to neighbouring properties.

Based on the geological and geotechnical conditions identified, the majority of any required excavation will extend through topsoil/fill, clay and silty clay soils with limited bedrock excavation anticipated. However, as the bedrock surface is expected to be highly irregular and at times covered in boulders this could vary in parts. Provided sensible excavation methodologies and equipment are utilized the risk to neighbouring properties or structures from excavation induced instability or from ground vibration impact is considered 'Very Low' (AGS 2007).

The site is proposed to be cleared for proposed subdivision following the demolition of the existing structures. Removal of existing supporting or retaining structures could lead to erosion/instability in supported soils and contribute to future hazards if care is not taken. Therefore, new supporting walls adjacent to property boundaries should replace any existing supporting walls. This will require a case by case assessment by the structural and geotechnical engineers, which may determine pre-removal support requirements.

For permanent boundary retention it is recommended that engineered concrete wall systems are implemented to ensure stability at lot boundaries for the design life of the new residential dwellings, taken as at least 50 years. Timber retention systems are not recommended as these structures have limited design life for stability and deterioration.

Removal of the trees and vegetation within the site (along with demolition of existing structures and services) can affect the underlying soil strength (i.e loosen the soils, allow increase stormwater penetration and softening) therefore, care should be taken after the removal of site vegetation/structures to minimize the erosion of site soils whilst any shallow/clay based footing development works will require assessment of the foundation conditions prior to design and construction.

Boulders were identified at or underlying the existing ground surface, predominantly towards the front north of the site. The boulders that were observed during the site investigation appeared to be stable and did not arise any concerns, however following the demolition and clearance of the site structures any exposed boulders will need to be geotechnically inspected to assess their need for stabilization or removal.

Groundwater was not encountered during the investigation and a groundwater table will not be intersected or impacted as a result of the proposed works. However, seepage is likely to be encountered at the bedrock interface during excavation work. The 'erosion and sediment control plan' indicates a sump at the southern end of the site, formed through shallow excavation whilst stockpiling is proposed near the north-east corner of the site. These locations are considered suitable for these activities provided all excavation/fill is formed as per the stable temporary batters detailed within this report.

The proposed subdivision and future dwelling construction works are considered suitable for the site and may be completed with negligible impact to existing nearby structures within the site or on neighbouring properties provided the recommendations of this report and any future development specific reporting are implemented in the design and construction phases.

The recommendations and conclusions in this report are based on an investigation utilising only surface observations and isolated boreholes. This test equipment provides limited data from small, isolated test points across the area of proposed works site. Therefore, some minor variation to the interpreted sub-surface conditions is possible, especially between test locations. However, the results of the investigation provide a reasonable basis for assessment and subsequent preliminary design of the proposed works.

4.2. Site Specific Risk Assessment:

The proposed works involve bulk excavation of topsoil, fill and natural soils as well as some potential very low to medium strength sandstone to allow for the construction of the road and individual building lot terraces. These excavations are limited at the site boundary (<0.50m depth) and only increase to heights at which hazards may develop in small areas within the central portions of the site. Therefore, the potential for instability impacting adjacent neighbouring properties is 'Unlikely to Rare' whilst geotechnical inspection during excavation can ensure that the potential for instability impacting the site itself remains 'Unlikely'.

The use of fill to isolated areas is proposed to occur behind retaining walls to create the level building lot terraces. Whilst some of this fill will occur adjacent to individual lot boundaries an the larger site boundary the works are proposed behind retaining walls therefor the potential for failure is 'Rare'.

The primary hazard is considered as:

A. Landslip (earth rock slide) following excavation or filling for lot terraces (<5m^3)

The hazard has been assessed in accordance with the methods of the Australian Geomechanics Society (Landslide Risk Management, AGS Subcommittee, May 2002 and March 2007), see Tables: A and B, Appendix: 3.

The Australian Geomechanics Society Qualitative Risk Analysis Matrix is enclosed in Appendix: 4 along with relevant AGS notes and figures. The frequency of failure was interpreted from existing site conditions and previous experience in these geological units.

The **Risk to Life** from **Hazard A** was estimated to be **6.25×10^{-8}** for a single person, whilst the **Risk to Property** from the hazards were considered to be **'Very Low'**.

The risk to life and property levels are considered to be 'Acceptable' against the AGS Guidelines, and the assessments were based on the 'worst case scenario' of excavations with no support or planning and non-engineered retention systems. As such, the project is considered suitable for the site provided the recommendations of this report and sensible engineering design and construction are implemented.

4.3 Design & Construction Recommendations:

Preliminary recommendations for Design and Construction are provided below for use in preliminary concept design only. Should new developments be proposed, a project specific geotechnical investigation report would be required.

4.3.1. New Footings:	
Site Classification as per AS2870 – 2011	Class 'S' due to presence of clay (potential variation at the front of the site – requires confirmation for individual lots)
Sub-grade material and Maximum Allowable Bearing Capacity*	- Stiff Clay: 100kPa - Very Stiff Clay: 200kPa - Hard Clay: 400kPa - Very Low Strength bedrock: 800kPa - Low Strength Sandstone: 1000kPa*
Site sub-soil classification as per *Structural design actions AS1170.4 – 2007, Part 4: Earthquake actions in Australia*	B_e (Rock site)

Remarks:

*All bearing pressures subject to geotechnical inspection during construction.

All new footings should be founded within residual clay or weathered bedrock of similar strength for each structure unless footings are designed to accommodate some differential movement.

All new footings must be inspected by an experienced geotechnical professional before concrete or steel are placed to verify their bearing capacity and the in-situ nature of the founding strata. This is mandatory to allow them to be 'certified' at the end of the project.

4.3.2. Excavation:

Property Separation:

The table below shows the properties potentially affected by the proposed excavation, excavation depths and the separation distances to the shared property boundary/structure.

Table 1: Property Separation Distances

Boundary	**Property**	**Structure**	**Bulk Excavation Depth (m bgl)**	**Separation Distances (m)***	
				Boundary	**Structure**
North	Blackbutts Road	Road reserve footpath	≤ 0.50	0.0m	+0.50m from boundary
East	3 – 4 Rickara Place	Residential dwellings	≤2.00	10	+ 1.0
South	19, 21, 21A and 23Warili Road	Residential dwellings	≤2.00	15	+ 5.0
West	9, 11 Malbara Cres	Residential dwellings	≤2.00	5.0	+ 5.0

Safe batter slopes appear possible for all of the proposed excavations due to the depths and separation distances to the site boundaries. The below recommended temporary batter slopes are provided for short term (< 6 month) within the site during excavation where the toe of the batter slope does not fall within the influence zone of neighbouring properties/structures or services, given as a 45º plane below the site boundaries, invert, founding level.

Guidelines for un-surcharged batter slopes for this site are tabulated below:

Material	Safe Batter Slope (H:V)*	
	Short Term/Temporary	Long Term/Permanent
Uncontrolled Fill	2.0:1.0	2.5:1.0*
Controlled Fill	1.5:1.0	2.0:1.0*
Clay (Stiff to hard, un-fissured)	1.5:1.0	2.0:1.0*
Very Low strength bedrock	0.25:1.0*	0.5:1.0*

*Dependent on assessment by geotechnical specialist.

Remarks:

Seepage and surface stormwater flow impacts can reduce the stability of batter slopes and invoke the need to implement additional support measures whilst ponding of water must be prevented behind crests and at the base of batter slopes. Where safe batter slopes are not implemented, the stability of the excavation cannot be guaranteed until permanent support measures are installed. This should also be considered with respect to safe working conditions. Batter slopes should not be left unsupported without geotechnical inspection and approval.

Equipment for Excavation	Fill and Residual soils	Excavator with bucket
	Bedrock	Very low strength – light ripping Low to Medium strength – hard ripping (large dozer) or rock hammer/saw/grinder.

Remarks:

Whilst not anticipated in significant volumes, some hard rock excavation may be required. Based on previous testing of ground vibrations created by various rock excavation equipment within medium strength Hawkesbury Sandstone bedrock, to achieve a low level of vibration (5mm/s PPV) the below hammer weights and buffer distances are generally required:

Maximum Hammer Weight	Required Buffer Distance from Structure
300kg	2.0m
400kg	3.0m
600kg	6.0m
≥1 tonne	Up to 20.0m

Onsite calibration and full-time vibration monitoring will provide accurate vibration levels to the site specific conditions and will generally allow for larger excavation machinery or smaller buffers to be used. Inspection of equipment and review of dilapidation surveys and excavation location is necessary to determine need for full time monitoring.

Recommended Vibration Limits (Maximum Peak Particle Velocity (PPV))	Neighbouring residential dwellings = 5mm/s
Full Time Vibration Monitoring Assessment Required	Where hard rock excavation is required and larger scale (i.e. rock hammer >500kg) excavation equipment is proposed.
Geotechnical Inspection Requirement	Yes, recommended that these inspections be undertaken as per below mentioned sequence: • Inspection of temporary and permanent batter slopes, • During excavation of rock • At completion of the excavation, • Prior to pouring concrete for footings, • Where ground conditions which do not conform to Paragraph 4.1 of this report are encountered.
Dilapidation Surveys Requirement	Recommended on neighbouring structures or parts thereof within 10m of any rock excavation perimeter prior to site work to allow assessment of the recommended vibration limit and protect the client against spurious claims of damage.

4.3.3. Retaining Structures:	
Required	To support fill along the southern sides of individual lot terraces and may be required adjacent to the access road pending depth of excavation and material encountered or neighbouring property boundaries.
Types	Post excavation or pre-filling engineered concrete retention systems designed in accordance with Australian Standard AS 4678-2002 Earth Retaining Structures.

Parameters for calculating unsurcharged pressures acting on retaining walls for the materials likely to be retained:

Material	Unit Weight (kN/m3)	Undrained cohesion (kPa)	Long Term (Drained)	Earth Pressure Coefficients		Passive Earth Pressure Coefficient *
				Active (Ka)	At Rest (K_0)	
Fill/Sandy Soils (uncompacted)	18	0	$\Phi' = 25°$	0.41	0.57	N/A
Fill (engineered/compacted)	22	0	$\phi' = 30°$	0.33	N/A	3.00
Clay Soils (stiff)	20	50	$\phi' = 28°$	0.36	0.50	2.00
Clay Soils (very stiff to hard)	20	150	$\phi' = 30°$	0.33	0.50	3.00
VLS bedrock	23	N/A	$\phi' = 35°$	0.10	0.15	300kPa

Remarks:

In suggesting these parameters, it is assumed that the retaining walls will be fully drained with suitable subsoil drains provided at the rear of the wall footings. If this is not done, then the walls should be designed to support full hydrostatic pressure in addition to pressures due to the soil backfill. It is suggested that the retaining walls should be back filled with free-draining granular material (preferably not recycled concrete) which is only lightly compacted in order to minimize horizontal stresses. The retaining walls should be designed using a triangular stress distribution.
Retaining structures near site boundaries or existing structures should be designed with the use of at rest (K_0) earth pressure coefficients to reduce the risk of movement in the excavation support and resulting surface movement in adjoining areas. Backfilled retaining walls within the site, away from site boundaries or existing structures, that may deflect can utilise active earth pressure coefficients (Ka).

4.3.4 Fill

The site won soils are generally sandy, though some silt component may exist in topsoil and fill soils near surface. Silty soils are not recommended for use as engineered fill and should be stockpiled for use as topsoil's or similar.

The underlying clay soils could be utilized as fill within this site, however their compaction characteristics will need to be confirmed prior to use and a methodology determined to ensure compaction is achieved to the specifications. This will require collection and laboratory analysis of samples.

However, it is recommended that a crushed sandstone (or similar granular fill) be utilized due to its reduced conditioning requirements and excellent drainage and compaction characteristics that can be achieved.

Due to the proposed terracing, it may be more practical to completed large scale fill placement and compaction across site prior to excavating terraces through the fill and constructing retention systems at lot boundaries. This will allow larger more cost effective equipment use and ensure consistent compaction throughout the fill, otherwise compaction adjacent to installed retaining walls will need to be undertaken with reduced compactive effort to ensure protection of the retention systems

Any fill that is used to support structure loads/on ground slabs etc. should be controlled (i.e., placed in layers not exceeding 250mm loose thickness pending equipment size) and uniformly compacted to an appropriate engineering specification. It is suggested that a minimum dry density ratio of 95% (Standard) be adopted within building areas.

Proof rolling, with a ≥12t roller, of the exposed sub-grade should under geotechnical inspection to assist in identification of soft/over wet soils/areas and modifications prior to fill placement.

Fill should be placed in layers with loose thickness of 100mm (2t) to 250mm (12t) prior to 4 – 6 passes of the steel drum roller before placement of the next layer.

Where service trenches are excavated through fill the trench should be backfilled with similar granular fill and compacted in <100mm thick loose layers using a plate compactor or similar.

Recommended compaction levels are provided in the table below within settlement sensitive areas.

Location	Minimum Dry Density Ratio
Floor slab and Foundation Support	100% (Standard Compaction)
Access driveway sub-grade- - >500mm below sub-grade level - Top 500mm of sub-grade	 98% (Standard Compaction) 100% (Standard Compaction)
General Fill (non-structural support)	93% (Standard compaction)

Remarks:

Geotechnical testing as set out in Section 8 of Australian Standard AS3798 – 2007 *Guidelines on Earthworks for commercial and residential developments* would be required to achieve adequate control of fill placement under settlement sensitive areas.

Any fill which is over-wet, contains oversize or organic matter should be removed or treated prior to use as fill. Where the use of clay soil as structural fill is proposed (though is not recommended) it should be placed 1% - 2% wet of optimum to reduce the potential for swell on rehydration.

If indirect methods of compliance testing are adopted (e.g., Penetrometer testing), acceptance criteria should be specified by the Structural Engineer prior to testing.

It is recommended that the vegetation and topsoil layer is removed prior to placement of new fill to reduce the potential for the interface of the fill/natural soils becoming a focal point for future water flow (via blocked drainage etc).

Due to the expansive soils underlying the site, it is suggested on any ground slabs (if proposed) within the fill be fully dowelled, that joints between slabs be sealed and that slab edges should be separated from edge restraint to minimise potential damage from surface movements caused by subgrade moisture variations. Allowance should be made in design for the effect of differential slab movements (due to reactive soil behaviour) if slabs are cast over differing subgrade types (e.g., controlled fill, natural sandy clay soils)

4.3.5. Drainage and Hydrogeology		
Groundwater Table or Seepage identified in Investigation		Minor seepage only
Excavation likely to intersect	Water Table	No
	Seepage	Possible in soils above bedrock and in defects within the bedrock, likely higher following periods of rainfall.
Site Location and Topography		Southern side of road within gently south dipping topography close to a ridge crest
Impact of development on local hydrogeology		Negligible
Onsite Stormwater Disposal		Collect and discharge off-site into Council stormwater system

Remarks:
An excavation trench should be installed at the base of excavations to below floor slab levels to reduce the risk of resulting dampness issues. Trenches, as well as all new building gutters, down pipes and stormwater intercept trenches should be connected to a stormwater system designed by a Hydraulic Engineer which preferably discharges to the Council's stormwater system off site.

4.4. Conditions Relating to Design and Construction Monitoring:

To allow certification at the completion of the project it will be necessary for Crozier Geotechnical Consultants to:

1. Complete further investigation into site conditions as detailed within this report
2. Review and approve the structural design drawings, including the retaining structure design and construction methodology, for compliance with the recommendations of this report prior to construction,
3. Inspect all new footings, pavement and earthworks to confirm compliance to design assumptions with respect to allowable bearing pressure and basal cleanness prior to the placement of steel or concrete.

Crozier Geotechnical Consultants cannot provide certification for the Occupation Certificate if it has not been called to site to undertake the required inspections.

5. CONCLUSION:

The geotechnical site investigation encountered sandy fill to a maximum depth of 1.00m depth (R.L 155.7, BH3) overlying clayey soils with interpreted very low strength bedrock at a maximum augured depth of 2.20m (R.L 161.8, BH1). A historic pond may have been situated towards the northern front of the site and DCP5 test extended to 4.50m depth without encountering bedrock, potentially indicating deeper clay soils or the effects of the pond. A water table was not encountered the investigation, however seepage was encounter within the soils and at the bedrock interface.

Significant geotechnical hazards were not encountered or identified during the investigation, which may impact the proposed sub-division and subsequent construction of residential dwellings. The proposed works appear generally limited to shallow (<1.0m depth) excavations with a small isolated area of increased excavation (<2.50m depth) whilst filing is required to generally low heights, increasing behind lot boundary retention systems to create level terraces.

The risks associated with the proposed works were assessed via the methods of the AGS 2007 landslide guidelines and were determined as 'Acceptable', therefore the proposed works are considered suitable for the site.

The recommendations and conclusions in this report are based on an investigation utilising only surface observations and a limited number of auger boreholes at isolated locations. This test equipment provides limited data from small, isolated test points with limited penetration into rock, therefore some minor variation to the interpreted sub-surface conditions is possible.

It is recommended that further development specific investigation occur to allow design and construction of individual structures for the sub-division (i.e. common road and lot boundary retention systems) which may be best undertaken following clearing of the site whilst individual lot developments/structures will require further detailed investigation and development specific reporting.

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6. REFERENCES:

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2. C. W. Fetter 1995, "Applied Hydrology" by Prentice Hall. V. Gardiner & R. Dackombe 1983, "Geomorphological Field Manual" by George Allen & Unwin
3. Australian Standard AS 3798 – 2007, Guidelines on Earthworks for Commercial and Residential Developments.
4. Australian Standard AS 2870 – 2011, Residential Slabs and Footings – Construction
5. Australian Standard AS1170.4 – 2007, Part 4: Earthquake actions in Australia

Appendix 1

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NOTES RELATING TO THIS REPORT

Introduction

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

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

Description and classification Methods

The methods of description and classification of soils and rocks used in this report are based on Australian Standard 1726, Geotechnical Site Investigation Code. In general, descriptions cover the following properties - strength or density, colour, structure, soil or rock type and inclusions.

Soil types are described according to the predominating particle size, qualified by the grading of other particles present (eg. Sandy clay) on the following bases:

Soil Classification	Particle Size
Clay	less than 0.002 mm
Silt	0.002 to 0.06 mm
Sand	0.06 to 2.00 mm
Gravel	2.00 to 60.00mm

Cohesive soils are classified on the basis of strength either by laboratory testing or engineering examination.
The strength terms are defined as follows:

Classification	Undrained Shear Strength kPa
Very soft	Less than 12
Soft	12 - 25
Firm	25 – 50
Stiff	50 – 100
Very stiff	100 - 200
Hard	Greater than 200

Non-cohesive soils are classified on the basis of relative density, generally from the results of standard penetration tests (SPT) or Dutch cone penetrometer tests (CPT) as below:

Relative Density	SPT “N” Value (blows/300mm)	CPT Cone Value (Qc – MPa)
Very loose	less than 5	less than 2
Loose	5 – 10	2 – 5
Medium dense	10 – 30	5 -15
Dense	30 – 50	15 – 25
Very dense	greater than 50	greater than 25

Rock types are classified by their geological names. Where relevant, further information regarding rock classification is given on the following sheet.

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

Disturbed samples taken during drilling to allow information on colour, type, inclusions and, depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are taken by pushing a thin-walled sample tube into the soil and withdrawing a sample of the soil in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Drilling Methods
The following is a brief summary of drilling methods currently adopted by the company and some comments on their use and application.

Test Pits – these are excavated with a backhoe or a tracked excavator, allowing close examination of the insitu soils if it is safe to descent into the pit. The depth of penetration is limited to about 3m for a backhoe and up to 6m for an excavator. A potential disadvantage is the disturbance caused by the excavation.

Large Diameter Auger (eg. Pengo) – the hole is advanced by a rotating plate or short spiral auger, generally 300mm or larger in diameter. The cuttings are returned to the surface at intervals (generally of not more than 0.5m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube sampling.

Continuous Sample Drilling – the hole is advanced by pushing a 100mm diameter socket into the ground and withdrawing it at intervals to extrude the sample. This is the most reliable method of drilling soils, since moisture content is unchanged and soil structure, strength, etc. is only marginally affected.

Continuous Spiral Flight Augers – the hole is advanced using 90 – 115mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or 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, or may be collected after withdrawal of the auger flights, but they are very disturbed and may be contaminated. Information from the drilling (as distinct from specific sampling by SPT's or undisturbed samples) is of relatively lower reliability, due to remoulding, contamination or softening of samples by ground water.

Non-core Rotary Drilling - the hole is advanced by a rotary bit, with water being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from 'feel' and rate of penetration.

Rotary Mud Drilling – similar to rotary drilling, but using drilling mud as a circulating fluid. The mud tends to mask the cuttings and reliable identification is again only possible from separate intact sampling (eg. From SPT).

Continuous Core Drilling – a continuous core sample is obtained using a diamond-tipped core barrel, usually 50mm internal diameter. Provided full core recovery is achieved (which is not always possible in very weak rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation.

Standard Penetration Tests

Standard penetration tests (abbreviated as SPT) are used mainly in non-cohesive soils, but occasionally also in cohesive soils as a means of determining density or strength and also of obtaining a relatively undisturbed sample. The test procedures is described in Australian Standard 1289, "Methods of Testing Soils for Engineering Purposes" – Test 6.3.1.

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

The test results are reported in the following form.

- In the case where full penetration is obtained with successive blow counts for each 150mm of say 4, 6 and 7
  as 4, 6, 7 then N = 13
- In the 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 then as 15, 30/40mm.

The results of the test can be related empirically to the engineering properties of the soil. Occasionally, the test method is used to obtain samples in 50mm diameter thin wall sample tubes in clay. In such circumstances, the test results are shown on the borelogs in brackets.

Cone Penetrometer Testing and Interpretation

Cone penetrometer testing (sometimes referred to as Dutch Cone – abbreviated as CPT) described in this report has been carried out using an electrical friction cone penetrometer. The test is described in Australia Standard 1289, Test 6.4.1.

In tests, a 35mm diameter rod with a cone-tipped end is pushed continually into the soil, the reaction being provided by a specially designed truck or rig which is fitted with an hydraulic ram system. Measurements are made of the end bearing resistance on the cone and the friction resistance on a separte 130mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are connected buy electrical wires passing through the centre of the push rods to an amplifier and recorder unit mounted on the control truck.

As penetration occurs (at a rate of approximately 20mm per second) their information is plotted on a computer screen and at the end of the test is stored on the computer for later plotting of the results.

The information provided on the plotted results comprises: -

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

There are two scales available for measurement of cone resistance. The lower scale (0 – 5 MPa) is used in very soft soils where increased sensitivity is required and is shown in the graphs as a dotted line. The main scale (0 – 50 MPa) is less sensitive and is shown as a full line. The ratios of the sleeve friction to cone resistance will vary with the type of soil encountered, with higher relative friction in clays than in sands. Friction ratios 1% - 2% are commonly encountered in sands and very soft clays rising to 4% - 10% in stiff clays.

In sands, the relationship between cone resistance and SPT value is commonly in the range: -

Q_c (MPa) = (0.4 to 0.6) N blows (blows per 300mm)

In clays, the relationship between undrained shear strength and cone resistance is commonly in the range: -

$Q_c = (12 \text{ to } 18)\ C_u$

Interpretation of CPT values can also be made to allow estimation of modulus or compressibility values to allow calculations of foundation settlements.

Inferred stratification as shown on the attached reports is assessed from the cone and friction traces and from experience and information from nearby boreholes, etc. This information is presented for general guidance, but must be regarded as being to some extent interpretive. The test method provides a continuous profile of engineering properties, and where precise information on soil classification is required, direct drilling and sampling may be preferable.

Dynamic Penetrometers

Dynamic penetrometer tests are carried out by driving a rod into the ground with a falling weight hammer and measuring the blows for successive 150mm increments of penetration. Normally, there is a depth limitation of 1.2m but this may be extended in certain conditions by the use of extension rods.

Two relatively similar tests are used.

- Perth sand penetrometer – a 16mm diameter flattened rod is driven with a 9kg hammer, dropping 600mm (AS1289, Test 6.3.3). The test was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.
- Cone penetrometer (sometimes known as Scala Penetrometer) – a 16mm rod with a 20mm diameter cone end is driven with a 9kg hammer dropping 510mm (AS 1289, Test 6.3.2). The test was developed initially for pavement sub-grade investigations, and published correlations of the test results with California bearing ratio have been published by various Road Authorities.

Laboratory Testing

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

Borehole Logs

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

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

Details of the type and method of sampling are given in the report and the following sample codes are on the borehole logs where applicable:

D	Disturbed Sample	E	Environmental sample	DT	Diatube
B	Bulk Sample	PP	Pocket Penetrometer Test		
U50	50mm Undisturbed Tube Sample	SPT	Standard Penetration Test		
U63	63mm " " " " "	C	Core		

Ground Water

Where ground water levels are measured in boreholes there are several potential problems:

- In low permeability soils, ground water although present, 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. They may not be the same at the time of construction as are indicated in the report.
- The use of water or mud as a drilling fluid will mask any ground water inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water observations are to be made. More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be interference from a perched water table.

Engineering Reports

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

Every care is taken with the report as it relates to interpretation of subsurface condition, 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 depend partly on bore spacing and sampling frequency,
- changes in policy or interpretation of policy by statutory authorities,
- the actions of contractors responding to commercial pressures,

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

Site Anomalies

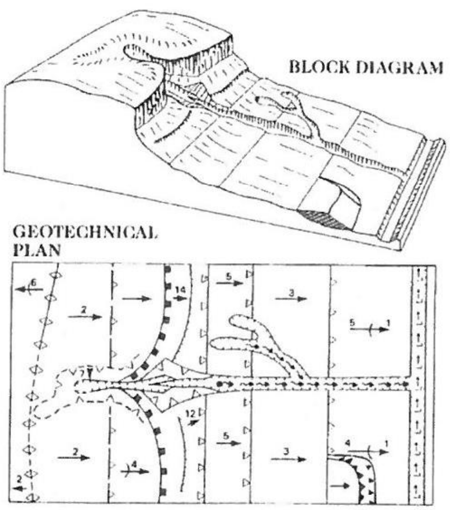
In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, the Company requests that it immediately be notified. Most problems are much more readily resolved when conditions are exposed than at some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

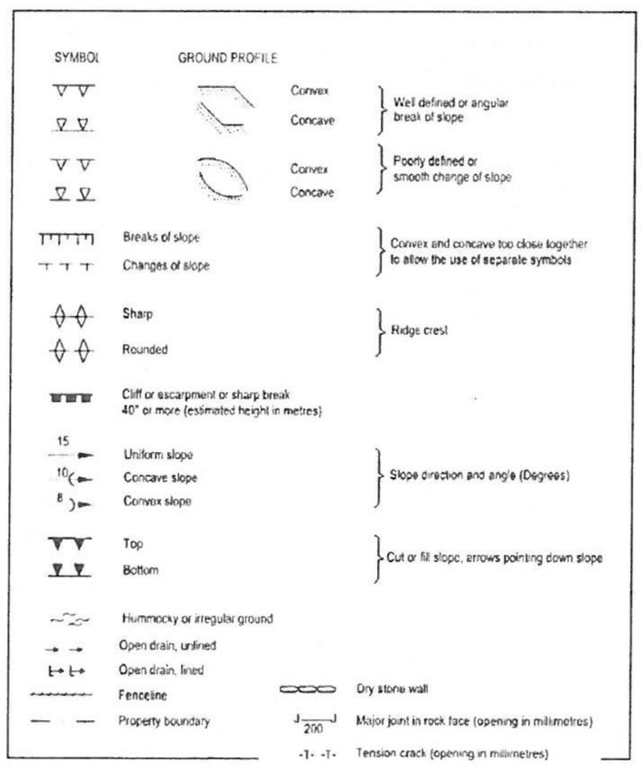
Reproduction of Information for Contractual Purposes

Attention is drawn to the document "Guidelines for the Provision of Geotechnical Information in Tender Documents", published by the Institution of Engineers Australia. Where information obtained from this investigation is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a special ally 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.

Site Inspection

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

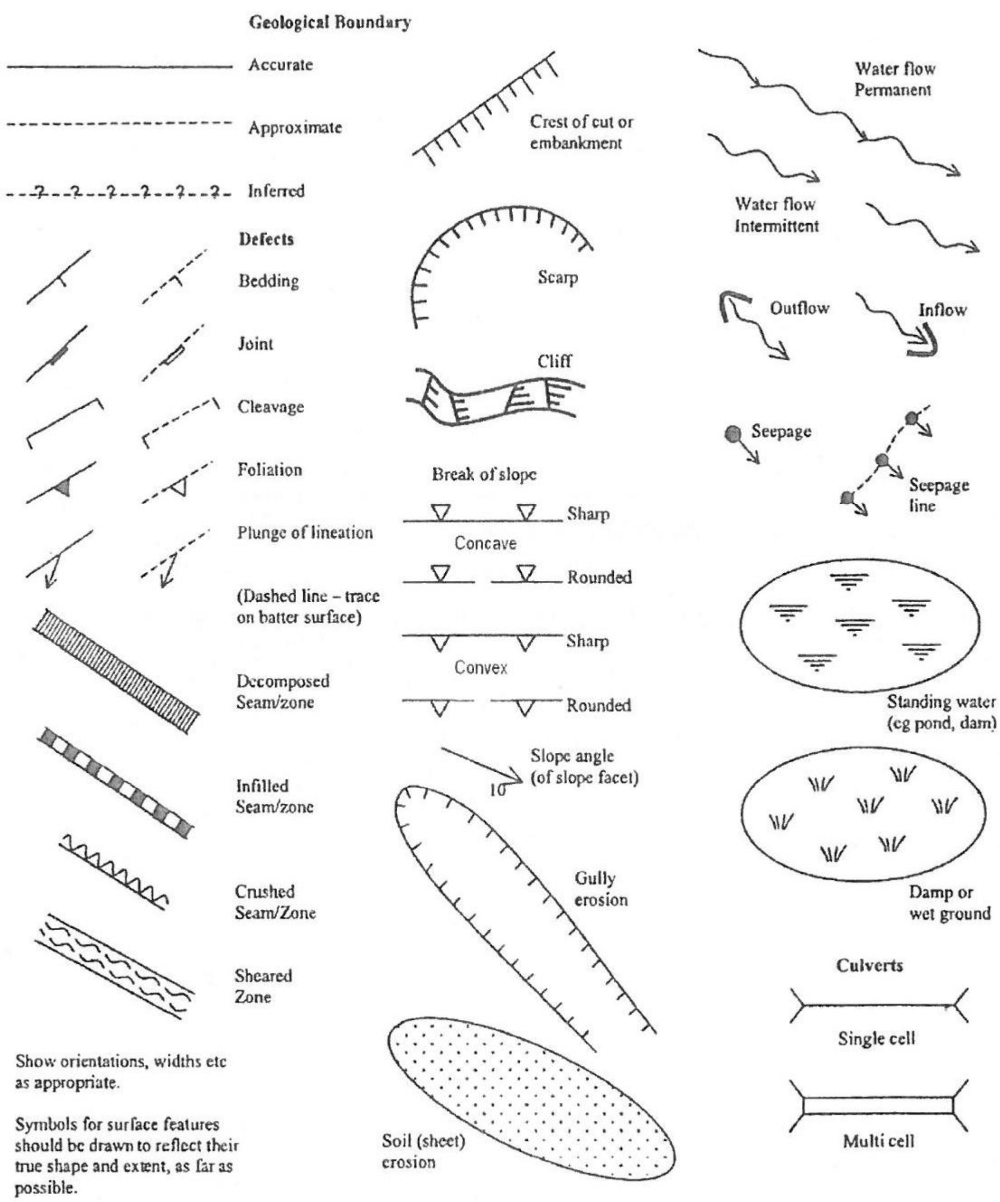




Example of Mapping Symbols

(after V Gardiner & R V Dackombe (1983).Geomorphological Field Manual. George Allen & Unwin).

APPENDIX E - GEOLOGICAL AND GEOMORPHOLOGICAL MAPPING SYMBOLS AND TERMINOLOGY



Examples of Mapping Symbols (after Guide to Slope Risk Analysis Version 3.1 November 2001, Roads and Traffic Authority of New South Wales).

Appendix 2

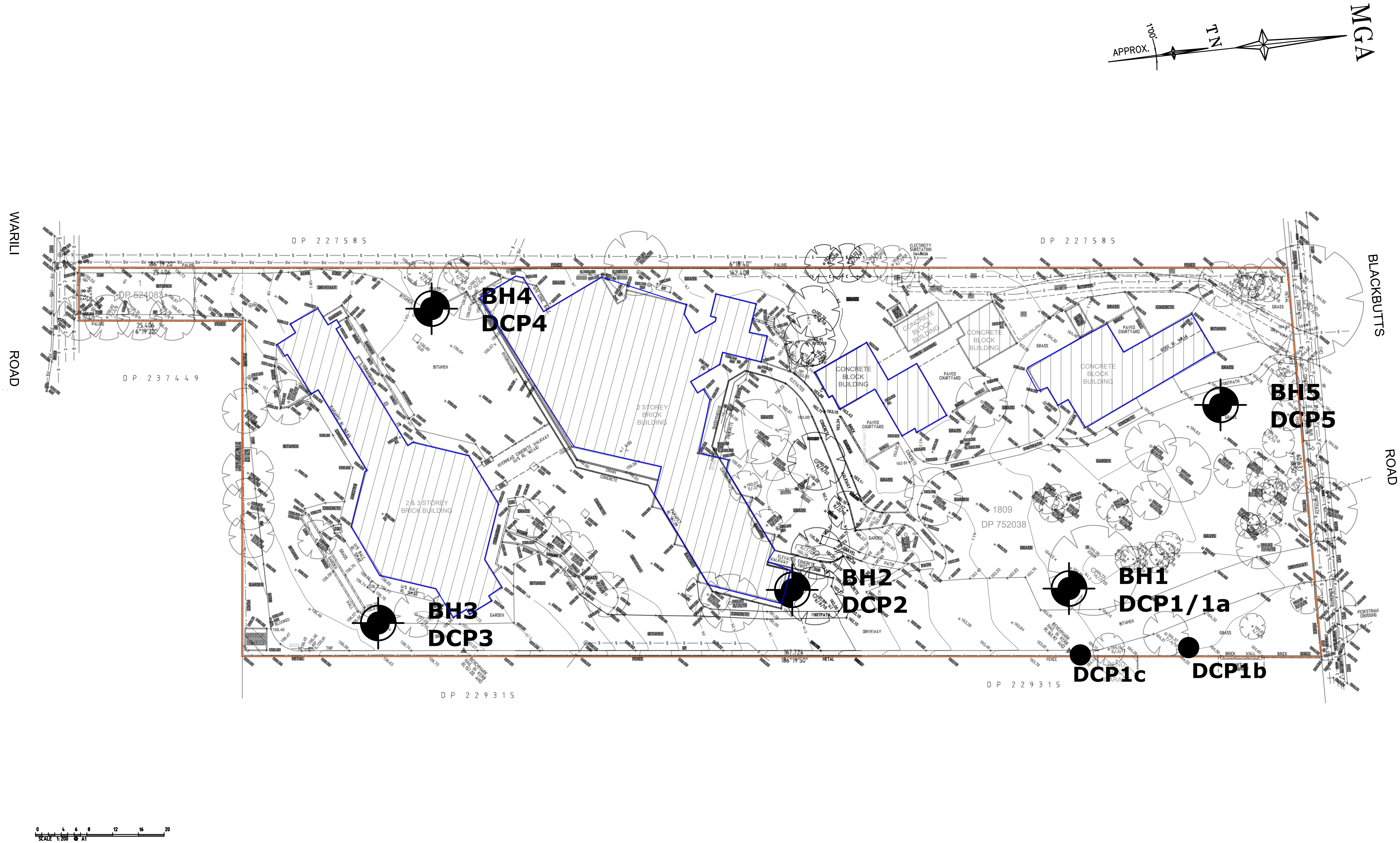


FIGURE 1.

CROZIER
GEOTECHNICAL CONSULTANTS

Crozier Geotechnical
Unit 12, 42-46 Wattle Road
Brookvale NSW 2100

ABN: 96 113 453 624
Phone: (02) 9939 1882
Fax: (02) 9939 1883

Crozier Geotechnical is a division of PJC Geo-Engineering Pty Ltd

LEGEND

BH DCP	AUGER / DYNAMIC CONE PENETROMETER LOCATION
DCP	DYNAMIC CONE PENETROMETER
(blue line)	EXISTING STRUCTURES
(orange dashed line)	PROPERTY BOUNDARY

DRAWING:	FIGURE 1
DATE:	06/2023
APPROVED BY:	TMC
DRAWN BY:	PS
PROJECT:	2023-107

PREPARED FOR:
SEKISUI HOUSE

ADDRESS:
49 Blackbutts Road, Frenchs Forest

BOREHOLE LOG

CLIENT: Sekisui House | **DATE:** 2/06/2023 | **BORE No.:** 1

PROJECT: Subdivision of the site | **PROJECT No.:** 2023-107 | **SHEET:** 1 of 1

LOCATION: 49 Blackbutts Road, Frenchs Forest | **SURFACE LEVEL:** R.L 164

Depth (m)	Classification	Description of Strata PRIMARY SOIL - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling Type	Sampling Tests	In Situ Testing Type	In Situ Testing Results
0.00		TOPSOIL/FILL: Dark brown, fine grained, moist sandy fill				
0.50		… becoming pale brown				
0.80	CI/CM	Silty CLAY: Hard, orange, low to medium plasticity, dry silty clay				
1.00						
1.30		… becoming reddish brown with sub rounded ironstone gravels				
			D	1.50 1.60		
2.00						
2.20		AUGER REFUSAL at 2.20m depth on interpreted very low strength sandstone bedrock				

RIG: k9-4 Dingo mini-digger with Ezi-probe drill mast

DRILLER: P.S

METHOD: Solid stem spiral flighted auger with tungsten carbide bit

LOGGED: P.S

GROUND WATER OBSERVATIONS: Not Encountered

REMARKS: N/A

CHECKED: B.T

BOREHOLE LOG

CLIENT: Sekisui House **DATE:** 2/06/2023 **BORE No.:** 2

PROJECT: Subdivision of the site **PROJECT No.:** 2023-107 **SHEET:** 1 of 1

LOCATION: 49 Blackbutts Road, Frenchs Forest **SURFACE LEVEL:** R.L 161

Depth (m)	Classification	Description of Strata **PRIMARY SOIL** - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling		In Situ Testing	
			Type	Tests	Type	Results
0.00		TOPSOIL/FILL: Dark brown, fine grained, moist sandy fill				
0.60		… becoming pale brown with clay				
0.80		… trace ironstone gravels				
1.00	CM	CLAY: Stiff, pale brown to reddish brown, medium plasticity, moist clay				
1.30		AUGER REFUSAL at 1.30m on interpreted very low strength sandstone bedrock				
2.00						

RIG: k9-4 Dingo mini-digger with Ezi-probe drill mast DRILLER: P.S

METHOD: Solid stem spiral flighted auger with tungsten carbide bit LOGGED: P.S

GROUND WATER OBSERVATIONS: Not Encountered

REMARKS: N/A CHECKED: B.T

BOREHOLE LOG

CLIENT: Sekisui House **DATE:** 2/06/2023 **BORE No.:** 3

PROJECT: Subdivision of the site **PROJECT No.:** 2023-107 **SHEET:** 1 of 1

LOCATION: 49 Blackbutts Road, Frenchs Forest **SURFACE LEVEL:** R.L 156.7

Depth (m)	Classification	Description of Strata PRIMARY SOIL - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling		In Situ Testing	
			Type	Tests	Type	Results
0.00		TOPSOIL/FILL: Dark brown, fine grained, moist sandy fill				
1.00		CLAY: Stiff, brown, low to medium plasticity, moist, clay				
1.30		… becoming moist to wet	D	1.30		
1.50		AUGER REFUSAL at 1.50m depth on interpreted very low strength sandstone bedrock		1.50		
2.00						

RIG: k9-4 Dingo mini-digger with Ezi-probe drill mast DRILLER: P.S

METHOD: Solid stem spiral flighted auger with tungsten carbide bit LOGGED: P.S

GROUND WATER OBSERVATIONS: Not Encountered

REMARKS: N/A CHECKED: B.T

BOREHOLE LOG

CLIENT: Sekisui House **DATE:** 2/06/2023 **BORE No.:** 4

PROJECT: Subdivision of the site **PROJECT No.:** 2023-107 **SHEET:** 1 of 1

LOCATION: 49 Blackbutts Road, Frenchs Forest **SURFACE LEVEL:** R.L 159.6

Depth (m)	Classification	Description of Strata **PRIMARY SOIL** - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling		In Situ Testing	
			Type	Tests	Type	Results
0.00		TOPSOIL/FILL: Brown to pale brown, fine to medium, moist sandy fill with gravels				
0.90		… becoming wet				
0.95		AUGER REFUSAL at 0.95m depth on interpreted very low strength sandstone bedrock				
1.00						
2.00						

RIG: k9-4 Dingo mini-digger with Ezi-probe drill mast — DRILLER: P.S

METHOD: Solid stem spiral flighted auger with tungsten carbide bit — LOGGED: P.S

GROUND WATER OBSERVATIONS: Not Encountered

REMARKS: N/A — CHECKED: B.T

BOREHOLE LOG

CLIENT: Sekisui House | **DATE:** 2/06/2023 | **BORE No.:** 5

PROJECT: Subdivision of the site | **PROJECT No.:** 2023-107 | **SHEET:** 1 of 1

LOCATION: 49 Blackbutts Road, Frenchs Forest | **SURFACE LEVEL:** R.L 164.75

Depth (m)	Classification	Description of Strata **PRIMARY SOIL** - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling		In Situ Testing	
			Type	Tests	Type	Results
0.00		TOPSOIL/FIL: Dark brown to dark grey fine grained, moist sandy fill				
0.40		… becoming brown				
0.70		… trace ironstone gravels				
0.90	CL/CM	Silty CLAY: Soft, orange, low to medium, dry silty clay				
1.00			D	1.00 1.10		
1.85		AUGER REFUSAL at 1.85m depth within interpreated hard clay				
2.00						

RIG: k9-4 Dingo mini-digger with Ezi-probe drill mast | DRILLER: P.S

METHOD: Solid stem spiral flighted auger with tungsten carbide bit | LOGGED: P.S

GROUND WATER OBSERVATIONS: Not Encountered

REMARKS: N/A | CHECKED: B.T

DYNAMIC PENETROMETER TEST SHEET

CLIENT: Sekisui House
DATE: 2/06/2023
PROJECT: Subdivision of the site
PROJECT No.: 2023-107
LOCATION: 49 Blackbutts Road, Frenchs Forest
SHEET: 1 of 2

	Test Location									
Depth (m)	1	1a	1b	1c	2	2a	3	4	5	
0.00 - 0.10	2	1	2	5	2	1	1	1	1	
0.10 - 0.20	4	3	6	4	10	4	2	13	2	
0.20 - 0.30	3	2	4	9	8 (B) at 0.30m	7	5	7	2	
0.30 - 0.40	2	0	13	5 (B) at 0.30m		7	9	5	5	
0.40 - 0.50	5	4	12			7	6	3	3	
0.50 - 0.60	10	5	13 (B) at 0.50m			9	14	4	1	
0.60 - 0.70	10	9				8	10	4	0	
0.70 - 0.80	6	10 (B) at 0.75m				6	13	4	0	
0.80 - 0.90	15					6	7	2	0	
0.90 - 1.00	27					5	6	3 (B) at 1.02m	1	
1.00 - 1.10						3	5		1	
1.10 - 1.20						5 (B) at 1.10m	4		2	
1.20 - 1.30							3		2	
1.30 - 1.40							2		2	
1.40 - 1.50							3 (B) at 1.60m		1	
1.50 - 1.60									2	
1.60 - 1.70									1	
1.70 - 1.80									8	
1.80 - 1.90									14	
1.90 - 2.00									12	
2.00 - 2.10									9	
2.10 - 2.20									9	
2.20 - 2.30									8	
2.30 - 2.40									9	
2.40 - 2.50									8	
2.50 - 2.60									8	
2.60 - 2.70									9	
2.70 - 2.80									9	
2.80 - 2.90									12	
2.90 - 3.00									12	
3.00 - 3.10									12	
3.10 - 3.20									12	
3.20 - 3.30									12	
3.30 - 3.40									11	
3.40 - 3.50									12	
3.50 - 3.60									13	
3.60 - 3.70									12	
3.70 - 3.80									13	
3.80 - 3.90									18	
3.90 - 4.00									16	

TEST METHOD: AS 1289. F3.2, CONE PENETROMETER

REMARKS:
(B) Test hammer bouncing upon refusal on solid object
-- No test undertaken at this level due to prior excavation of soils

DYNAMIC PENETROMETER TEST SHEET

CLIENT: Sekisui House **DATE:** 2/06/2023

PROJECT: Subdivision of the site **PROJECT No.:** 2023-107

LOCATION: 49 Blackbutts Road, Frenchs Forest **SHEET:** 2 of 2

	Test Location									
Depth (m)	1	1a	1b	1c	2	2a	3	4	5	
4.00 - 4.10									16	
4.10 - 4.20									14	
4.20 - 4.30									17	
4.30 - 4.40									15	
4.40 - 4.50									18	
4.50 - 4.60										
4.60 - 4.70										
4.70 - 4.80										
4.80 - 4.90										
4.90 - 5.00										

TEST METHOD: AS 1289. F3.2, CONE PENETROMETER

REMARKS:

(B) Test hammer bouncing upon refusal on solid object

-- No test undertaken at this level due to prior excavation of soils

Appendix 3

TABLE : A

Landslide risk assessment for Risk to life

HAZARD	Description	Impacting	Likelihood of Slide	Spatial Impact of Slide		Occupancy	Evacuation	Vulnerability	Risk to Life
A	Landslip (earth slide <10m³) in soils due excavation or placement of fill		Excavation to 2.50m depth or placement of fill to approximately 2.50m depth proposed	a) boundary >15.0m from excavation, house a further 5.0m, impact 1% b) boundary >5.0m from excavation, house a further 5.0m, impact 1%		a) Person in house 20hrs/day avge. b)Person in house 20hrs/day avge.	a) Likely to not evacuate b) Likely to not evacuate	a) Person in building, minor damage only b) Person in building, minor damage only	
			Possible	**Prob. of Impact**	**Impacted**				
		a) Houses No. 19 to 23 Warila Rd	0.001	0.05	0.01	0.8333	0.75	0.1	**1.56E-08**
		b) Houses 9 - 11 Malbara Cres	0.001	0.01	0.01	0.8333	0.75	1	**6.25E-08**

* hazards considered in current condition and/or without remedial/stabilisation measures or poor support systems

* likelihood of occurrence for design life of 100 years

* Spatial Impact - Probaility of Impact refers to slide impacting structure/area expressed as a % (i.e. 1.00 = 100% probability of slide impacting area if slide occurs).

Impacted refers to expected % of area/structure damaged if slide impacts (i.e. small, slow earth slide will damage small portion of house structure such as 1 bedroom (5%), where as large boulder roll may damage/destroy >50%)

* neighbouring houses considered for impact of slide to bedroom unless specified, due to high occupancy and lower potential for evacuation.

* considered for person most at risk, where multiple people occupy area then increased risk levels

* for excavation induced landslip then considered for adjacent premises/buildings founded off shallow footings, unless indicated

* evacuation scale from Almost Certain to <u>not</u> evacuate (1.0), Likely (0.75), Possible (0.5), Unlikely (0.25), Rare to not evacuate (0.01). Based on likelihood of person knowing of landslide and completely evacuating area prior to landslide impact.

* vulnerability assessed using Appendix F - AGS Practice Note Guidelines for Landslide Risk Management 2007

TABLE : B

Landslide risk assessment for Risk to Property

HAZARD	Description	Impacting	Likelihood		Consequences		Risk to Property
A	Landslip (earth slide <10m³) in soils due excavation or placement of fill	a) Houses No. 19 to 23 Warila Rd	Rare	The event is conceivable but only under exceptional circumstances over the design life.	Minor	Limited Damage to part of structure or site or INSIGNIFICANT damage to neighbouring properties, requires some stabilisation .	Very Low
		b) Houses 9 - 11 Malbara Cres	Rare	The event is conceivable but only under exceptional circumstances over the design life.	Minor	Limited Damage to part of structure or site or INSIGNIFICANT damage to neighbouring properties, requires some stabilisation .	Very Low

* hazards considered in current condition, without remedial/stabilisation measures and during construction works.
* qualitative expression of likelihood incorporates both frequency analysis estimate and spatial impact probability estimate as per AGS guidelines.
* qualitative measures of consequences to property assessed per Appendix C in AGS Guidelines for Landslide Risk Management.
* Indicative cost of damage expressed as cost of site development with respect to consequence values: Catastrophic : 200%, Major: 60%, Medium: 20%, Minor: 5%, Insignificant: 0.5%.

CROZIER
GEOTECHNICAL CONSULTANTS

Appendix 4

APPENDIX A

DEFINITION OF TERMS

INTERNATIONAL UNION OF GEOLOGICAL SCIENCES WORKING GROUP ON LANDSLIDES, COMMITTEE ON RISK ASSESSMENT

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.

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.

Elements at Risk – Meaning the population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by landslides.

Probability – The likelihood of a specific outcome, measured by the ratio of specific outcomes to the total number of possible outcomes. Probability is expressed as a number between 0 and 1, with 0 indicating an impossible outcome, and 1 indicating that an outcome is certain.

Frequency – A measure of likelihood expressed as the number of occurrences of an event in a given time. See also Likelihood and Probability.

Likelihood – used as a qualitative description of probability or frequency.

Temporal Probability – The probability that the element at risk is in the area affected by the landsliding, at the time of the landslide.

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.

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.

Risk Analysis – The use of available information to estimate the risk to individuals or populations, property, or the environment, from hazards. Risk analyses generally contain the following steps: scope definition, hazard identification, and risk estimation.

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 judgements 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 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 Management – The complete process of risk assessment and risk control (*or risk treatment*).

Individual Risk – 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.

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.

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.

Tolerable Risk – A risk that society is willing to live with so as to secure certain net benefits in the confidence that it is being properly controlled, kept under review and further reduced as and when possible.

In some situations risk may be tolerated because the individuals at risk cannot afford to reduce risk even though they recognise it is not properly controlled.

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, kinetic energy per unit area.

Note: Reference should also be made to Figure 1 which shows the inter-relationship of many of these terms and the relevant portion of Landslide Risk Management.

APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

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

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

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

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

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

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

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

APPENDIX C: – QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

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

Notes: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.

(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

RISK LEVEL IMPLICATIONS

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

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