Attachment B - Geotechnical Assessment

Mosbri Crescent, The Hill

By Douglas Partners, December 2015

Douglas Partners
Geotechnics / Environment / Groundwater

Integrated Practical Solutions

Report on Desktop Geotechnical Assessment

Proposed Apartments
NBN Studio, Mosbri Crescent, The Hill

Prepared for
Nine Network Australia Pty Ltd

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Report on Desktop Geotechnical Assessment
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1. Introduction

This report presents the results of a desktop geotechnical investigation for the proposed apartment development to be located at NBN Studios, Mosbri Crescent, The Hill. The work was carried out for Mr Warwick McInnes on behalf of The Nine Network Australia Pty Ltd.

We understand that the proposed development includes the construction of two six-storey and one 12-storey residential apartment buildings. Two levels of basement car parking is currently proposed for each building. Douglas Partners Pty Ltd (DP) were provided a copy of the architectural plans for the proposed development and these are attached in Appendix A.

The purpose of the geotechnical investigation was to address the following:

- Geotechnical suitability of the site;
- Potential slope stability issues;
- Mine Subsidence requirements.

DP have previously undertaken geotechnical investigations at the site for several proposed antenna, Project 31423 and 31423A, dated October 2001 and September 2005 respectively. The previous investigations included three cored boreholes to a depth of up to 10 m as well as comments on slope stability for part of the site. The results of the field work from the previous investigations have been utilised in this report.

2. Site Description and Regional Geology

The site is located at Mosbri Crescent, The Hill and currently contains the NBN studio buildings (refer Figure 1). The existing main NBN studio building covers much of the central part of the site.

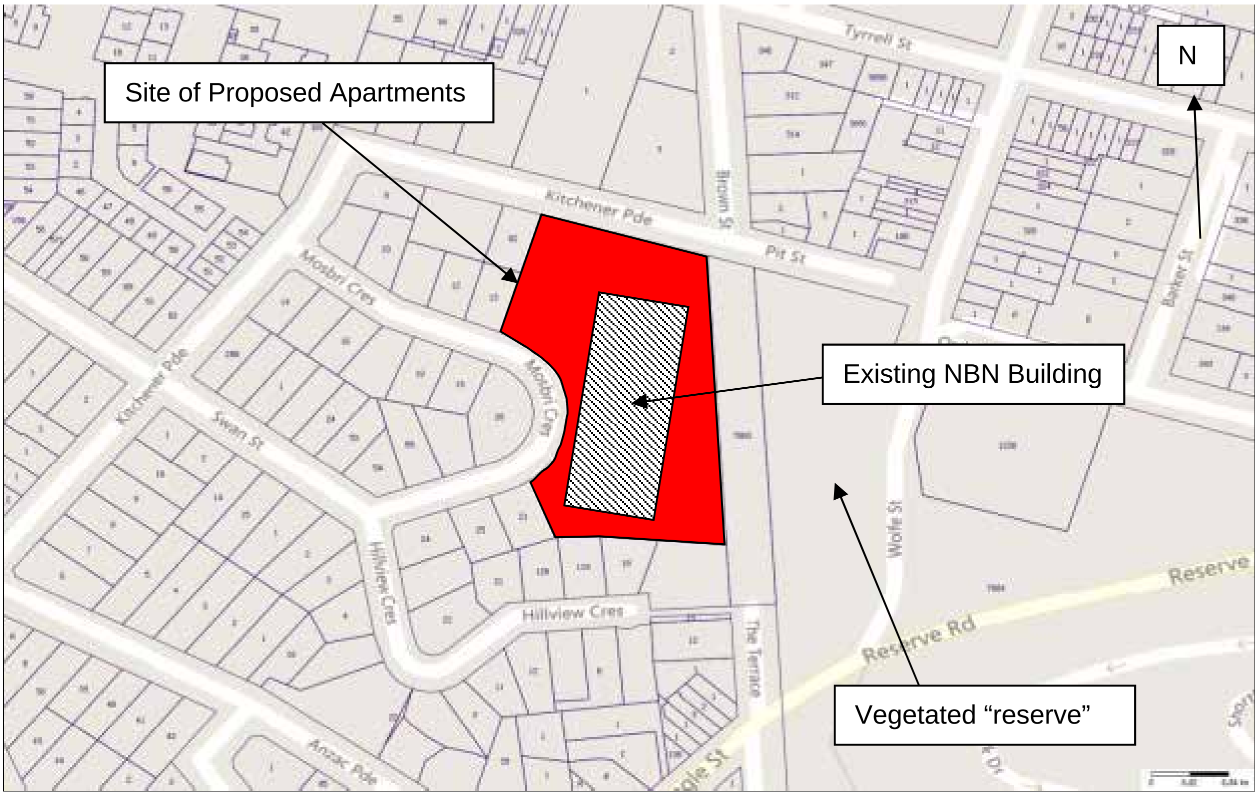


Figure 1: Mosbri Street Site Location

The site has been extensively modified by cutting and filling, typified by a number of existing rock and crib walls extending around much of the existing NBN studio building.

The site is bounded on the east by what appears to be a heavily vegetated reserve and easement that adjoins Wolfe Street.

Reference to the Newcastle Coalfield Surface Geology Map published by BHP indicates that the site is within the area of outcrop of the Shepherds Hill Formation of the Lambton Sub Group of the Newcastle Coal Measures. This formation is of Permian Age and is predominantly siltstone and sandstone with some conglomerate. The Nobbys Tuff occurs at the base of the Shepherds Hill formation and is typically about 1 m thick (Ref 1). In Newcastle the Shepherds Hill formation is typically about 27 m thick (Ref 1). The Shepherds Hill Formation is underlain by the Nobbys Coal Seam and overlain by the Victoria Tunnel Seam.

3. Desktop Assessment and Field Work

3.1 Methods

3.1.1 Desktop Assessment

A review of the existing data in relation to the site was undertaken and included:

- Review of in-house geotechnical data for the area;
- Review of published geological and geotechnical maps, including soil landscape maps and mine record tracings;
- Liaison with the mine subsidence board with regards to any restrictions to the development.

3.1.2 Field Work

A site inspection was carried out by a Principal Geotechnical Engineer on 5 November 2015. The purpose of the inspection was to assess the slope stability and photograph relevant aspects of the site. No assessment was made in relation to the design or structural integrity of the adjacent crib block and rock retaining walls.

3.2 Results

3.2.1 Desktop Assessment

Existing geotechnical investigations at the site (Project 31423 and 31423A, dated October 2001 and September 2005 respectively) included three cored boreholes to a depth of up to 10 m. The following is a general summary of the subsurface conditions previously encountered on site (Project 31423A). A more extensive description is provided in the original reports.

Based on the observations made during the site walkover assessment and the results of previous investigations by DP, the residual soil profile on site generally comprises clay overlying weathered rock.

From (m)	To (m)	Description
0	0.4 / 0.7	Filling / Soil – Typically sandy gravel and silty clay / clayey silt
0.4 / 0.7	2.5 / 3.4	Siltstone – Extremely low to very low strength, medium strength in parts
2.5 / 3.4	6.1 / 6.8	Siltstone – Low to medium strength, very low strength in parts
6.1 / 6.8+		Sandstone – Medium strength or better

No free groundwater was observed during the previous drilling or the recent site visit. It should be noted that groundwater levels are affected by recent weather conditions and soil / rock permeability and may vary with time.

3.2.2 Field Observations

Topography
Elevation contours for the site are shown in Figure 2. Two existing gully lines were observed during the site visit extending from the eastern site boundary adjacent to Wolfe Street through the adjacent vegetated reserve towards the site.

Figure 2: Elevation contours (2 m) at Mosbri Street Site Location

The existing NBN building has been extensively cut into the landscape and is surrounded on the northern, eastern and southern edges by crib retaining walls (refer Figure 3).

Figure 3: Existing Crib Retaining Wall along Eastern edge of existing NBN building (looking north, looking south)

Figure 4: Existing Crib Retaining Wall along Southern Site Boundary (looking west)

Figure 5: Existing Rock Retaining Wall along Eastern Site Boundary

Figure 6: Existing Crib Retaining Wall along Northern Site Boundary (looking east)

In addition to the retaining walls surrounding the main NBN building, the northern, eastern and southern car park / pavement areas are also supported by a mixture of crib and rock retaining walls (refer Figure 4, Figure 5 and Figure 6).

From the eastern boundary of the site the terrain slopes down to the west with a slope of about 14° to 17° which terminates at the crest of a cutting which ranges in height from about 1.25 m to 1.75 m. The bottom 1.25 m of the cutting is battered at a 75° angle and faced with mortared rock blocks. No weep holes were observed in the rock facing (Figure 5). The upper section of the cutting, where present, has been battered to a slope ranging from 35° to 50°. The material exposed on the face of the cut batter is predominantly clay soil with some intermittent exposures of extremely weathered siltstone.

From the toe of the rock facing, the terrain slopes at about 5° to the west for a distance of about 12 m. This area is presently a bitumen paved car park.

Figure 7: Exposed Siltstone along parts of eastern boundary (adjacent to air conditioning containers)

The bitumen car park terminates at a concrete kerb which is about 1 m from the crest of a crib wall. The area between the kerb and the crib wall is also bitumen paved.

The crib wall is about 4.15 m in height with a batter slope of about 75° to 80° (Figure 3). The upper 0.75 m of the crib wall is of different appearance and slightly different batter from the remainder of the wall which may indicate two stages of wall construction.

At the toe of the crib wall a paved area continues to the adjacent studio building.

Vegetation

The northern and southern boundaries are grass covered with she-oaks and other shrubs with a basal diameter of up to 200 mm, several very large diameter trees exist along the very far length of the southern boundary.

Figure 8: Large diameter trees along far southern boundary adjoining Mosbri Crescent

4. Comments

4.1 Mine Subsidence

The site lies within the Newcastle Mine Subsidence District and the approval of the NSW Mine Subsidence Board (MSB) is required for development of the site (refer Figure 9).

Correspondence between DP and the MSB (email dated 4 November 2015, Mr Ian Bullen, Newcastle District Manager) indicates the allotment is undermined by first workings in the Borehole Seam at 95 m in depth. The guideline for the area is a G09 which is three storey construction, so any development above that height would need to be assessed on its merit. The site would require geotechnical assessment to determine the long term stability of the workings. The colliery was the Australian Agricultural Co, there is no details on the Record Trace and / or lease details.

Restrictions will be necessary in relation to the type of development permitted in specific areas. There will also be special requirements in relation to the type of construction, particularly the foundations. The policy of MSB is that it will not issue general guidelines but will only respond to specific development proposals.

DP can undertake a mine subsidence assessment and prepare a specific MSB application on behalf of Nine Network Australia Pty Ltd at the appropriate stage of the development process.

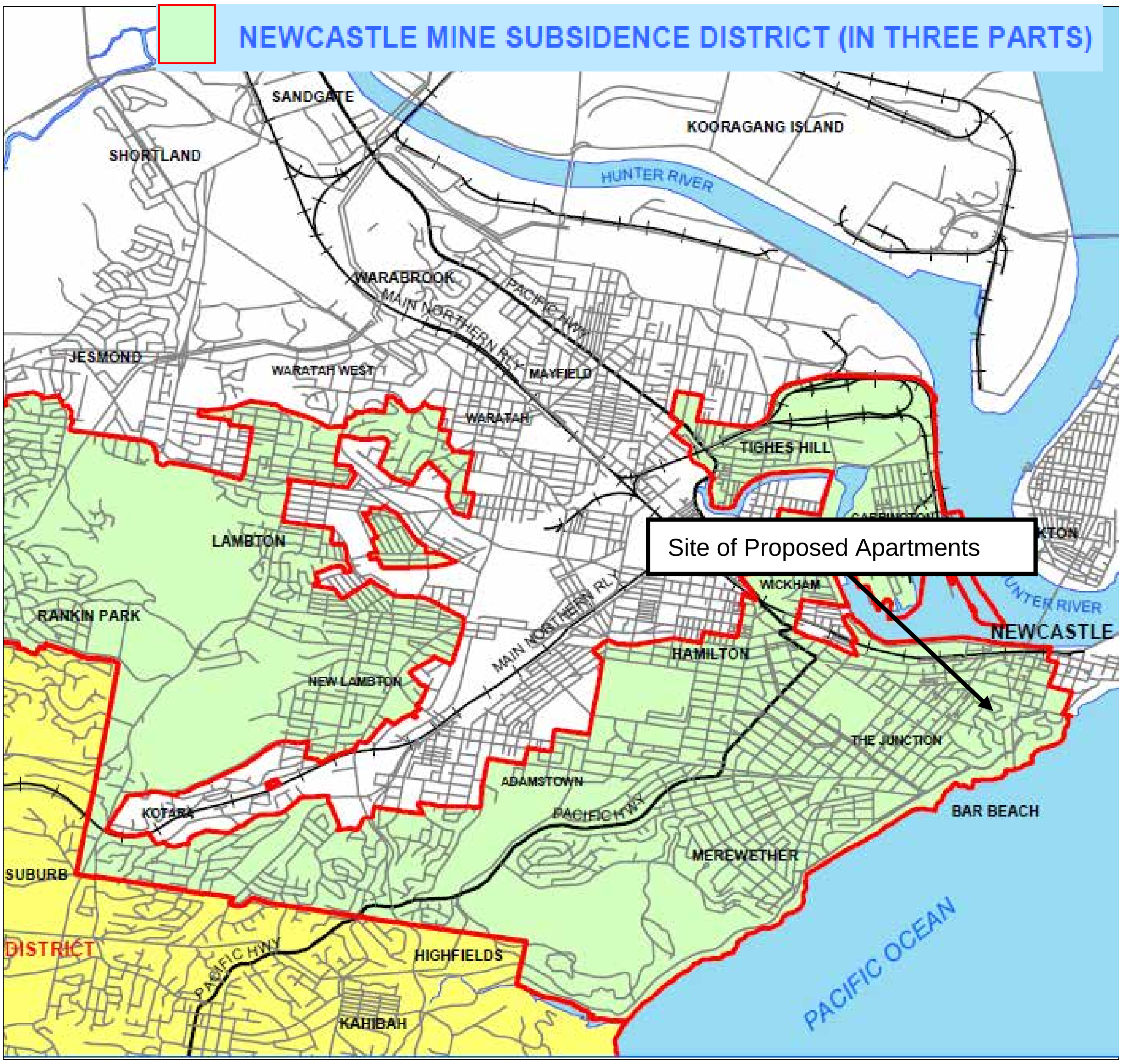


Figure 9: Mine Subsidence Districts and location of existing site (Adapted from MSB Plan No. MSD12b)

4.2 Footings

The following general advice is provided in relation to footings and foundations. It should be pointed out that further subsurface investigations will be required once the final structural building loads are known, in order to determine the design allowable loads for all foundation types.

Shallow Footings

Due to the relatively shallow depth to rock across the site, it is anticipated that founding on strip or pad footings will be appropriate for most smaller structures and possibly larger buildings. Slab on grade construction is also suitable with the appropriate site preparation. For preliminary design it is considered that pad or strip footings founded within the extremely low strength or better bedrock would be suitable for support of small structural loads provided that they are at least 0.5 m deep. For preliminary design footings in extremely low to very low strength rock should be proportioned for a maximum allowable bearing pressure of 700 kPa. Higher allowable bearing pressures may be possible subject to detailed investigation and assessment of total settlements. Concentrated loads, not able to be adequately supported on shallow footings, may be supported on deeper pad footings and/or bored cast in situ concrete piers

Deep Footings

Based on the previous geotechnical investigations at this site (Project 31423 and 31423A, dated October 2001 and September 2005 respectively), it is suggested that bored cast in situ piles socketed into the underlying bedrock would be a suitable pile option at this site. The following table presents preliminary allowable shaft adhesion and end bearing capacity of the bedrock.

Table 1: Preliminary Allowable Design Values for Foundations – Compression

Rock Strength	End Bearing Pressure (kPa)	Shaft Adhesion (kPa)
Extremely low strength	700	70
Very low strength	1000	100
Low Strength	1500	150
Medium strength or better	3500	350

As the depth to rock and depth of weathering is expected to vary across the site, the actual conditions and allowable pressures should be confirmed by further geotechnical investigations.

The allowable shaft adhesion for tensile loading on piles should be reduced by 50%. The shaft adhesion should only be calculated for that part of the socket length which is greater than 1 m below ground surface.

Bored pile excavation should be cleared of all loose material and if water is present in the bore this should be removed or the concrete should be added to the base of the bore using a tremie pipe to displace water above the concrete.

Subsidence Considerations

The selection of foundation types for structures should be based on adequate consideration of the effects of mine subsidence, including grounds tilts and strains, if applicable.

4.3 Slope Stability Assessment

The following sections present a qualitative risk assessment of the proposed site based on guidelines proposed by the Australian Geomechanics Society (AGS) Landslide Risk Management (Ref 2).

An explanation of risk categories and implications to development is attached in Appendix C. The risk of slope instability affecting the site has been assessed on the basis of the geotechnical units with results presented in Section 3.2.1.

It should be noted that there were no overt signs of deep seated instability at the site and its immediate surrounds at the time of the assessment and site inspection. The absence of visually obvious structural distress in the many retaining walls on site is consistent with this observation.

4.3.1 General Observations

The following general observations can be made based on the site walkover undertaken on 5 November 2015:

- Based on the site walkover, no evidence of deep seated or overall slope instability was observed;
- Some evidence of very minor creep or translational sliding was observed in the gullies of the adjoining property to the east (Figure 2);
- In the absence of detailed design and works-as-executed drawings, it is not possible to comment on the suitability of an existing retaining wall. Nonetheless, the existing crib walls immediately surrounding the NBN building (Figure 3 and Figure 6) do not appear to show evidence of significant distress. The crib walls along the southern, eastern and northern site boundaries (Figure 4 and Figure 6) do show signs of localised distress and spalling that has exposed the internal reinforcement. This reinforcement has corroded significantly where spalling has occurred;
- No groundwater seepage was observed on the site during the inspection. During a previous investigation in 2001, the standing water level in a standpipe piezometer about 2.5 m behind the crest of the eastern site boundary rock / crib wall (Figure 5) was 6.6 m below the level of the car park paving (i.e. below the toe of the crib wall).

4.3.2 Identified Hazards and Inferred Consequences

Using the nomenclature presented in Ref 2, the following potential hazards were identified for the site:

1. Hazard 1 relates to creep of colluvial or residual soils affecting structures. This has been assessed to be ‘unlikely’ given previous subsurface investigations indicate shallow depths to rock over the site.
2. Hazard 2 relates to a slow deep seated failure beneath the constructed building. This has been be considered a ‘rare’ event given no known recent or past occurrence of deep seated failure has been observed at the NBN site;

3. Hazard 3 relates to the stability failure of newly proposed fill embankments and batters affecting adjacent properties. Minor fill embankments could be anticipated to accommodate the proposed development and slide debris impacting on downslope areas is identified as a hazard should these fill slopes collapse. This has been assessed to be 'rare' provided engineered batter and/or retaining systems are provided to support all filling when required;
4. Hazard 4 relates to the stability failure of cut embankments and batters (existing retained areas or newly proposed) affecting adjacent properties to the north and south. Cuttings are anticipated to accommodate the proposed development and the failure of these will impact the adjacent residential properties and infrastructure. This has been assessed to be 'unlikely' provided engineered batter and/or retaining systems are provided to support all cuttings when required;
5. Hazard 5 relates to the stability failure of slopes modified by earthworks and the propagation upslope towards the eastern vacant property. This has been assessed to be 'rare' provided engineered batter and/or retaining systems are provided to support all cuttings when required. This consequence of failure was based on the assumption that no development is proposed on the adjoining eastern property which is currently a Council reserve; and
6. Hazard 6 relates to the stability failure of slopes modified by earthworks and the downslope impacts to properties to the west. This has been considered a 'rare' event assuming a thorough engineering assessment of new building foundations and their effects is undertaken.

4.3.3 Property Risk

The site has been assessed with reference to the Australian Geomechanics Society Landslide Taskforce "Practice Note Guidelines for Landslide Risk Management" March 2007 (Ref 2). There are no site specific data that would allow a quantitative assessment of risk. Based on site geomorphology, geology and general history of landslips in the Newcastle/Lake Macquarie area, a qualitative assessment of the risk for property can be made as outlined in Appendix C of Ref 2. A copy of that appendix is included in Appendix C.

Table 2 summarises the results of this assessment, together with a qualitative assessment of the likelihood of occurrence of a landslide after construction, its consequence and risk to the building that has been designed and constructed taking the advice contained in this report into account.

Table 2: Risk Assessment for Property – Proposed Development

Hazard		Likelihood	Consequence	Risk to Proposed Development
1	Slow creep of soils within footprint of the development	Unlikely	Minor	Low
2	Deep seated failure of site affecting current lot and adjacent properties	Rare	Major	Low
3	Stability failure of fill embankment and batters affecting adjacent properties	Rare (provided engineered batter and/or retaining system provided to support all filling)	Major	Low
4	Stability failure of cut embankment and batters affecting adjacent properties to the north and south.	Rare (provided engineered batter and/or retaining system provided to support all cuttings)	Major	Low
5[1]	Stability failure of slopes modified by earthworks – propagation upslope towards eastern property.	Unlikely (provided engineered batter and/or retaining system provided to support cuttings along eastern boundary)	Minor	Low
6	Stability failure of slopes modified by earthworks – downslope impacts to properties to the west.	Rare (provided engineering assessment of new building foundations and their effects is undertaken)	Major	Low

Notes to Table 2:

(1) This was based on no development proposed on the adjoining eastern property which is currently assumes to be a Council reserve.

As a guide, in our experience, low and risks to properties from slope failure are commonly accepted by owners, developers and development regulating authorities. Reference to the AGS guidelines indicates that for residential sites, for which an importance Level 2 would apply in accordance with Ref 2, a low risk level is usually acceptable to society and regulators.

4.3.4 Risk to Life

The AGS Practice Note Guidelines (Ref 2) also provides a framework for landslide risk management, guidance on risk analysis methods and information on acceptable or tolerable risks for loss of life.

Risk analysis can be broken up into four components, namely:

- Hazard identification;
- Frequency analysis;
- Consequence analysis; and
- Risk estimation.

For the loss of life, the individual risk can be calculated using:

$R_{LOL} = P_H \times P_{S:H} \times P_{T:S} \times V_{D:T}$

Where:

- R_{LOL} is the risk, or annual probability of death of an individual;
- P_H is the annual probability of the hazardous event;
- $P_{S:H}$ is the probability of spatial impact by the hazard given the event;
- $P_{T:S}$ is the temporal probability given the spatial impact; and
- $V_{D:T}$ is the vulnerability of the individual.

Table 3 details the results of the assessment undertaken in relation to risk to life of the hazards identified at this site.

Table 3: Risk Assessment for Life – Proposed Development

Hazard		$P_{(H)}$	$P_{(S:H)}$	$P_{(T:S)}$	$V_{(D:T)}$	Risk $R_{(LOL)}$
1	Slow creep of soils within footprint of the development	1×10^{-4}	1	0.75 (people in building three quarters of the time)	1×10^{-3} (evacuation possible)	7.5×10^{-8}
2	Deep seated failure of site affecting current lot and adjacent properties	1×10^{-5}	1	0.75 (people in building three quarters of the time)	1×10^{-3} (evacuation possible)	7.5×10^{-9}
3	Stability failure of fill embankment and batters affecting adjacent properties	1×10^{-5} (provided engineered batter and/or retaining system provided to support all filling)	0.25 (proposed filling areas for development covering 25% of site area)	0.75 (people in building three quarters of the time)	1×10^{-3} (evacuation possible)	1.8×10^{-9}
				0.05 (people adjacent to fill areas 5% of the time)	0.5	6.3×10^{-8}
4	Stability failure of cut embankment and batters affecting adjacent properties to the north and south.	1×10^{-5} (provided engineered batter and/or retaining system provided to support all cuttings)	0.5 (proposed cuttings for development covering 50% of the site area)	0.75 (people in building three quarters of the time)	1×10^{-3} (evacuation possible)	3.7×10^{-9}
				0.05 (people adjacent to fill areas 5% of the time)	0.5	1.25×10^{-7}
5	Stability failure of slopes modified by earthworks – propagation upslope towards eastern property.	1×10^{-4} (provided engineered batter and/or retaining system provided to support cuttings along eastern boundary)	0.5 (proposed cuttings for development covering 50% of the site area)	0.05 (people adjacent lot (reserve) to the east 5% of the time)	0.5	1.25×10^{-6}

Table 3: Risk Assessment for Life – Proposed Development (cont)

Hazard		$P_{(H)}$	$P_{(S:H)}$	$P_{(T:S)}$	$V_{(D:T)}$	Risk $R_{(LOL)}$
6	Stability failure of slopes modified by earthworks – downslope impacts to properties to the west.	1×10^{-5} (provided engineering assessment of new building foundations and their effects is undertaken)	0.3 (proposed building foundation area covering 30% of the site area)	0.75 (people in downslope properties three quarters of the time)	1×10^{-3} (evacuation possible)	2.3×10^{-9}

Notes to Table 3:

(1) Based on limited access to rear of site as indicated on site plan of proposed development TP-01 attached.

There are no established individual or societal risk acceptance criteria for the loss of life due to a hazardous event such as a landslide or rock fall. Australian Geoguide LR7 of Ref 2 (Included in Appendix C) discusses "acceptable" and "tolerable" levels of risk which have been proposed by several authorities including the ANCOLD Guidelines for Risks from Large Dams, the Australian Geomechanics Society and the Department of Urban Affairs and Planning. The AGS Guidelines (Ref 2) indicates that for most developments in existing urban areas, "tolerable" risk levels can be considered as the "acceptable" risk, with Table 1 of the Practice Note (Ref 2) indicating that a risk of loss of life of 10^{-5} would be tolerable for new constructed slopes and a risk of life of 10^{-4}, would be tolerable for existing slopes and developments.

Based on this information, given that the risk to life is generally less than 10^{-6} for the hazards identified above, the risk to life associated with the proposed development is likely to be acceptable to society and regulators.

5. Conclusion

In summary, the proposed development is considered suitable from a geotechnical perspective provided the following is undertaken at the appropriate stage of the development process:

- Detailed geotechnical site investigations to determine the subsurface conditions at the location of the proposed structures. This information is required for detailed design of foundations, excavations and retaining structures;
- Undertake mine subsidence risk assessment to establish mine subsidence design parameters and guide foundation selection;
- Submission of Mine Subsidence Board (MSB) building application for approval;
- Undertake a condition assessment of existing retaining structures that will not be demolished and are to remain as part of the new development.

6. References

1. Packham G H (ed), 1969; "The Geology of NSW", Geological Society of Australia, 1969.
2. Australian Geomechanics (2009). Practice Note Guidelines for Landslide Risk Management, Vol. 42, No. 1 pp. 63-114, March.
3. "Engineering Geology of the Newcastle – Gosford Region", Australian Geomechanics Society, 1995.

7. Limitations

Douglas Partners Pty Ltd (DP) has prepared this report (or services) for this project at NBN Studio, Mosbri Crescent, The Hill in accordance with DP's proposal dated and acceptance received from Scott Soutar (Station Manager) dated 23rd October 2015. The work was carried out under DP's Conditions of Engagement. This report is provided for the exclusive use of Nine Network Australia Pty Ltd for this project only and for the purposes as described in the report. It should not be used by or relied upon for other projects or purposes on the same or other site or by a third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

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

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

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

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

Douglas Partners Pty Ltd

Appendix A

Proposed Development

SJB Architects

11 Mosbri Crescent

The Hill, Newcastle
Nine Network Australia

27 July 2015 | Version 04

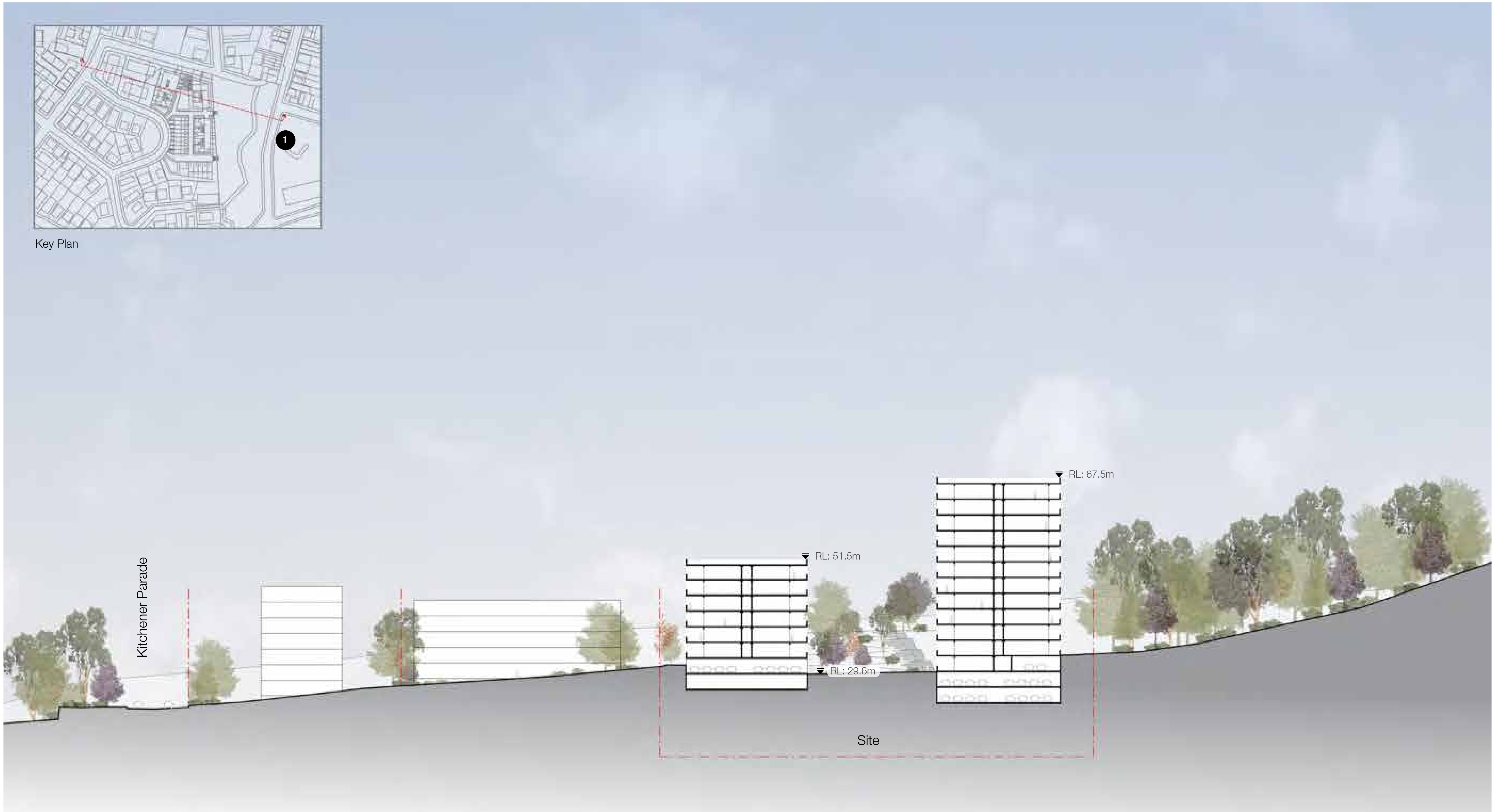
3.7 Option 03 (Preferred) - Basement Plan

3.7 Option 03 (Preferred) - Ground Floor Plan

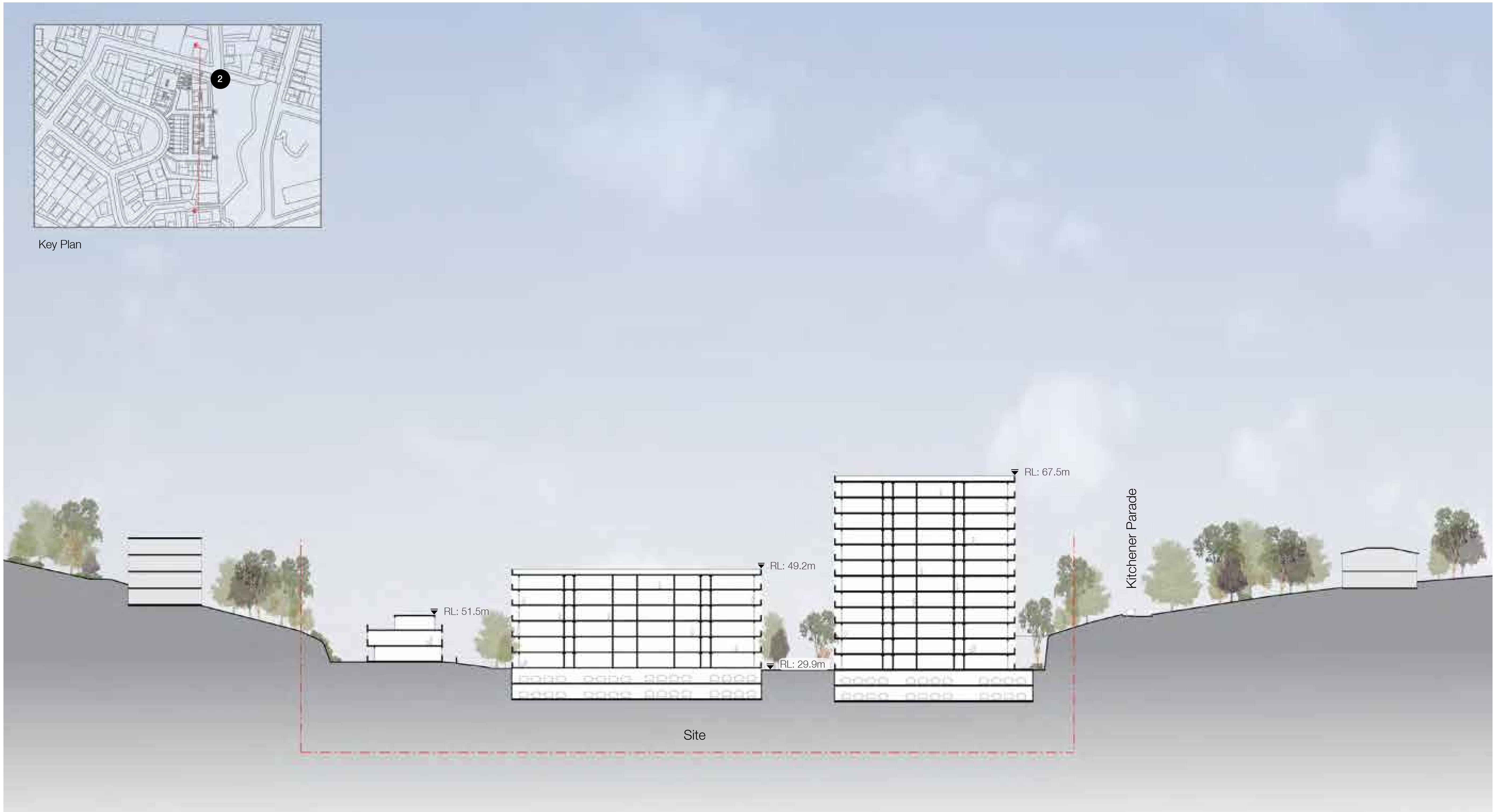
3.7 Option 03 (Preferred) - First Floor Plan

3.7 Option 03 (Preferred) - Typical Floor Plan

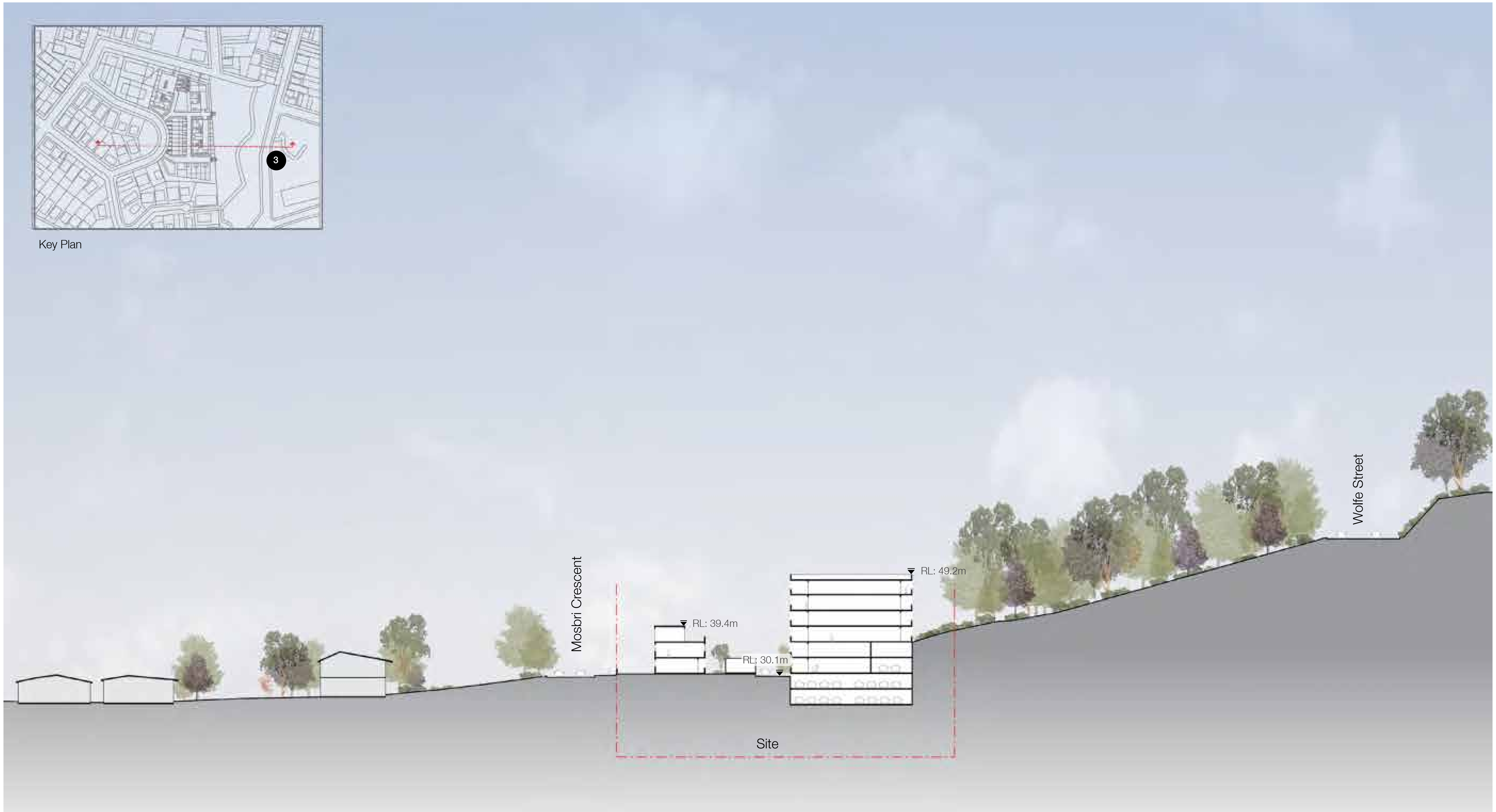
3.8 Option 3 (Preferred) - Section 1



3.8 Option 3 (Preferred) - Section 2



3.8 Option 3 (Preferred) - Section 3



Appendix B

About This Report

Introduction

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

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

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This report is the property of Douglas Partners Pty Ltd. The report may only be used for the purpose for which it was commissioned and in accordance with the Conditions of Engagement for the commission supplied at the time of proposal. Unauthorised use of this report in any form whatsoever is prohibited.

Borehole and Test Pit Logs

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

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

Groundwater

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

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

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

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP will be pleased to review the report and the sufficiency of the investigation work.

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

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

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

About this Report

Site Anomalies

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

Information for Contractual Purposes

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

Site Inspection

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

Appendix C

AGS Slope Stability Documents

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.

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 (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 often covered by special regulations. If you are contemplating building, or buying an existing house, particularly in a hilly area, or near cliffs, 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 repairs and temporary loss of use if a 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 tolerated", 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 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. Importantly, 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 any day. If this were not so, no one would ever be struck by lightning.

Most local councils and planning authorities that stipulate a tolerable risk to property also stipulate a tolerable risk to life. The AGS Practice Note Guideline recommends that 1:100,000 is tolerable in newly developed areas, where works can be carried out as part of the development to limit risk. The tolerable level is raised to 1:10,000 in established areas, where specific landslide hazards may have existed for many years. The distinction is deliberate and intended to prevent the concept of landslide risk management, for its own sake, becoming an unreasonable financial burden on existing communities. Acceptable risk is usually taken to be one tenth of the tolerable risk (1:1,000,000 for new developments and 1:100,000 for established areas) and efforts should be made to attain these where it is practicable and financially realistic to do so.

TABLE 3: RISK TO LIFE

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

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

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

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