Crozier Geotechnical Consultants
Unit 12/ 42-46 Wattle Road
Brookvale NSW 2100
Crozier Geotechnical Consultants , a division of PJC Geo-Engineering Pty Ltd
ABN: 96 113 453 624
Phone: (02) 9939 1882
Email: info@croziergeotech.com.au

TECHNICAL REPORT

on

GEOTECHNICAL FEASIBILITY STUDY

at

REMEMBRANCE DRIVE and ARGYLE STREET, PICTON, NSW

Prepared For

Wollondilly Shire Council

Project No.: 2022-095

August 2022

Document Revision Record

Issue No	Date	Details of Revisions
0	10 June 2022	Draft Issued for Comment
	24 August 2022	Final Issued

EXECUTIVE SUMMARY

A Geotechnical Study has been undertaken to identify assess the suitability of proposed rezoning from Primary Production (RU1) to light commercial/industrial use within to areas located to the east and west of Remembrance Drive, Picton, NSW.

The study comprised a desktop review of available maps, plans and online resources followed by a walkover assessment of the area proposed for rezoning to identify potential constraints to the proposal.

The study identified several potential geotechnical conditions which need to be considered and are detailed in this report. However, the conditions are not considered to be represent significant constraints based on the probable type of structures proposed and can be further mitigated with site specific subsurface investigation prior to the design and construction of both the subdivision layout and proposed new structures.

CROZIER
GEOTECHNICAL CONSULTANTS

TABLE OF CONTENTS

Crozier Geotechnical Consultants ABN: 96 113 453 624
Unit 12/ 42-46 Wattle Road Phone: (02) 9939 1882
Brookvale NSW 2100 Email: info@croziergeotech.com.au
Crozier Geotechnical Consultants, a division of PJC Geo-Engineering Pty Ltd

TECHNICAL REPORT ON GEOTECHNICAL FEASIBILITY STUDY AT REMEMBRANCE DRIVE AND ARGYLE STREET, PICTON, NSW

1. INTRODUCTION:

This report details the results of a geotechnical feasibility assessment carried out at Remembrance Drive and Argyle Street, Picton, NSW. The assessment was undertaken by Crozier Geotechnical Consultants (CGC) at the request of and in conjunction with Metech Consulting for Wollondilly Shire Council.

The geotechnical assessment and reporting are required to support a proposed rezoning of several currently rural zoned (RU1 - Primary Production) properties to light industrial/commercial use. Development proposals have not been finalised. For the purposes of this study, the new structures/developments have been assumed to comprise warehouse type buildings with on grade slabs and parking areas. Deep basements, large commercial/retail structures or multistorey buildings are not anticipated.

A fee proposal (Fee Proposal P22-134, Dated: 14 March 2022) was submitted and subsequently accepted by the client to undertake the nominated scope of works. The assessment was undertaken in accordance with the Fee Proposal. This report is one of three geotechnical feasibility studies compiled for Wollondilly Shire Council (Locations within Bargo and Silverdale being the other two study areas) which were included in the requested scope of works.

This study comprised:

- Desktop review of geological, soil landform, topographic maps.
- Air-photo interpretation and mapping of the site and adjacent land.
- A walkover inspection and geomorphological mapping of the properties proposed for rezoning by a Senior Engineering Geologist.

The following document was supplied and relied upon for the preparation of the proposal:

- RFQ – Employment Land Rezoning – Technical Study (Reference: 13494).

Specific detailed guidelines or required deliverables to be included within the Technical Study Report have not been provided by Wollondilly Shire Council. Based on our understanding of the purpose of the Technical Study it is considered that information on the following 'key' elements will need to be addressed to enable Council/stakeholders/public to make an assessment of the proposed rezoning:

- What are likely to be the most significant geotechnical constraints/considerations relating to commercial/industrial developments within the study area.
- What potential impact could the geotechnical constraints/considerations have on the feasibility of the rezoning proposal.
- Can the constraints/considerations be controlled/further delineated.

1.1 Methodology

To address the key elements required to be fulfilled, the following methodology was adopted:

- Undertake desk top review of available geological/landform maps, Lotsearch information, arial photographs and online resources.
- Site walkover of proposed subdivision lots to assess erosion potential, slope stability, terrain and drainage conditions.
- Outline any identified constraints relevant to the proposed subdivision.
- Assess the significance of those constraints based on severity and distribution.

In addition to this report, an additional Technical Studies Outcome Paper has also been prepared which summaries the key geotechnical constraints and considerations in assessment of the rezoning proposal.

1.2 Proposed Land Rezoning Study Area

The site is approximately 55 hectares and consists of two areas located either side of Remembrance Drive. The site is located to the south of Picton town centre and is bounded to the north by a high school and light commercial properties. Most of the site area consists of large lot rural residential properties and remnant bushland. A commercial landscaping supplies and civil earthworks company is located on the site.

An aerial view of the study area with the lot boundaries/references shown is provided as Photograph 1 and was supplied within the Council RFQ documentation.

Photograph 1: Aerial view of the study area

2.0 OVERVIEW OF STUDY AREA

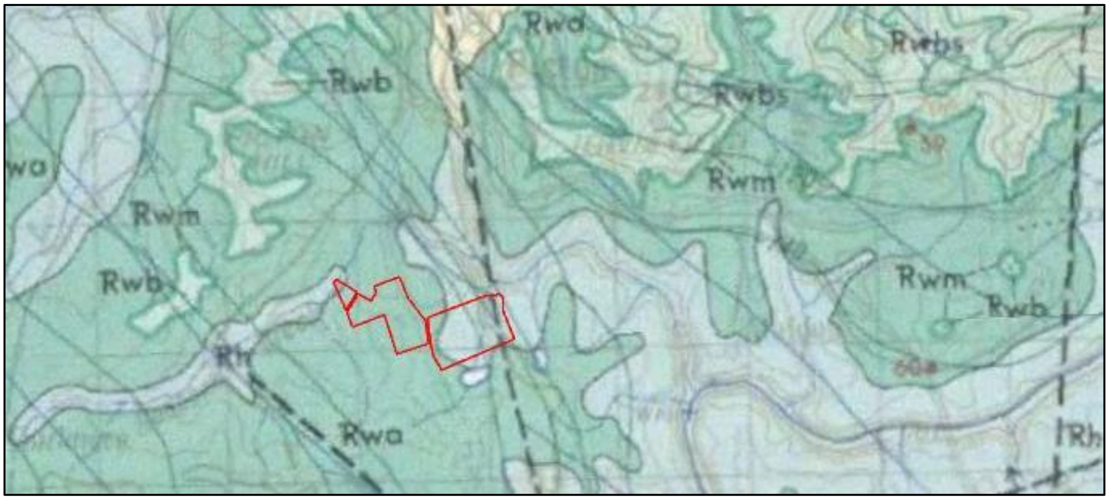
2.1 Geological Setting

Reference to the Wollongong Port Hacking 1:100,000 Geological Series sheet (9029 - 9129) indicates that the majority of the west portion of the study area is located in an area underlain by the Ashfield Shale (Rwa) with the older and underlying Hawkesbury Sandstone (Rh) indicated across the east of the study area.

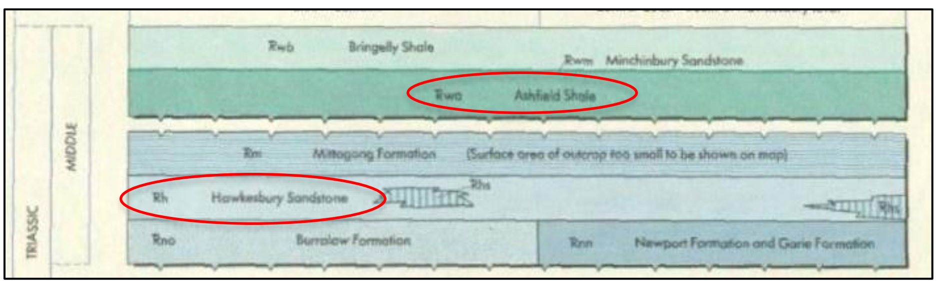
Ashfield Shale rocks are dominated by shales with occasional thin laminite or siltstone beds, they often form rounded low angle convex ridge tops with undulating low angle (<10°) side slopes. These side slopes can be either concave or convex depending on geology, internally they comprise either thinly bedded shales or interbedded shale and siltstone beds with close spaced bedding partings that have either close spaced or large discontinuous vertical joints. The siltstone often forms deeply weathered silty sandy clay profiles while the shale forms medium to high plasticity soil profiles, both can have thick silty colluvial topsoil cover.

The Hawkesbury Sandstone typically comprises medium to coarse grained quartz sandstone with minor lenses of shale and laminite. Morphological features often associated with the weathering of Hawkesbury Sandstone are the formation of near flat ridge tops with steep angular side slopes. These slopes often consist of sandstone terraces and cliffs with steep colluvial slopes below. The outline of the cliff areas is often rectilinear in plan view, controlled by large bed thickness and wide spaced near vertical joint pattern, many cliff areas are undercut by differential weathering. Slopes below these cliffs are often steep 15 to 23° with moderately thick sandy colluvial soil profile that are randomly covered by sandstone boulders.

Extracts of the relevant geological map sheet are provided below. It should be noted that the locations of the geological boundaries indicated on the map should be considered approximate at a scale of 1:100,000.



Extract 1: Extract from the 9029-9129 Wollongong Port Hacking Series sheet with site outlined red

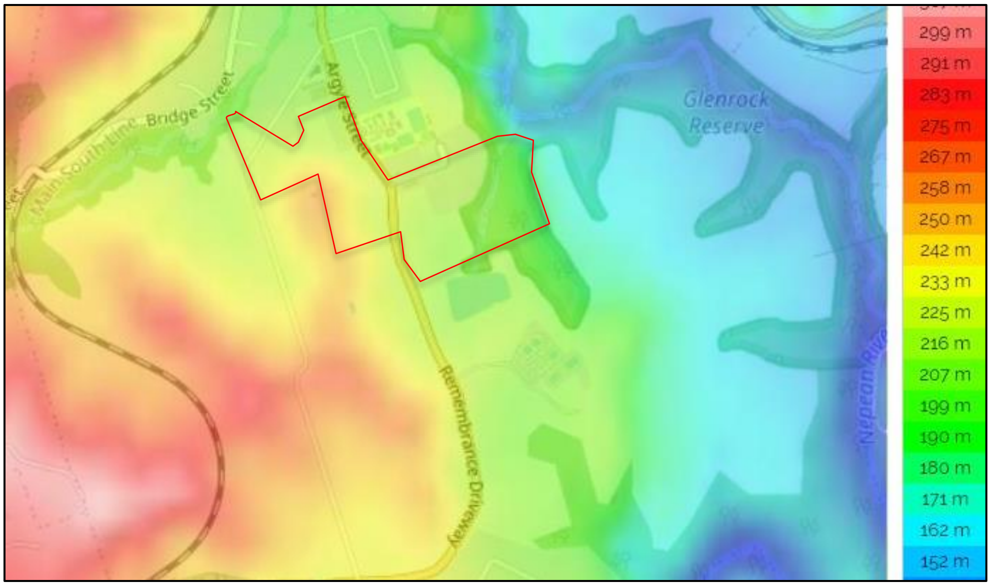


Extract 2: Key to Geological Map

Within the east of the study area, the Lapstone Monocline is indicated trending broadly north south.

2.2 Study Area and Surrounding Topography

The study area lies within east sloping topography which varies in elevation between a high of approximately RL250m at the crest of a hill within the west and a low of approximately RL180m within a drainage pathway within the east of the study area. The topography of the majority of the study area broadly dips gently towards the east. The area to the southwest of the study area increases in elevation and the area to the east reduces in elevation towards Stonequarry Creek to the east. An extract of a topographic map of the area is provided as Extract 3 with a contour map provided as Extract 4.



Extract 3: Extract of the topographic map obtained from OpenStreetMap©

Extract 4: Extract of a contour map of the study area obtained from Mecone Mozaic showing approximate contour elevations

2.3 Acid Sulphate Soils

According to information contained within the Lotsearch Report obtained for the study area (Reference: LS031588 EP), the site lies within an area of extremely low chance (1% to 5%) of encountering acid sulphate soils with ground surface elevation of the study area at >RL180m.

2.4 Salinity

According to information contained within the Lotsearch Report obtained for the study area (Reference: LS031588 EP), the site lies within an area of predominately moderate salinity potential with two areas of high salinity potential within the south of the study area.

2.5 Mining Subsidence

According to information contained within the Lotsearch Report obtained for the study area (Reference: LS031589 EP), the site lies within the Bargo Mine Subsidence with the Picton Mine subsidence area directly to the north.

Based on the information provided within the NSW Government ePlanning Spatial Viewer, the following building requirements (Guideline 5) apply to new residential constructions:

'Single or two storey clad frame or brick veneer on footings/slabs to minimum H2 AS 2870 site classification and design features. Maximum length of 24m and maximum footprint of 400sqm'

However, no construction requirements are specified for commercial developments.

3.0 FIELD MAPPING/DETAIL DESK STUDY RESULTS

3.1 Methods:

The fieldwork comprised a walk over inspection of the study area and adjacent properties on the 20 May 2022 by a Senior Engineering Geologist.

The walk over inspection comprised geological/geomorphological field mapping and observation of structures/conditions within and adjacent to the site to assess topography, slopes and existing structures. The inspection was restricted to observations made from the ground surface of the site or adjacent, accessible land. Photographs of relevant observations were taken for inclusion in the report and to allow the creation of a photographic record to be made prior to commencement of construction works within the site.

Detail survey information was not available at the time of reporting. Lot measurements and elevation information has been determined from a combination of information provided by Council, NSW Government Six Maps website, Google Earth, the relevant Lotsearch Report (Provided by Metech Consulting) and various other open source/spatial data/mapping websites.

Where appropriate (and where access was available) the mapping results are provided on a lot by lot basis, where limited information (or limited access) was available for a particular lot, the lot descriptions have been combined. Detail desk study information is also included where relevant.

Aerial images have been provided in the following section to highlight lot features. A key to the symbols provided on aerial images is provided below.

Key to Aerial Images:

	Wet areas		Minor drainage path
	Dip Direction with slope (white on aerial images)		Major drainage path
	Ponds		Fill areas (various shapes)
	Sandstone bedrock outcrops		

3.1.1 Number 5 and 15 Stilton Lane (Lot 10 DP583245 and Lot 2 DP583247)

Lot 10 DP583245 (not accessible at the time of inspection due to livestock within the lot) appears to contain a grass paddock with mature trees within the center and north of the site. The lot is the furthest north and west within the study area and appears undeveloped. The overall ground surface displayed a gentle dip from south to north which appears to become steeper adjacent to the northern boundary of the lot between a low of approximately RL202m and a high of approximately RL223m and occupies an area of approximately 15,212m^2.

Photograph 2: View looking north to east from near the south boundary of Lot 10 DP583245

Signs of excessive erosion, potential areas of landslip, discoloured grass/vegetation were not observed within the lot. A watercourse (Redbank Creek) lies adjacent to the north boundary of the lot. Areas of suspected fill were not observed from outside the lot.

Lot 15 DP583247 contains open paddocks, two residential dwellings and outbuildings/storage sheds. The lot slopes from the south to the north between a high of approximately RL250m adjacent to the south boundary to a low of RL219m adjacent to the north boundary and occupies an area of approximately 46,957m^2 in plan. The lot represents the highest point within the study area with the steepest section sloping between 13° and 15° towards the northwest.

Signs of excessive erosion, potential areas of landslip, discoloured grass/vegetation were not observed within the lot. No significant drainage pathways were observed within the lot although the west side of the lot did appear wet underfoot during the inspection.

Photograph 3: View looking west to north from near the south boundary of Lot 2 DP583247

Photograph 4: View looking north to east from near the south boundary of Lot 2 DP583247

The ground surface surrounding the main residence and rear shed to the east appeared elevated in comparison with the adjacent properties/natural contours. It has been interpreted that some minor cut/fill of the lot has been undertaken previously in order to construct a level construction pad.

Mature trees were generally limited to the north and east lot boundaries.

Photograph 5: View looking north from near the main residence within Lot 2 DP583247

Photograph 6: Aerial view of Lot 10 DP583245 and Lot 2 DP583247

3.1.2 Number 465 and 467 Argyle Street (Lot 141 DP997490 and Lot 1 DP537245)

Lot 141 DP997490 comprises a vacant undeveloped lot which slopes from the south to the north between a high of approximately RL223 m adjacent to the south boundary to a low of RL214m adjacent to the north and occupies an area of approximately 10,864m^2.

Photograph 7: View looking north from near the south boundary of Lot 141 DP997490

Signs of surface erosion or potential landslip movements were not observed. No areas of discoloured grass or vegetation were observed to indicate the presence of potential contaminants or elevated salinity.

Lot 1 DP537245 comprises a small, subdivided portion of land to the west of Argyle Street which slopes from the south to the north between a high of approximately RL218 m adjacent to the south boundary to a low of RL216m adjacent to the north boundary and occupies an area of approximately 1,939m^2 in plan.

Inspection of the existing structures within the lot did not indicate any significant cracks to indicate excessive shrink swell movements of the founding soils. Signs of surface erosion or potential landslip movements were not observed. Potential areas of fill were not observed within the lot.

Photograph 8: Aerial view of Lot 141 DP997490 and Lot 1 DP537245

3.1.3 Number 469 Argyle Street (Lot 15 DP1105675)

The lot slopes from the south to the north between a high of approximately RL227m adjacent to the southwest corner of the lot to a low of RL217m adjacent to the north boundary.

The front of the lot is near level and contains a single storey residential dwelling and lawn which appeared in good condition with no signs of cracking or distress observed to indicate potential excessive shrink swell movements.

Photograph 9: View looking west from near the east boundary of Lot 15 DP1105675

The rear of the lot contained an open paddock which dipped toward the north at approximately 5°- 7° with scattered tress around the perimeter of the lot.

Photograph 10: View looking west from near the rear garden of Lot 15 DP1105675

Signs of surface erosion or potential landslip movements were not observed. No areas of discoloured grass or discoloured vegetation were observed to indicate the presence of potential contaminants or elevated salinity. Potential areas of fill were not observed within the lot.

Photograph 11: Aerial view of Lot 15 DP1105675

3.1.4 Number 475 Argyle Street (Lot 16 DP979250)

The lot slopes from the south to the north between a high of approximately RL235m adjacent to the south boundary to a low of RL218m adjacent to the north boundary.

The front of the lot is gently sloping and contains a single storey residential dwelling and lawn which appeared in good condition with no signs of cracking or distress observed to indicate potential excessive shrink swell movements.

The rear of the lot contained an open paddock which dipped toward the north at approximately 5°- 7° with scattered tress around the south and west perimeter of the lot which increased in steepness towards the west boundary to around 9°

Photograph 12: View looking west from near the center of Lot 16 DP979250

Signs of surface erosion or potential landslip movements were not observed. No areas of discoloured grass, poor drainage or discoloured vegetation were observed to indicate the presence of potential contaminants or elevated salinity

Photograph 13: Aerial view of Lot 15 DP979250

3.1.5 Number 485 Argyle Street (Lot 1 DP207443)

Lot 1 DP207443 is the second largest lot in the study area and is located to the west of Argyle Street. The lot occupies an area of approximately 93,691m^2 and is undeveloped with the majority comprising open paddock.

The lot slopes to the north and south either side of a broadly east-west trending ridge line. The elevation varies from a high of RL235m adjacent to the west boundary to a low of RL218m adjacent to the east boundary. A drainage channel which occupies a topographic low point is present within the south of the lot.

Signs of significant slope stability were not observed. Some localised exposed earth/scarring was observed within the north of the lot however no indications of widespread dispersive/erosion prone soils were observed.

Photograph 14: View looking west from near the east boundary of Lot 1 DP207443

Photograph 15: View looking north from near the south boundary of Lot 1 DP207443

A small pond is present within the northeast corner of the lot which is surrounded to the south by mature trees.

Photograph 16: View looking south from near the north boundary of Lot 1 DP207443

No areas of discoloured grass/vegetation or poor drainage were observed to indicate the presence of potential contaminants or elevated salinity.

Photograph 17: Aerial view of Lot 1 DP207443

3.1.6 Number 2225 Remembrance Driveway (Lot 911 DP1121899)

This lot slopes from the north to the south between a high of approximately RL224m adjacent to the northwest corner to a low of RL RL212m adjacent to the south boundary.

The north portion of Lot 911 DP1121899 is occupied by a warehouse type structure (Derks Pet and Rural Supplies) which is surrounded by a concrete slab used for parking and delivery vehicle access. A masonry retaining wall is present within the northwest corner of the lot and is up to approximately 1.5m in height. It appears the existing warehouse type structure is constructed on a cut/fill pad will maximum estimated fill depth of around 1.5m depth, estimated from the retaining wall height.

A drainage pathway appears to run east from the south end of the retaining wall, then flow south through the center of the site.

Photograph 18: View looking east from near the west boundary of Lot 11 DP1121899

Photograph 19: View looking north from near the east boundary of Lot 11 DP1121899

The central and south of the lot is occupied by a grass paddock with a residential dwelling within the west of the lot to the east of Remembrance Driveway.

Photograph 20: View looking south to west from near the center of Lot 11 DP1121899

Signs of surface erosion or potential landslip movements were not observed. No areas of discoloured grass or vegetation were observed to indicate the presence of potential contaminants or elevated salinity. The area directly to the south of the area of suspected fill appeared wet underfoot in comparison with the rest of the lot.

Significant cracking of the pavement or signs of movement were not observed within the warehouse type structure within the lot.

Photograph 21: Aerial view of Lot 11 DP1121899

3.1.7 Number 18 Wonga Road (Lot 910 DP1121899)

This lot is occupied by a bus depot comprising a large warehouse/garage type structure to accommodate/service buses which is surrounded by a concrete parking area which occupies the majority of the site area of approximately 20,108m^2. The existing warehouse and concrete parking area appear to have been formed using cut/fill with retaining walls up to around 2m in height present within the northwest and southwest corners of the site.

The lot slopes from the south to the north between a high of approximately RL220m adjacent to the north boundary to a low of RL212m adjacent to the south boundary.

Photograph 22: View looking south from within the east of Lot 910 DP1121899

Photograph 23: View looking east from near the southwest corner of Lot 910 DP1121899

A fill batter sloping at around 12° to the south is present adjacent to the south end of the lot which did not appear to be slumping or displaying significant signs of erosion. Drainage within the site appears to be collected via a series of grated drains then diverted off site via an open drainage channel located within the southeast corner of the lot.

Photograph 24: View of the drainage channel within the southeast corner of Lot 910 DP1121899

The existing slab did display some cracking and some evidence of cracking of the existing retaining wall within the southwest corner of the lot was observed.

Photograph 25: Aerial view of Lot 910 DP1121899

3.1.8 Number 28 Wonga Road (Lot 2 DP570466)

Lot 910 DP570466 is occupied by a sand and gravel supply business and occupies an area of approximately 54,634m^2. The lot slopes from the north to the south between a high of approximately RL219m adjacent to the northboundary to a low of RL184m adjacent to the south boundary of the lot.

The lot contains a two-storey administration office near the front entrance (within the north), a variety of sand/gravel storage areas, a warehouse type workshop and a lay down area containing machinery and equipment.

The southeast portion of the lot contains overgrown bushland which is steeper than the majority of the lot and in situ bedrock comprising low to medium strength sandstone was observed in outcrop within this area.

Photograph 26: View of the entrance of Lot 2 DP570466 looking east.

Photograph 27: View of the south end of Lot 2 DP570466 looking east

In general, the ground surface dips from north to south at <5° and it appears (although unconfirmed) that the useable space may have been extended in a series of cut/fill modifications which, in one area was supported by a concrete/blockwork retaining wall up to around 2.5m in height.

Photograph 28: View of the retaining structure within the south of Lot 2 DP570466

Photograph 29: Aerial view of Lot 2 DP570466

Inspection of the existing structures did not indicate any significant cracks to indicate excessive shrink swell movements of the founding soils. No signs of excessive surface erosion or potential landslip movements were observed. The surface of the lot appeared generally well drained with no uncontrolled water/erosion observed.

3.1.9 Number 2235 Remembrance Driveway (Lot 11 DP3007)

This lot is occupied by a lawn within the west, a pond, a residential dwelling with associated outbuildings near the middle, an asphalt driveway adjacent to the south boundary and gardens/overgrown bushland within the east. The lot slopes from the west to the east between a high of approximately RL220m adjacent to the west boundary to a low of RL204m adjacent to the east boundary.

Photograph 30: View of the front lawn within Lot 11 DP3007 looking east from the west end of the lot

The pond is approximately 40m in length (maximum dimension) and it appears that excavated material has been apparently deposited to the east of the excavation, creating an approximately 2-3m high detention bund with batter slope.

Photograph 31: View of the south side of the pond within Lot 11 DP3007 looking north from near the site access driveway.

Within the east of the site, a stream is present in which exposed bedrock was observed and the topography increased in steepness. The bedrock comprised low to medium strength sandstone which was also observed outcropping within the adjacent bushland.

Photograph 32: View of bedrock exposures within Lot 11 DP3007 looking east from south of the site residence

Inspection of the existing structures did not indicate any significant cracks to indicate excessive shrink swell movements of the founding soils. No signs of excessive surface erosion or potential landslip movements were observed. The surface of the lot appeared generally well drained with no uncontrolled water/erosion observed.

No areas of discoloured grass or vegetation were observed to indicate the presence of potential contaminants or elevated salinity.

Photograph 33: Aerial view of Lot 11 DP3007

3.1.10 Number 2245 Remembrance Driveway (Lot 1 DP570466)

This lot is the largest lot in the study area and can be separated into two areas. It contains two single storey residential dwellings and pond within the west of the lot and overgrown bushland with temporary structures within the east of the lot. The ground surface within the east of the lot sloped to the east and west, either side of a broadly north-south trending ridgeline between approximately RL172m and RL210m. Within the west of the lot the terrain displays a gentle west to east dip between approximately RL218m and RL208m. The ground surface within the west of the lot did not appear significantly altered/filled however some excavated spoil was associated with the pond excavation and construction.

Photograph 34: View of existing pond within Lot 1 DP570466 looking east from south of the site residence

Access to the east portion of the site is provided by an earth fill bridge which traverses a small creek which runs broadly north south through the center of the lot (separating the east and west portions) draining from a large dam in an adjacent property to the south and outside the study area. Some minor slumping of the earth bridge was observed near the crest of the fill.

Photograph 35: View of the earth bridge with Lot 1 DP570466 looking west

In situ bedrock comprising low to medium strength sandstone was observed within the east of the lot at numerous locations. The surface of the site appeared generally well drained. Standing water or significant soft spots were not observed during the site walkover with the exception of the small creek passing through the center of the lot. Densely vegetated areas of variable steepness up to 15° were located to the east and west of the ridgeline.

Photograph 36: View of a densely vegetated slope towards the west boundary of Lot 1 DP570466 looking west

Photograph 37: Aerial view of Lot 1 DP570466

Inspection of the existing structures did not indicate any significant cracks to indicate excessive shrink swell movements of the founding soils. No signs of excessive surface erosion or potential landslip movements were observed with the exception of the minor slippage associated with the earth bridge. The surface of the lot appeared generally well drained with no uncontrolled water/erosion observed. No areas of discoloured grass or vegetation were observed to indicate the presence of potential contaminants or elevated salinity.

4.0 GEOTECHNICAL ASSESSMENT

4.1 Potential Constraints

Based on the results of the desk study and site walkover, the following potential constraints have been identified within the study area and are discussed in the following sections.

- Soft/loose or filled ground
- Potential highly shrinkable clay soils
- Shallow/variable bedrock depths
- Areas of steep ground
- Existing vegetation
- Potential mine subsidence constraints

4.1.1 Soft/Loose or Filled Ground

It is envisaged that soft or loose soil will be encountered within the existing ponds within the study area. The depth of the ponds unlikely exceeds 1m-2m however this would require confirmation should development occur. The areas directly adjacent to the ponds are likely to comprise fill soils from the pond excavation works. Additionally, cut/fill works appear to have taken place within at least two of the lots in the east of the study area to create level construction/laydown pads or for landscaping purposes.

It is unlikely the fill soils are controlled and placed to an engineering specification therefore potential for adverse variation exists in both the composition and degree of compaction of the fill. The presence of voids within uncontrolled fill as well as potential soft/loose zones or inclusions of deleterious materials may lead to potentially significant future total and differential settlements, occurring possibly over relatively short distances. This will likely only be of concern where fill soils are left in place and utilised for foundation or subgrade.

It is probable that, as part of any future development works, all uncontrolled fill present in settlement sensitive areas would either require removal and replacement with controlled fill of low 'reactivity' or any new structures should be supported on foundations extending through the fill and founding in suitable materials.

Due to the anticipated type of developments proposed, if the proposed chance of use is successful, it is anticipated that if soft/fill soils are encountered around the existing ponds, the impact could be mitigated via relatively minor earthworks and/or modifications in footing design.

Subject to the depth and composition of existing fill associated with the landscaped areas within the study area deeper earthworks may need to be undertaken within these areas however the depth of the fill or composition/characteristics are unknown currently.

4.1.2 Expansive Clay Soils

The western region of the study area is underlain by the Ashfield Shale which can display high volume changes with varying moisture content. Where shrinkable clay soils are identified underlying a site, an estimation of the potential magnitude of movement should be undertaken as part of preliminary subsurface investigations. The magnitude of shrink swell movements and variation may significantly increase where the effect of mature trees and wet areas (e.g. ponds are) present.

Based on the determined magnitude of shrink swell movements, a variety of measures can be adopted to prevent structural damage to new buildings including:

- Designing new structures to be tolerant of potential movements via flexible building materials, expansion/slip joints etc.
- Reinforcement thicker floor slab, deeper footings
- Fully suspended floor slab
- Replacement of expansive clay below floor slabs with inert, granular fill

Regardless of the proposed design to accommodate movement, protection of the new structures requires the prevention of abnormal moisture contents developing below structures therefore ongoing maintenance, landscaping, surface/subsurface drainage and proposed vegetation must all be designed to control water throughout the design life of the building.

Due to the climate in Picton, the depth of seasonal moisture variation is unlikely to exceed 2.0m below ground level which reduces the magnitude of likely shrink swell movements in comparison to other states in Australia. Additionally, due to the nature of the probable structures some tolerance to movement may be accommodated however where high shrink swell movements are anticipated, construction of some structure types (brick/masonry, low movement tolerant structures) may not be economically feasible.

The significance of expansive clay impacting proposed future constructions will vary across the study area and will require subsurface investigation to further assess.

4.1.3 Shallow/Variable Bedrock Depth

In addition to the Ashfield Shale underlying west of the study area, sandstone bedrock is visible in outcrop within the east of the study area. Where bedrock is located near the existing ground surface additional requirements for bedrock removal may be required to construct new footings, service trenches etc. Subject to the strength and depth to bedrock, additional excavation requirements may be necessary.

In addition, where variable depth to bedrock is encountered underlying a single structure, additional footing/slab requirements may be necessary to reduce the potential for differential settlement (i.e., a footing founded on/off low strength or stronger bedrock will settle far less under an applied load than a footing founded in clay soils).

The impact of shallow bedrock on project costs can be reduced provided the location and variation are known prior to construction.

4.1.4 Topography

The west of the study area is underlain by the Ashfield Shale and the lots display the characteristic low angle concave/convex undulating slope morphology of less than around 4°-8° therefore the majority of the site is not prone to landslip hazards or potential instability.

The residual soils of the weathered Ashfield Shale are anticipated at a shallow depth below the existing ground surface and very limited thicknesses of superficial/colluvial soils are anticipated. This reduces the probability of widespread low angle slump/sliding failures developing at the interface of superficial/residual soils resulting in development of slope stability problems.

Related to the outcrops of sandstone bedrock at the surface of the study area, the east of the study area contains moderately to steeply dipping terrain. Moderately and steeply dipping terrain can pose significant challenges in both design and construction where new structures are proposed to be constructed and may be cost prohibitive for the proposed commercial type developments.

Where moderately dipping (10°- 18°) terrain is present underlying warehouse type buildings with large footprints, significant earthworks would likely be required therefore these areas may not be suitable for these types of structures however may be suitable for car parking areas.

Where steeply dipping terrain (>18°) is present below proposed warehouse type structures, high additional costs are anticipated to provide adequate footings to resist downslope creep as well as the potential for ground stabilization/retaining structures. This terrain is not likely suitable for light industrial purposes.
It is recommended a full topographic survey is undertaken to adequately delineate the terrain/slope morphology to more accurately delineate useable construction areas.

4.1.5 Existing Vegetation

Mature trees are present within the study area and range from densely populated woodland to lawn areas with sparsely distributed trees. It is envisaged where development is to occur within these areas, the roots ball/system as well as any affected soils would require removal prior to construction. The majority of the densely vegetated areas occur within the east of the study area which may be underlain by a limited amount of soil (<1.0m depth) underlain by sandstone bedrock. The depth of the affected soils requiring removal may therefore be determined by the depth to bedrock which is unlikely to be significantly affected by tree roots/vegetation.

4.1.6 Potential Mine Working Constraints

The study area falls within the Bargo Mine District and has minimum requirements pertaining to the construction of residential dwellings and slab dimensions and rigidity for residential constructions. This requirement may be due to the potential for larger, on ground slabs to increase the depth of the zone of influence below ground level, therefore are more likely to be impacted by subsidence where a portion of the load is supported in potentially unstable ground. Although the slab requirements relate to residential dwellings, clarification with the Subsidence Advisory Committee NSW should be sought to determine if large commercial type developments are required to adhere to any construction conditions or whether any additional works are required to confirm status/extent of prior workings. It is recommended this potential constraint is further assessed at an early stage as it may have significant financial implications.

4.2 Severity of Anticipated Geotechnical Constraints/Conditions

To enable the identified constraints to be assessed, a system of assessing the impact of those constraints on the feasibility of the rezoning proposal is required. A framework of assessing the constraints has not been specified by Wollondilly Shire Council however for preliminary purposes the following framework is proposed:

- Identify constraint

- Determine the distribution of constraint within study area where:

Rating	Definition
1	occurs within <10% of total study area
2	occurs between 10% and 20% of total study area
3	occurs between 20% and 50% of total study area
4	occurs between 50% and 70% of total study area
5	occurs within greater than 70% of total study area

+

- Assess the impact of constraint on feasibility of development where:

Rating	Definition
1	Minor Impact – Typically allowed for in design, no significant additional costs
2	Low Impact - Proposed structures/layout can be readily modified to suit conditions
3	Moderate Impact – Elements of the development may require specialist engineering solutions/significant design modification during construction or may require significant additional earthworks/structural design to address constraint
4	High Impact – The constraint has a significant impact on the financial feasibility of the development or the construction timetable
5	Project Wide Impact – The constraint is such that it is a key element in determining the future of the project.

Using the above assessment methods, the identified constraints to development have been assessed as a whole of the study are the results are provided in the table below.

Constraint	Distribution	Rating	Impact	Rating	Score (max 10)
Very soft/loose/filled ground	10%-20%	2	Minor to low	1 to 2	**3 to 4**
Expansive Clay Soils	50% - 70%	4	Low to Moderate	2 to 3	**6 to 7**
Shallow/Variable Depth to Bedrock	10%-20%	2	Minor to Low	1 to 2	**3 to 4**
Steeply Sloping Ground	<10%	1	High	3-4	**4**
Existing Vegetation	20%-50%	3	Minor to Low	2	**5**
Poorly Drained areas	10% - 20%	2	Minor	1	**3**
Mine Subsidence	Requires Clarification with Mine Subsidence Advisory				

5.0 RECOMMENDATIONS

Based on the results of the desk study and walkover assessment it appears that there are limited significant geotechnical constraints to developing the study area based on the anticipated type of proposed structures. However, it is considered highly likely that expansive clay soils will underlie the majority of the site which will likely reduce in thickness towards the east. This is assessed as the greatest development constraint to the proposed development with potentially existing vegetation and steeply sloping ground also a consideration, both of which are dominant in the eastern lots only.

The geotechnical properties of the areas underlain by potentially loose/soft/filled ground should also be determined to enable better assessment of likely development impacts.

It is recommended that a broadscale subsurface investigation is undertaken to determine the thickness and distribution of clay soils to enable determination on any potential future development.

Additionally, detailed elevation survey of the study area should be undertaken to enable accurate assessment of topography/sloping terrain.

The steeper terrain within the east of the study area is unlikely to be viable where slopes exceed 15° however the occurrence of this topography forms a relatively minor portion of the study area.

Prepared by:

Kieron Nicholson
Senior Engineering Geologist

Reviewed by:

Troy Crozier
Principal
MIE Aust
MAIG. RPGeo-Geotechnical & Engineering
Registration No.: 10197

6. REFERENCES:

1. Geological Society Engineering Group Working Party 1972, “The preparation of maps and plans in terms of engineering geology” Quarterly Journal Engineering Geology, Volume 5, Pages 295 - 382.
2. C. W. Fetter 1995, “Applied Hydrology” by Prentice Hall. V. Gardiner & R. Dackombe 1983, “Geomorphological Field Manual” by George Allen & Unwin

Appendix 1

CROZIER
GEOTECHNICAL CONSULTANTS

Crozier Geotechnical Consultants ABN: 96 113 453 624
Unit 12/ 42-46 Wattle Road Phone: (02) 9939 1882
Brookvale NSW 2100 Email: info@croziergeotech.com.au
Crozier Geotechnical Consultants, a division of PJC Geo-Engineering Pty Ltd

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: -

$$Q_c \text{ (MPa)} = (0.4 \text{ to } 0.6)\ N \text{ blows (blows per 300mm)}$$

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

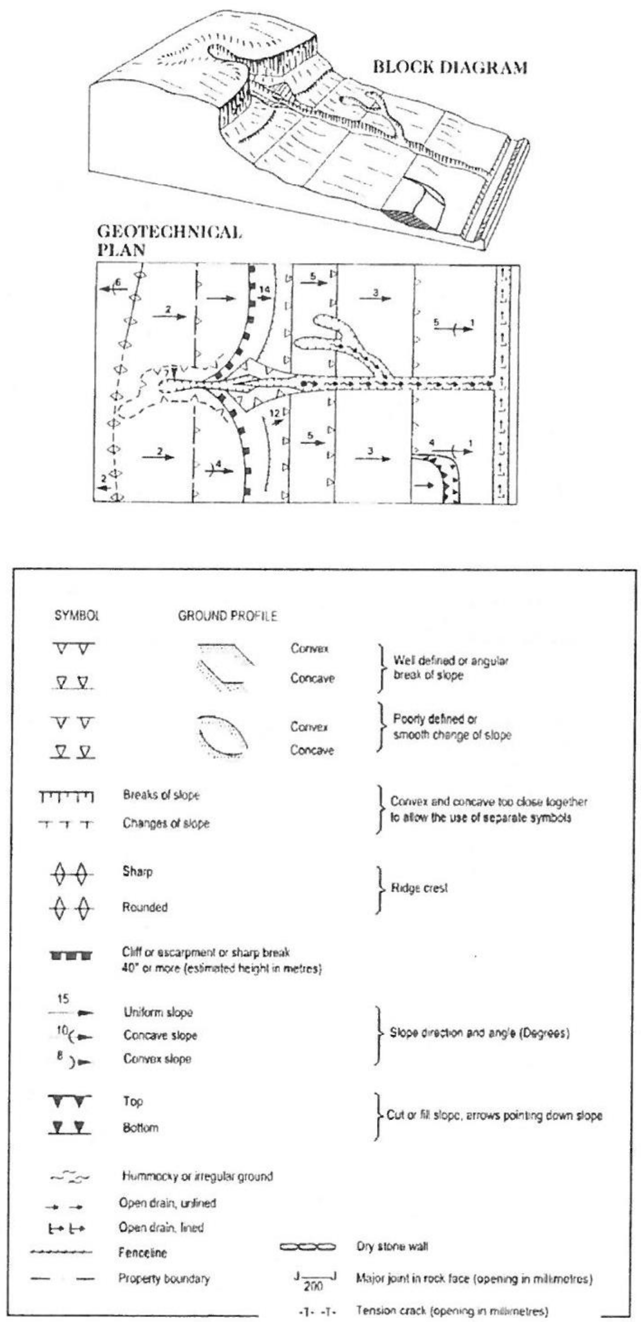
In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, the Company requests that it immediately be notified. Most problems are much more readily resolved when conditions are exposed than at some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

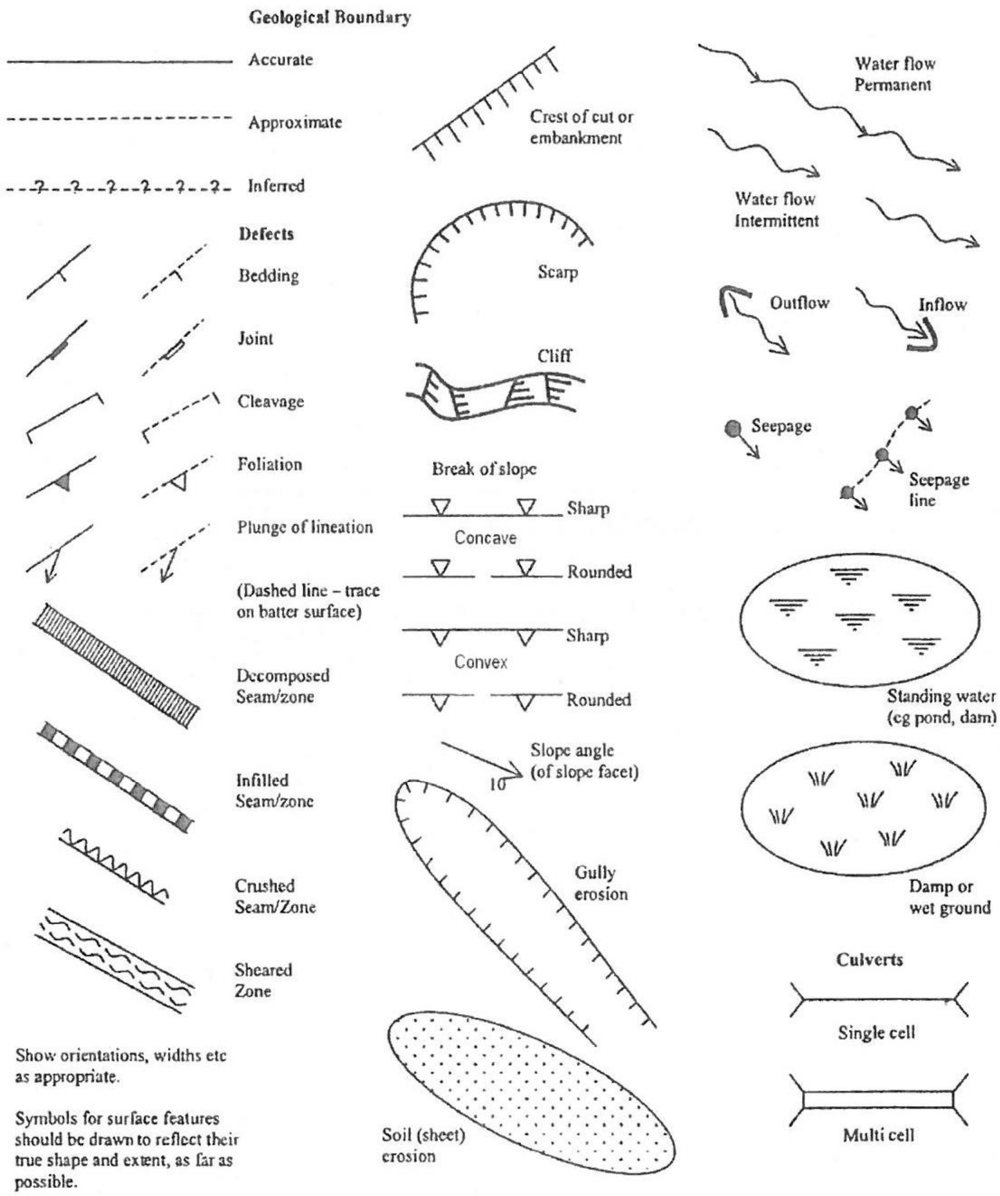
Site Inspection

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

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.

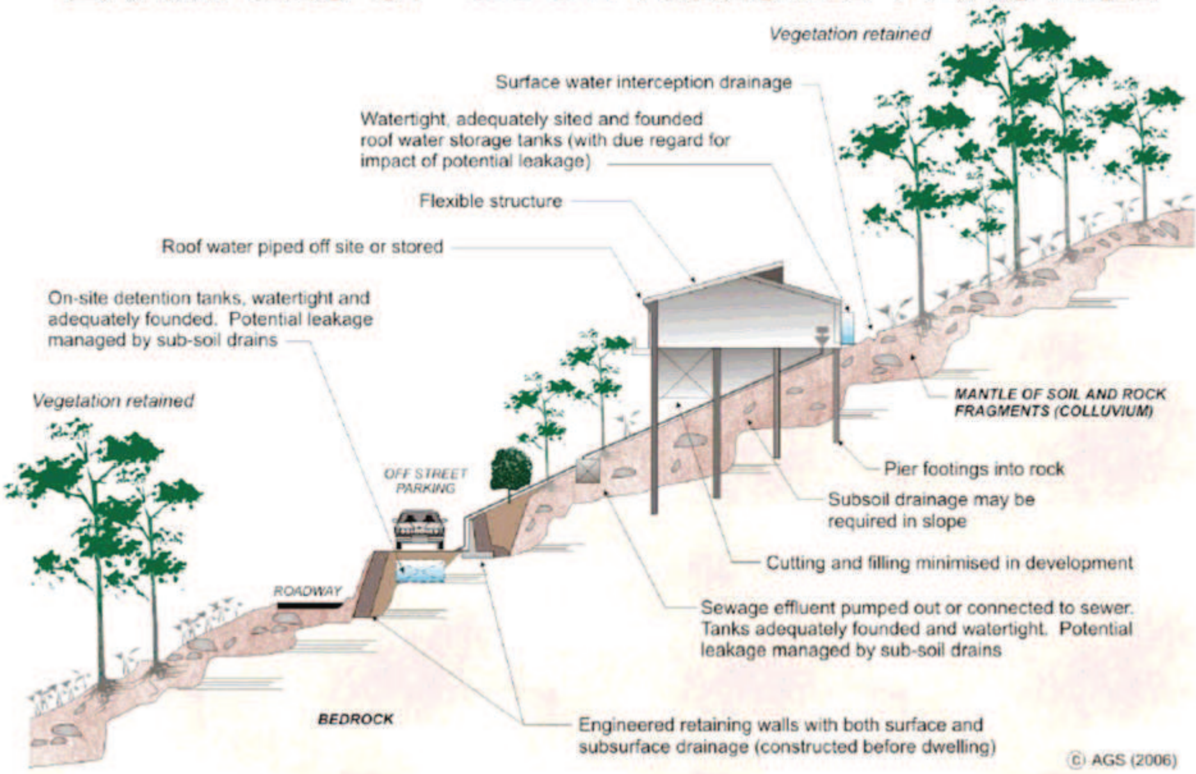
CROZIER
GEOTECHNICAL CONSULTANTS

Appendix 3

APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	*POOR ENGINEERING PRACTICE*
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical practitioner at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminatory bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance including onto property below. Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on rock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within rock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE		
SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide general falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond on bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge roof runoff into absorption trenches.
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by geotechnical consultant	
SITE VISITS	Site Visits by consultant may be appropriate during construction/	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident see advice. If seepage observed, determine causes or seek advice on consequences.	

EXAMPLES OF GOOD HILLSIDE PRACTICE



EXAMPLES OF POOR HILLSIDE PRACTICE