DM & RD DOSSOR **PROPOSED RESIDENTIAL SUBDIVISION** 1 Survey Street, Lennox Head, NSW SLOPE STABILITY ASSESSMENT

NR1059/3-AD 31 August 2006 NR1059/3-AD 31 August 2006

SAKE Development Suite 11, 340 Darling Street BALMAIN NSW 2041

Attention: Sarah Kelly

Dear Madam,

RE: PROPOSED RESIDENTIAL SUBDIVISION – 1 SURVEY STREET, LENNOX HEAD SLOPE STABILITY ASSESSMENT

Coffey Geosciences Pty Ltd is pleased to present our report on the slope stability assessment carried out at the above site. The assessment comprised collation of information obtained during previous studies at the site, and presentation of a slope stability hazard assessment based on the assessment methodology presented by the Australian Geomechanics Society Landslide Risk Management Concepts and Guidelines 2000.

We draw your attention to the attached sheet entitled "Important Information About Your Coffey Report" which should be read in conjunction with this report.

We trust that this report meets with your requirements. If you require further information please contact the undersigned in our Coffs Harbour office.

For and on behalf of

COFFEY GEOSCIENCES PTY LTD

DAVID BARKER Senior Geotechnical Engineer

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1/18 Hurley Drive Coffs Harbour , NSW 2450 Australia Telephone +61 2 6651 3213

Facsimile +61 2 6651 5194

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1. INTRODUCTION

Coffey Geosciences Pty Ltd (Coffey) has carried out a Slope Stability Assessment (SSA) for a proposed residential subdivision at 1 Survey Street, Lennox Head. The current assessment was commissioned by DM & RD Dossor for the preparation of a Project Application and Environmental Assessment under Part 3A of the Environmental Planning and Assessment Act 1979.

Based on the brief for the work, we understand that the aim of the SSA was to satisfy the requirements of the Director General of the Department of Planning with respect to slope stability. Documentation provided to Coffey indicates that the requirement for the SSA is as follows:

"A detailed geotechnical assessment is required to establish certainty regarding the site stability and suitability for the proposal. This should consider the Australian Geomechanics Society landslide Risk Management Guidelines 2000."

This report collates the available information from the previous investigations and presents a SSA using an updated assessment methodology developed and presented in the Australian Geomechanics Society Sub-Committee (March 2000) Landslide Risk Management publication titled "Landslide Risk Management Concepts and Guidelines" (AGS 2000). Coffey conducted the work in general accordance with proposal NR1059/3-AA dated 2 June 2006.

2. PREVIOUS WORK

Coffey has previously conducted investigation and assessment work which included or was specific to the site of the proposed subdivision in 1986, 1999 and 2002. In addition, Coffey provided expert witness and geotechnical consultancy services in 2001 and 2002. The results of the previous work are discussed below.

2.1 1986 Coffey Report

The site was included in a geotechnical zoning survey carried out by Coffey in 1986 for Ballina Shire Council, the results of which were presented in report S7761/1-AA dated March 1986. This survey was primarily based on aerial photography interpretation, with some ground truthing.

Drawing S7761/1-3 in the report indicated that the site of the proposed subdivision is located within Zones IIA and III defined as Medium and Low to Very Low risk of instability respectively.

2.2 1999 Coffey Report

In September and October 1999, Coffey carried out a geotechnical and site stability assessment at the site, the results of which were presented along with comments and recommendations in report NR1059/1-C dated 11 October 1999.

Field work for the geotechnical and site stability assessment consisted of the excavation of 18 test pits (TP1 to TP18) to depths of between1.5m and 3m, and a site walkover and stability assessment by a Coffey Senior Engineering Geologist. The engineering logs of the test pits are presented in Appendix A. Reference should be made to the original report for explanation sheets defining the term and symbols used in the preparation of these logs. Laboratory testing comprised California Bearing Ratio (CBR) and shrink/swell tests for pavement thickness design and lot classification purposes respectively. The report presented the results of the investigation and laboratory testing, summarised the site conditions, and provided comments and recommendations on slope stability, lot classification, pavement thickness design, detention pond construction and site preparation.

With respect to slope stability, it was assessed that the site could be divided into three zones. The zones can be summarised as comprising a low risk zone (areas of flatter ground along the base of the valley and on the

lower slopes of the ridges), a low to medium risk zone (areas of steeper slopes above the valley floor forming the middle slopes of the ridgelines) and a medium risk zone (areas of steeper slopes on the upper areas of the eastern ridge). General recommendations for development within the different risk zones were provided in the report.

2.3 Expert Witness Work and 2002 Coffey Report

Following the issue of the above report, we understand that the development application was rejected by Ballina Shire Council, and an appeal was heard before the Land and Environment Court (Dossor v Ballina Shire Council [2001] NSWLEC 173). During the appeal, Coffey provided expert evidence for Dossor regarding the geotechnical and slope stability issues for the development. For Ballina Shire Council, Robert Carr & Associates Pty Ltd (RCA) were engaged to provide expert evidence.

RCA raised several issues upon review of the Coffey reports, and considered that further investigations were required to investigate the interface between the basalt and underlying agglomerate geological units at the site and the presence of any weak layers, and to refine the understanding of groundwater flows. Both RCA and Coffey agreed that even if weak layers were present along with adverse groundwater conditions, technical solutions could be designed to allow residential development to proceed.

On 1 August 2001 the NSW LEC dismissed the appeal against Ballina Shire Council's refusal of the subdivision development application. With regard to geotechnical issues, the following conclusions were stated:

172(7) the site stability issues should be fully addressed before consent is given for any residential development of the subject land.

172(10) the subsurface drainage proposals which directly affect residential development on individual lots of the subject land should be fully designed and evaluated before consent is granted.

Discussions between Coffey and RCA continued following the judgement, and from these discussions it was agreed that additional investigations consisting of the drilling of four boreholes and installation of standpipe piezometers would resolve the geotechnical issues in relation to stability and drainage. On this basis, four boreholes (BH1 to BH4) were drilled in February 2002 to depths of between 6.2m and 19.58m at locations nominated by RCA during the discussions. One borehole was located within north western area of the site, with the remaining three boreholes located within the south eastern area of the site. The results of the drilling were presented in report CH1059/2-K dated 11 March 2002. The engineering logs of the boreholes are presented in Appendix B. Reference should be made to the original report for explanation sheets defining the term and symbols used in the preparation of these logs. Based on the drilling results, Coffey concluded that no significant clay layers that could adversely impact on the stability of the site were evident in the boreholes. Groundwater levels were measured in BH2 and BH4, and no groundwater was encountered in BH1. A blockage in BH3 prevented measurement of water levels.

2.4 Current Work

The current geotechnical work comprised the following:

- Review of available geotechnical data from previous work carried out by Coffey, and provision of an updated geotechnical report (including a plan of the currently proposed subdivision layout) which addresses the requirements of the Director General of the Department of Planning with respect to slope stability;
- A site walkover assessment carried out by a Coffey Senior Engineering Geologist on 10 August 2006. The purpose of the walkover was to observe the current site conditions with respect to slope

stability, and to map areas where groundwater seepage was evident.

The locations of the previous investigations and observations from the current site walkover assessment are shown on the current proposed subdivision layout on Figure 1. Figure 1 is based on a plan provided by Sarah Kelly of SAKE Developments.

Coffey is currently in the process of carrying out an Environmental Site Assessment at the site, the results of which will be presented in a separate report.

3. SITE CONDITIONS

3.1 General

The surface and subsurface conditions information presented in this report is based on Coffey reports NR1059/1-C and NR1059/2-K and the site walkover assessment carried out on 10 August 2006.

3.2 Surface Conditions

The information presented in this section is based on that presented in Coffey report NR1059/1-C dated 11 October 1999 and a site walkover carried out by a Coffey Senior Engineering Geologist on 10 August 2006.

The site of the proposed subdivision covers an area of around 9.9ha and lies on the eastern side of Survey Street and Amber Drive, Lennox Head. The site is bordered by existing residential subdivisions on the western and northern sides. The site is currently used as a pasture and is predominantly open paddock. A small area of woodland is present on the southern end of the site.

Topographically, the site lies in a broad, north-south trending valley, open to the south and bounded on the east, west and north sides by low ridges. Hills slopes on the ridges are generally moderate, varying from around 18° to 20° on the upper slopes to 12° to 15° on the lower slopes. The base of the valley is occupied by a broad, gently sloping area with slope angles of typically around 3° to 5°. A small creek runs along the base of the valley, draining to the south.

Localised areas of rock outcrop were noted along the bed of the creek and scattered basalt cobbles were noted on the upper slopes of the ridges.

During the previous work, the gently sloping area between the base of the lower slopes and the creek were noted to be wet and boggy, with widespread surface water and groundwater seepage. These wet and boggy soils were again evident during the recent site walkover. Groundwater seepage was inferred where surface water, wet/boggy surface soils and variations in vegetation were observed on the mid-slopes of the hills near proposed lots 27 to 32 on the eastern side of the creek. Areas of wet/boggy surface soils and inferred groundwater seepage observed during the recent site walkover are shown on Figure 1.

Localised soil erosion/scour was evident near the outlet of a stormwater drain on the western side of the site near proposed lots 1 and 2, and near a pump station/stormwater drain outlet near the northern end of the site. The approximate locations of the erosion/scour are shown on Figure 1.

3.3 Subsurface Conditions

The information presented in this section is based on that presented in Coffey reports NR1059/1-C dated 11 October 1999 and NR1059/2-K dated 11 March 2002.

The 1:250,000 scale, "Murwillumbah", geology map of the area indicates the site is underlain by weathered volcanic rocks of the Tertiary Lismore Basalt, described as bedded basalt flows with layers of volcanic ash, agglomerate and sedimentary rocks.

Site observations indicated that the underlying geology on the site consists of three different subsurface units described as follows:

- On the crest and upper slopes of the ridge to the east of the site, the underlying rock appears to comprise highly weathered, low to medium strength, highly fractured basalt, overlain by gravelly clays with basalt cobbles and boulders;
- On the middle and lower slopes, the thickness of residual soils is considerably greater than on the upper slopes, and the underlying basalt appears to be more deeply weathered, possibly indicating a different composition or structural geology;
- On the bed of the creek in the southern and central area of the site, the rock exposed consists of
 rounded to sub-angular basalt gravel, cobbles and small boulders in a fine-grained matrix. This rock
 is considered to be volcanic agglomerate or possibly an alluvial deposit of basalt cobbles and
 boulders in a matrix of volcanic ash. This material appears to be less weathered and more resistant
 to erosion than the overlying basalt and was observed to be massive with very few joints or fractures.

The generalised subsurface conditions as indicated by the test pitting are shown in Table 1.

UNIT	OBSERVED THICKNESS (m)	DESCRIPTION
Topsoil	0.1 to 0.4	Generally comprising Gravelly Silt Clay, high plasticity, red-brown and grey, typical unit thickness observed was 0.2m.
Residual Soil	0.7 to >3	Gravelly CLAY, high plasticity, fine to coarse grained gravel, orange-brown and grey, extent of gravel depends on the topographic location on site, refer to geological descriptions above.
Bedrock	-	BASALT, highly weathered, low to medium strength, highly to slightly fractured, fine to cobble size particles in matrix, red- brown and grey-brown, refer descriptions above.

TABLE 1: SUMMARY OF SUBSURFACE CONDITIONS OBSERVED IN TEST PITS

The subsurface conditions encountered in each of the four boreholes drilled on site are summarised in Table 2.

TABLE 2: SUMMARY OF SUBSURFACE CONDITIONS OBSERVED IN BOREHOLES

BOREHOLE NO.	1	2	3	4						
MATERIAL TYPE		DEPTH (m)								
Colluvial Soil	0.0-0.8									
Residual Clay Soil	0.8-6.2	0.0-2.8	0.0-4.1	0.0-3.2						
XW Basalt		2.8-5.7	4.1-6.6	3.2-4.8						
HW to MW Basalt			6.6-7.8	4.8-5.4, 8.5-12.2						
MW to SW Basalt		5.7-6.65	7.8-13.5	5.4-8.5, 12.2-13.4, 18.8-19.6						
SW to Fr Basalt				13.4-18.8						

The subsurface conditions interpreted from the boreholes are further discussed below.

Western Hillside

BH1 was drilled on moderately sloping ground on the lower part of the western hillside near the creek. BH1 encountered a surface layer of 0.8m of very stiff silty clay (possible colluvium) with basalt gravel, cobbles and boulders. This was underlain by hard, residual sandy and silty clay with occasional basalt cobbles continuing to borehole termination depth at 6.2m.

Eastern Hillside

BH2 was drilled on the lower part of the eastern hillside at approximately RL21.1m. BH2 encountered a 0.3m thick surface layer of soft, water affected clay underlain by stiff to very stiff residual clay to a depth of 2.8m. This was underlain by hard, residual clay (extremely weathered basalt) to a depth of 5.7m. Diamond coring commenced at 5.7m and encountered moderately and slightly weathered basalt to borehole termination depth at 6.65m. Significant clay seams were not observed.

BH3 was drilled in the lower to middle slopes of the eastern hillside. BH3 encountered stiff to very stiff residual clay soils to a depth of 1.7m underlain by hard residual clay to 4.15m. Diamond coring commenced at 4.15m depth. Extremely and extremely to highly weathered, very low strength basalt was encountered to a depth of 6.5m, becoming stronger towards base of this layer. Highly weathered, medium strength basalt was encountered to 7.9m and moderately weathered, medium to high strength basalt to a depth of 9.3m. From 9.3m to borehole termination depth at 13.5m, BH3 encountered inter-layered moderately weathered, moderately to slightly weathered basalt, varying in strength from medium to high to very high strength. The basalt in BH3 was observed to be locally vesicular/amygdaloidal with clay and zeolite-filled vesicles. A number of clay and fragmented rock seams were noted at various depths. These zones were typically 20mm to 50mm thick.

BH4 was drilled on the middle slopes of the hillside at approximately RL34.9m. BH4 encountered very stiff to hard residual clay soils to a depth of 4.8m, grading to extremely weathered basalt below approximately 4m depth. Diamond coring commenced at 4.8m depth. Highly weathered basalt (with a thin layer of extremely weathered basalt) was encountered from 4.8m to 5.4m, underlain by inter-layered moderately weathered, medium to high strength basalt and slightly weathered, high to very high strength basalt continuing to a depth of 8.5m. This was underlain by highly to moderately weathered, medium to high strength basalt to 12.2m, moderately to slight weathered, high strength basalt to 13.4m, slightly weathered to fresh, high to very high strength basalt to 18.8m and moderately weathered, medium to high strength basalt to borehole termination depth at 19.58m. No significant clay seams were observed in the drill core from BH4.

In general, the subsurface conditions encountered in boreholes BH2 and BH4 consist of a surface layer of around 3m to 4m of residual clay soils underlain by 1.5m to 3m of extremely weathered and highly weathered basalt grading to slightly weathered basalt continuing to depth. Significant clay seams (defined for the purposes of this report are typically 100mm or greater in thickness of predominately clay with less than 50% gravel or crushed rock) were not observed in any of the core sampled from the boreholes. Borehole BH3 encountered a small number of thinner clay seams, however these were not present in borehole BH2 or BH4.

3.4 Groundwater

Groundwater inflows were observed in all pits located in the lower sections of the site, namely TP6, TP7, TP8, and TP17. These pits appear to correspond to groundwater flows in top of the interface of volcanic agglomerate observed in the base of the creek. It is noted that the test pitting fieldwork carried out in September 1999 followed a protracted period of wet weather.

The standing groundwater table was measured on 26 February 2002 at a depth of 0.98m in borehole BH2 and 10.4m in borehole BH4. A blockage in BH3 prevented measurement of water levels. Groundwater was not

observed in borehole BH1.

4. SLOPE STABILITY

4.1 General

With reference to AGS 2000, the assessment of risk should consider two factors, namely the likelihood of an event occurring and the consequences should it occur. The risk can be assessed for any number of identified hazards at the site (e.g. small slumps, large scale rotational failures or debris flows, global failure of retaining walls).

Previously, Coffey carried out an assessment (report NR1059/1-C) which divided the site into three "risk" zones based on the conditions evident at the site. The report indicated that it is not technically feasible to assess stability in absolute terms such as "stable" or "unstable", and therefore its intent was to consider the "risk" of slope movement, where "risk" classes were defined in terms of the likelihood of slope instability (e.g. low risk was defined as "slope stability is very unlikely"). On this basis, though the previous Coffey report refers to "risk", the assessment could be considered to be referring to the "likelihood" of slope instability with reference to AGS 2000.

In terms of slope stability risk, the likelihood and consequences of instability would depend on the nature, location and type of the development at the site. Without details of the proposed developments (e.g. specific locations and types of residential developments and details of site earthworks such as the location and depth of excavations, filling), the assessment of slope stability would be limited to consideration of hazards for the site in its undeveloped state, and an assessment of the relative likelihood of occurrence of these hazards. This was the intent of Coffey report NR1059/1-C, though with likelihood referred to as risk.

It is considered that the division of the site into zones of differing slope stability characteristics is appropriate for the site based on the site conditions. The delineated boundaries between the zones are shown on Figure 2, which also shows the current proposed subdivision layout. The zones are referred to as Zone 1, Zone 2 and Zone 3 as shown, and are discussed in section 4.2. Recommendations for development both in general and specifically related to each of these zones are presented in section 5 of this report.

In terms of the SSA for each of the site zones, it is considered that slope stability risk can be assessed with reference to AGS 2000 based on consideration of the likely type of development at the site and the likelihood and consequences of the identified hazards. The assessment of risk assumes that developments are designed and constructed in accordance with the recommendations for development in this report. The risk assessment is presented below.

4.2 Site Zones

The consideration of likelihood of slope instability is based on a number of factors including slope angle, subsurface conditions, groundwater levels and the existence of indicators of past instability. Based on the assessment, the site is divided into three zones. The three zones are shown on Figure 2 and are described below.

- Zone 1: Areas of flatter ground along the base of the valley and on the lower slopes of the ridges. Slope angles in this area are generally less than about 10° to 12°. Subsurface conditions in this zone generally comprise stiff to very stiff residual Gravelly Clay soils, with water inflows observed in several test pits at various depths. It is noted that previous reports indicated wet boggy surface soils in some portions of this zone at times of field work. No evidence of slope instability was observed in this zone during previous investigations.
- Zone 2: Areas of steeper slopes above the valley floor forming the middle slopes of the ridge lines on the eastern and western sides of the valley. Slope angles in this zone are typically in the range of

15° to 18°. Subsurface conditions in this zone generally comprise very stiff to hard residual Gravelly Clay soils overlying weathered basalt at depth. In general, the water inflows were not observed in the test pits excavated in this zone except for TP17, in which groundwater inflows were observed at a depth of between 1m and 1.5m. Groundwater seepages were evident in parts of this zone as shown on Figure 1 (near proposed lots 27 to 32). The ground surface in this zone shows some signs of soil creep. No evidence of significant past instability was observed in this zone.

• Zone 3: Areas of steep slopes on the upper areas of the eastern ridge. Slope angles in this zone are typically in the range of 18° to 22°. Subsurface conditions in this zone generally comprise very stiff to hard residual Gravelly Clay soils overlying weathered basalt at varying depths. In general, no water inflows observed in the test pits at the time of field work. The ground surface in this area shows some more widespread signs of soil creep. No evidence of significant past instability was observed in these areas.

4.3 Identification of Hazards

The hazards considered in the risk assessment for the site are shown below:

- Hazard 1: Shallow seated instability of the natural and altered slopes in the vicinity of the proposed developments. This failure might take the form of relatively minor slips and/or slumping of site soils;
- Hazard 2: Deep seated instability of the natural and altered slopes in the vicinity of the proposed developments. This failure might take the form of a significant slip/slump, with a relatively large amount of soil and/or rock material displaced;
- Hazard 3: Instability of appropriately battered and treated slopes or failure of engineer designed retaining walls.

4.4 Assessed Risk

For the purposes of this assessment, the terms and descriptions provided in Appendix G of AGS 2000 have been used. The terms and descriptions are summarised in Appendix C.

For the hazards indicated above, the assessed likelihood and consequences of each hazard and the associated risk is presented in Table 6.

ZONE	HAZARD	ASSESSED LIKELIHOOD	ASSESSED CONSEQUENCES	ASSESSED RISK	
	Hazard 1	Rare	Minor	Very Low	
Zone 1	Hazard 2	Not credible	Major	Very Low	
	Hazard 3	Rare	Medium to major	Low	
	Hazard 1	Unlikely	Minor	Very Low to Low	
Zone 2	Hazard 2	Not credible to rare	Major	Low	
	Hazard 3	Rare	Medium to major	Low	
	Hazard 1	Possible	Minor	Low to Moderate	
Zone 3	Hazard 2	Rare	Major	Low to Moderate	
	Hazard 3	Rare	Medium to major	Low	

TABLE 6:ASSESSED RISK FOR SLOPE INSTABILITY HAZARDS

A discussion of the assessed likelihood and consequences used to assess the risk of slope instability is presented in Appendix C.

Based on the above, the highest assessed risk for each of the zones is shown below:

- Zone 1 Very low to low risk of slope instability.
- Zone 2 Low risk of slope instability.
- Zone 3 Low to moderate risk of instability.

The above assessed risks are based on the developments being designed and constructed in accordance with the recommendations outlined in section 5 of this report.

AGS 2000 provides example implications for very low, low and moderate risk levels as follows:

- Very Low Risk: Acceptable. Manage by normal slope maintenance procedures.
- Low Risk: Usually accepted. Treatment requirements and responsibility to be defined to maintain or reduce risk.
- Moderate Risk: Tolerable provided treatment plan is implemented to maintain or reduce risks. May be accepted. May require investigation and planning of treatment options.

Recommended treatment options, slope maintenance procedures and limitations on development are provided in section 5 to achieve the assessed risks.

5. RECOMMENDATIONS FOR DEVELOPMENT

5.1 Limitations and Intent

This report provides an assessment of the risk associated with slope instability at the site. It must be accepted that the potential risks associated with hillside construction are greater than construction on level ground in the same geological environment, and inappropriate construction techniques can increase the potential for ground movement. Recommendations for development are provided below.

<u>All</u> developments should be designed and constructed in accordance with the recommendations presented in sections 5.2 and 5.3. In addition, developments should be designed and constructed in accordance with the recommendations in sections 5.4, 5.5 or 5.6 as appropriate for their location on the site with respect to the site stability zones.

This report should not be regarded as a site investigation report for the specific design of developments, though general comments regarding geotechnical issues have been made so far as these affect slope stability. Coffey has carried out an assessment of site contamination resulting from past uses of the land which has been issued under separate cover.

Site conditions exposed during site earthworks should be observed by a suitably experienced engineer to confirm conditions which have been inferred in this assessment.

5.2 General Guidelines for Construction

The following guidelines are recommended for <u>all</u> developments at the site (regardless of their location):

Design and Construction

• The design and construction of all developments should be carried out in accordance with good hillside practice as shown on Figure 3 and Figure 4, and the relevant recommendations for development presented in this report.

- All developments should be designed by an engineer with appropriate experience and knowledge of the site conditions, using sound engineering principles and in accordance with the relevant Australian Standard or appropriate industry standard.
- Foundations for residential structures should be designed and constructed in accordance with the
 recommendations and advice of AS2870-1996, 'Residential Slabs and Footings'. Footings should be
 founded outside or below the zone of influence of any existing or excavations (e.g. batter slopes,
 services trenches or retaining walls etc) where the structure loads have not been incorporated into the
 design of the excavation.

Earthworks

- Earthworks should be carried out in accordance with the guidelines presented in AS3798-1996 "Guidelines on Earthworks for Commercial and Residential Developments".
- The removal of vegetation has the potential to increase the risk of instability. It is recommended that existing vegetation be maintained where practicable and that stripped areas be revegetated as soon as possible. Where a hole is created from the removal of tree root balls, the hole should be backfilled in a controlled manner using fill materials which are similar in nature to the surrounding natural soils. The areas should then be revegetated as soon as possible. At the subdivision development stage, existing vegetation within the crown land road reserve near the eastern site boundary will be removed. Provided that the above recommendations are adopted, it is considered that the removal of this vegetation would not affect the slope stability risk assessment outcomes presented above.
- Prior to the placement of any fill, the proposed areas should be stripped to remove all existing
 uncontrolled fill, vegetation, topsoil, root affected or other potentially deleterious material. Following
 stripping, the exposed materials should be proof rolled to identify any wet or excessively deflecting
 material. Any such areas should be over excavated and backfilled with an approved select material.
 Fill should be compacted in layers to appropriate engineering specifications.
- Where fill is placed on slopes in excess of 1V:8H (7°), horizontal benches should be cut into the natural slope prior to placement of the fill.
- Where fill is placed across an existing watercourse, a culvert of adequate size to accommodate design flows should be installed. A subsoil drain along low point of the filled area will also be required.
- Excavations and batter slopes should be designed for surcharge loading from slopes, retaining walls, structures and other improvements in the vicinity of the excavation.
- Temporary slopes in soil strength materials up to 3m in height should be formed at no steeper than 1H:1V. Further geotechnical advice should be sought where cuts greater than 3m in height are proposed. Adequate drainage should be provided for all batter slopes. During rainfall periods, temporary slopes should have surface water on the high and low side diverted away from the batter face. The face may also need to be protected by the placement of plastic sheeting.
- Unsupported permanent batter slopes in soil strength materials should be battered at no greater than 2H:1V. All batter slopes should be protected against erosion by appropriate plantings or fabric.

Retaining Walls

- Retaining walls should be designed by a suitably qualified engineer who is familiar with the site conditions.
- Design of the walls must take into account any surcharge from sloping ground or other loadings behind the wall. The design should incorporate an allowance for water pressures.

• Adequate drainage should be provided for all retaining walls. Flushing points should be incorporated into the design of the perimeter drain to allow for maintenance.

Stormwater and Sewerage

• All collected stormwater run-off or stormwater discharging on to the site should be piped into the street drainage system or the existing watercourse in a controlled manner. Septic wastes should be connected to a reticulated disposal system.

5.3 Surface and Subsurface Drainage and Areas of Groundwater Seepage

5.3.1 General

The failure to provide adequate drainage is often a predominant cause of slope instability. Adequate surface and subsurface drainage should be provided for all site developments regardless of their location on the site. Surface and subsurface drainage should be considered at the subdivision development stage (e.g. prior to the sale and development of individual allotments) and during the individual allotment development stage.

During both stages of development, careful attention should be paid to the treatment of water emanating from springs and the like, as these have the potential to significantly increase the likelihood of instability if they are not appropriately treated. The need for treatment of springs and the appropriate treatment method should be assessed on a case by case basis as encountered during any site earthworks. Assessment and design of treatment systems should be carried out by an experienced consultant. In general, methods for treatment of water emanating from springs may take the form of trench drains or drainage blankets, with flows piped to the street stormwater system.

Specific comments and recommendations for subsurface drainage are provided below.

5.3.2 Subdivision Development Stage

It is recommended that subsurface drainage as recommended below be installed as soon as practicable during site earthworks. Having subsurface drainage in-place will reduce the likelihood of slope instability, and potentially reduce the likelihood of construction problems associated with groundwater such as heaving of subgrade soils and trafficability.

With respect to roads, it is recommended that subsurface drainage be provided along the high side of all roads (or road sections) aligned across site slopes, and along both sides of all roads (or road sections) aligned down site slopes. Subsurface drains should extend to at least 0.3m below the top of the natural undisturbed site soils, though this depth may need to be increased depending on site conditions exposed during site earthworks. Particular attention should be paid to subsurface drainage design in the area where groundwater seepage was evident (i.e. near lots 27 to 32) and near the southern end of the site.

Significant groundwater seepage was evident where surface water, wet/boggy surface soils and variations in vegetation were observed on the mid-slopes of the hills near proposed lots 27 to 32 on the eastern side of the creek. Previously, groundwater seepages were observed near proposed lots 24 to 32, and groundwater inflows were evident in TP17 which was located near the boundary between lots 24 and 25. These seepages could have an effect on residential developments on these allotments and on the road and other associated developments downslope of these allotments.

Based on the site conditions evident at the time of the current and previous field work, it is recommended that trench drains be constructed as follows:

• Trench drains should be constructed along the full length of the common boundaries of adjacent allotments inclusive of lots 24 to 33 (i.e. the southern boundaries of allotments 24 to 32).

- The trench drains should be of the order of 1.5m deep below the existing ground surface level and 0.5m wide.
- Perforated drainage pipe (min. 0.1m to 0.15m diameter, though a larger diameter may be required depending on flows encountered during construction) should be placed in the base of the trench and connected to the street stormwater drainage system.
- The trenches should be backfilled with an appropriate free draining granular material. The upper 0.7m of the trench should be backfilled with a clayey material to act as a capping layer for the trench and to allow the installation of fence post footings along the boundary. The clay material should be compacted to a target density ratio of 95% Standard compaction.

It is recommended that an experienced consultant be engaged to assess groundwater conditions during the construction of drainage trenches and to provide additional advice on subsurface drainage. It is noted that the recommendations provided above are based on the conditions evident at the time of field work. Additional subsurface drainage may be required depending on the conditions encountered during construction.

5.4 Specific Guidelines for Construction in Zone 1

It is considered that no geotechnical restrictions on dwelling type or design other than good engineering and construction practice are applicable in this zone. The recommendations provided in sections 5.2 and 5.3 should be adopted for design and construction in Zone 1.

5.5 Specific Guidelines for Construction in Zone 2

It is considered that the recommendations provided in sections 5.2, 5.3 and as shown below be adopted for design and construction in Zone 2.

- More flexible structures of timber or steel framed clad, brick veneer or similar construction should be adopted.
- Footings for developments should be founded within the natural undisturbed residual soils beneath all topsoil, uncontrolled fill or other deleterious materials.
- Cut and fill should be limited to 2.5m in depth/height unless subject to a site/development specific geotechnical assessment. Appropriate batters and/or retaining walls designed by an engineer who is familiar with the site conditions should be provided. The expertise of the contractor, the nature of the fill material and the degree of monitoring and testing of the filling will control the footing design required for any structures placed on the fill.

5.6 Specific Guidelines for Construction in Zone 3

It is considered that the recommendations provided in sections 5.2, 5.3 and as shown below should be adopted for design and construction in Zone 3.

- Flexible structures of timber or steel framed clad, brick veneer or similar construction should be adopted. Split level and suspended design should be considered to limit slope modification.
- Foundations should be designed and constructed in accordance with AS2870-1996, with footings for developments founded at least 0.6m into the natural undisturbed residual soils or weathered rock beneath all topsoil, uncontrolled fill or other materials.
- Cut and fill should be limited to 1.5m in depth/height unless subject to a site/development specific geotechnical assessment. Appropriate batters and/or retaining walls designed by an engineer who is familiar with the site conditions should be provided. The expertise of the contractor, the nature of the fill material and the degree of monitoring and testing of the filling will control the footing design required for any structures placed on the fill.

6. CONCLUSIONS

This report presents the results of a slope stability assessment carried out for a proposed residential subdivision development at 1 Survey Street, Lennox Head. The assessment comprised collation of information obtained during previous studies at the site, and presentation of a slope stability risk assessment based on the assessment methodology presented in AGS 2000.

Based on the work carried out, we consider that the site is appropriate for residential subdivision development, subject to the adoption of recommendations contained in this report. The decision as to the level of risk to be accepted or tolerated needs to be considered by both the owner and consent authorities involved. The onus is on the owner, potential owner or interested party to decide whether the assessed level of risk is acceptable taking into account likely economic consequences of the risk and the recommended geotechnical constraints.

Development should be carried out in accordance with good hillside practice and the specific geotechnical recommendations defined in this report.

7. CONSTRUCTION RISK

The extent of testing associated with the current and previous assessments is limited and variations in ground conditions may occur between the test locations. If conditions other than those described in this report are encountered during construction further advice should be sought without delay. It is expected that geotechnical consultations will be required throughout the development of the site.

We draw your attention to the attached sheet entitled "Important Information About Your Coffey Report" which should be read in conjunction with this report.

For and on behalf of COFFEY GEOSCIENCES PTY LTD

DAVID BARKER Senior Geotechnical Engineer

Information

Important information about your Coffey Report

As a client of Coffey you should know that site subsurface conditions cause more construction problems than any other factor. These notes have been prepared by Coffey to help you interpret and understand the limitations of your report.

Your report is based on project specific criteria

Your report has been developed on the basis of your unique project specific requirements as understood by Coffey and applies only to the site investigated. Project criteria typically include the general nature of the project; its size and configuration; the location of any structures on the site; other site improvements; the presence of underground utilities; and the additional risk imposed by scope-of-service limitations imposed by the client. Your report should not be used if there are any changes to the project without first asking Coffey to assess how factors that changed subsequent to the date of the report affect the report's recommendations. Coffey cannot accept responsibility for problems that may occur due to changed factors if they are not consulted.

Subsurface conditions can change

Subsurface conditions are created by natural processes and the activity of man. For example, water levels can vary with time, fill may be placed on a site and pollutants may migrate with time. Because a report is based on conditions which existed at the time of the subsurface exploration, decisions should not be based on a report whose adequacy may have been affected by time. Consult Coffey to be advised how time may have impacted on the project.

Interpretation of factual data

Site assessment identifies actual subsurface conditions only at those points where samples are taken and when they are taken. Data derived from literature and external data source review, sampling and subsequent laboratory testing are interpreted by geologists, engineers or scientists to provide an opinion about overall site conditions, their likely impact on the proposed development and recommended actions. Actual conditions may differ from those inferred to exist, because no professional, no matter how qualified, can reveal what is hidden by earth, rock and time. The actual interface between materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions. For this reason, owners should retain the services of Coffey through the development stage, to identify variances, conduct additional tests if required, and recommend solutions to problems encountered on site.

Your report will only give preliminary recommendations

Your report is based on the assumption that the site conditions as revealed through selective point sampling are indicative of actual conditions throughout an area. This assumption cannot be substantiated until project implementation has commenced and therefore your report recommendations can only be regarded as preliminary. Only Coffey, who prepared the report, is fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered as the project develops. If another party undertakes the implementation of the recommendations of this report there is a risk that the report will be misinterpreted and Coffey cannot be held responsible for such misinterpretation.

Your report is prepared for specific purposes and persons

To avoid misuse of the information contained in your report it is recommended that you confer with Coffey before passing your report on to another party who may not be familiar with the background and the purpose of the report. Your report should not be applied to any project other than that originally specified at the time the report was issued.

Interpretation by other design professionals

Costly problems can occur when other design professionals develop their plans based on misinterpretations of a report. To help avoid misinterpretations, retain Coffey to work with other project design professionals who are affected by the report. Have Coffey explain the report implications to design professionals affected by them and then review plans and specifications produced to see how they have incorporated the report findings.

Data should not be separated from the report*

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way.

Logs, figures, drawings etc. are customarily included in our reports and are developed by scientists, engineers or geologists based on their interpretation of field logs (assembled by field personnel) and laboratory evaluation of field samples. These logs etc. should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

Geoenvironmental concerns are not at issue

Your report is not likely to relate any findings, conclusions, or recommendations about the potential for hazardous materials existing at the site unless specifically required to do so by the client. Specialist equipment, techniques, and personnel are used to perform a geoenvironmental assessment. Contamination can create major health, safety and environmental risks. If you have no information about the potential for your site to be contaminated or create an environmental hazard, you are advised to contact Coffey for information relating to geoenvironmental issues.

Form CCR 2.1 Issue 1 Rev 0 Sheet 2 of 2

Rely on Coffey for additional assistance

Coffey is familiar with a variety of techniques and approaches that can be used to help reduce risks for all parties to a project, from design to construction. It is common that not all approaches will be necessarily dealt with in your site assessment report due to concepts proposed at that time. As the project progresses through design toward construction, speak with Coffey to develop alternative approaches to problems that may be of genuine benefit both in time and cost.

Responsibility

Reporting relies on interpretation of factual information based on judgement and opinion and has a level of uncertainty attached to it, which is far less exact than the design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded. To help prevent this problem, a number of clauses have been developed for use in contracts. reports and other documents. Responsibility clauses do not transfer appropriate liabilities from Coffey to other parties but are included to identify where Coffey's responsibilities begin and end. Their use is intended to help all parties involved to recognise their individual responsibilities. Read all documents from Coffey closely and do not hesitate to ask any questions you may have.

* For further information on this aspect reference should be made to "Guidelines for the Provision of Geotechnical Information in Construction Contracts" published by the Institution of Engineers Australia, National Headquarters, Canberra, 1987.



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SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

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GOOD ENGINEERING PRACTICE

POOR ENGINEERING PRACTICE

ADVICE GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical consultant at early stage of planning and before site works.	Prepare detailed plan and start site works befor geotochnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk	Plan development without regard for the Risk.
SHEFLMINING	arising from the identified hazards and consequences in mind.	I WE SCHOOL WITCH I CERT IN THE FURT
DESIGN AND CON		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber	Floor plans which require extensive cutting an
HOUSE DESIGN	or steel frames, timber or panel cladding.	filling.
	Consider use of split levels.	Movement intolerant structures.
	Use decks for recreational areas where appropriate.	
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS &	Satisfy requirements below for cuts, fills, retaining walls and drainage.	Excavate and fill for site access before
DRIVEWAYS	Council specifications for grades may need to be modified.	geotechnical advice.
	Drive ways and parking areas may need to be fully supported on piers.	
EARTHWORKS	Retain patural contours wherever possible.	Indiscriminant bulk earthworks.
CUTS		Large scale cuts and benching.
	Support with engineered retaining walls or batter to appropriate slope.	Unsupported cuts.
	Provide drainage measures and crossion control.	Ignore drainage requirements
FILS	Minimise beight.	Loose or poorly compacted fill, which if it fail
	Strip vegetation and topsoil and key into natural slopes prior to filling.	may flow a considerable distance including
	Use clean fill materials and compact to engineering standards.	onto property below.
	Batter to appropriate slope or support with engineered retaining wall.	Block natural drainage lines.
	Provide surface drainage and appropriate subsurface drainage.	Fill over existing vegetation and topsoil.
		Include stumps, trees; vegetation, topsoil,
		boulders, building rubble etc in fill.
ROCK OUTCROPS	Remove or stabilise boulders which may have unacceptable risk.	Disturb or undercut detached blocks or
& BOULDERS	Support rock faces where necessary.	boulders.
RETAINING	Engineer design to resist applied soil and water forces.	Construct a structurally inadequate wall such a sandstone flagging, brick or unreinforced
WALLS	Found on rock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope	blockwork.
	Apove.	Lack of subsurface drains and weepholes.
	Construct wall as soon as possible after cut/fill operation.	
FOOTINGS	Found within rock where practicable.	Found on topsoil, loose fill, detached boulders
	Use rows of piers or strip footings oriented up and down slope.	or undercut cliffs.
	Design for lateral creep pressures if necessary.	
	Backfill footing excavations to exclude ingress of surface water.	
SWIMMING POOLS	Engineer designed.	
	Support on piers to rock where practicable.	
	Provide with under-drainage and gravity drain outlet where practicable.	
1	Design for high soil pressures which may develop on uphill side whilst there	
ATRIACER	may be little or no lateral support on downhill side.	
DRAINAGE Surface	Provide at tops of cut and fill slopes.	Discharge at top of fills and cuts.
JUNUAL	Discharge to street drainage or natural water courses.	Allow water to pond on bench areas.
	Provide general fails to prevent blockage by situation and incorporate silt traps.	
	Line to minimize infiltration and make flexible where possible.	
· ·	Special structures to dissipate energy at changes of slope and/or direction.	
SUBSURFACE	Provide filter around subsurface drain.	Discharge roof runoff into absorption trenches.
	Provide drain behind retaining walls.	
	Use flexible pipelines with access for maintenance.	
· · · · · · · · · · · · · · · · · · ·	Prevent inflow of surface water.	
SEPTIC &	Usually requires pump-out or mains sewer systems; absorption trenches may	Discharge sullage directly onto and into slopes
SULLAGE	be possible in some areas if risk is acceptable.	Use absorption trenches without consideration of landslide risk.
Theorem 1	Storage tanks should be water-tight and adequately founded.	Failure to observe earthworks and drainage
ROSION	Control crossion as this may lead to instability.	recommendations when landscaping.
NONTROL &	Revegetate cleared area.	townition and the super supervision is a supervision of the supervisio
ANDSCAPING		
	TE VISITS DURING CONSTRUCTION	
DRAWINGS	Building Application drawings should be viewed by geotechnical consultant	······································
SITE VISITS	Site Visits by consultant may be appropriate during construction/	
NSPECTION AND I	MAINTENANCE BY OWNER	
WNER'S	Clean drainage systems; repair broken joints in drains and leaks in supply	
RESPONSIBILITY	pipes.	
	Where structural distress is evident see advice. If scepage observed, determine causes or seek advice on consequences.	

FIGURE 3: SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

This figure is an extract from LANDSLIDE RISK MANAGEMENT CONCEPTS AND GUIDELINES as presented in Australian Geomechanics, Vol 35, No. 1, 2000 which discusses the matter more fully.

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EXAMPLES OF GOOD HILLSIDE PRACTICE



EXAMPLES OF POOR HILLSIDE PRACTICE



FIGURE 4: ILLUSTRATIONS OF GOOD AND POOR HILLSIDE PRACTICE

This figure is an extract form LANDSLIDE RISK MANAGEMENT CONCEPTS AND GUIDELINES as presented in *Australian Geomechanics*, Vol 35, No 1, 2000 which discusses the matter more fully.

APPENDIX A

ENGINEERING LOGS (TP1 TO TP18)



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GURCEY	pit no
engineering log - excavation office job no: NR105	TP9 sheet 1 of 1
client: GeoLINK GROUP pit commenced: 17-9- principal: project: DOSSER SUBDIVISION, LENNOX HEAD logged by: CMc pit location: REFER FIGURE 1 checked by: data	99
equipment type and model: JCB-BACKHOE B.L.S	Surface: NOT MEASURED
excavation dimensions: 2.0 m long 0.6 m wide arientation: -90. datum	
optimize samples. image samples. samples. image samples. sa	1
Image: Strain	TOPSOIL
CH SILIY CLAY: nign plasticity, rea-brown. St /	RESIDUAL; pp 180-220kPa
	_ pp 190-250xPa
trace of fine to coarse size gravel,	
% <t< td=""><td>★ pp >500kPa -</td></t<>	★ pp >500kPa -
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B 2 CH GRAVELLY CLAY: high plasticity, brown, with grey mottle, fine to coarse size gravel, trace of fine to	
CH GRAVELLY CLAY: high plasticity, brown, with grey mottle, fine to coarse size gravel, trace of fine to medium grained sand.	
	-
Pit TP9 Terminated at 3.00 m	
B I I I I WETHOD PENETRATION SAMPLES, TESTS, ETC CLASSIFICATION Sig N natural exposure SYMBOLS AND SOIL	CONSISTENCY/DENSITY INDEX VS very soft
X existing excavation 1 2 3 4 little resistance U undisturbed sample (mm) DESCRIPTION BH backhoe bucket Francing to disturbed sample based on unified	S soft F firm
BH Dacknow bucket ranging to U Olsturded sample based on unified SB B bulldozer blade very slow progress Bs bulk sample classification system B B bulldozer ripper WATER VS vage share WOTSTURE	St stiff VSt very stiff
Constraint WAILH VS vane shear MOISTURE B HA hand auger D none observed DP dynamic penetrometer D dry HI hand tools X not measured FD field density H moist	H hard Fb friable
SUPPORT Water level WS water sample W wet	VL very loose L loose · MD medium dénse
SUPPCAT V water level WS water sample W water SH shoring SC shotcrete V water outflow Wp plastic limit Wil no support W water inflow Wl liquid limit	D dense • VD very dense

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	Geoscier	ย 1 1 1 1 1	4	exca hand	vator auger tools		WAT D X	none	obser measuri			VS vane shear DP dynamic genetrometer	MOISTU D	dry				H hard Fb friable
	-239 Coovright Geosciences Ptv. Ltd. 1998	S S	UPPO 1 sh	AT oring	SC	shotcrete	¥∆uid	wate	r leve r outf	1		WS water sample	н N Vp	mois wet plas	t tic Jimi	t		VL very loose L loose MD medium dense
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	!	clia pria proj	ent: Icipal Iect:	l:		. Gi	eolin Osser	k group Subdivi:	SION, L	.ennox hea	D		, <u>, </u>		pi pi la	ffice job it commen it comple ogged by:	nced: eted:	NR109 20-9 20-9 CMc	-99		
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		method	penetration		Mater Mater	samples, tests, etc	<u>₿</u> .Ľ	depth metres	graphic log	classification Symbol			material city or particle and minor compo			moisture condition	consistency/ density index	datu pueu kP	er perieurua in	EXIST SURFACE structure and additional observations	
	ON B4.		123 						ष्ट्र))	СК 2007 2007			CLAY: high plast gravel, with b		brown,		문원 St	28;		TOPSOIL	
السيا السيا	VERSION					D		-		Сн			e gravel, with b n plasticity, re basalt cobbles		1		VSt			RESIDUAL pp 200kPa -	
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	239 Copyright Geosciences Pty. Ltd. 1998	N X BI B R	l	exist backh bulld	ing e loe bu lozer			2 3		ittle resi anging to ery slow p	istance progress	D dis Bs bul	listurbed sample iturbed sample k sample vironmental sampl		DESCRI based c	S AND S PTION on unifie fication	ed			VS very soft S soft F firm St stiff VSt very stiff	
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188-239 (C) Copyr	SH Ni RB	shor 1 no s rock	υρρο	rt	shotcrete.	-l-™		outfi inflo					Ур - Ж1	plas	stic limi vid limit			MD medium dense D dense VD very dense

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		ACN 056 3: Client: principa project: pit loca equipmen excavati	ACN 056 335 518 CNG ine excavaliant type excavation dir posta 1234 E METHOD ME	ACN 056 335 515 engineer excavation client: project: pit location: equipment type and excavation dimension 1 2 34 E 1 2 34 E 0 0 0 0 0 0 0 0 0 0 0 0 0	excavation client: principal: project: pit location: equipment type and model: excavation dimensions: Image: State	ACN 056 335 516 engineering log excavation client: GealIN project: DOSSER pit location: REFER equipment type and model: JCB-9A excavation dimensions: 2.0 m Endities and augentiated and a	ACN 056 335 516 engineering log - excavation client:	ACN 056 335 516 Project: DOSSEN SUBDIVISION, I principal: project: DOSSEN SUBDIVISION, I equipment type and model: JCB-BACKHOE excavation dimensions: 2.0 m long project: DOSSEN SUBDIVISION, I project: DOSSEN SUBDIVI	ADN 056 335 516 engineering log - excavation client: BeuLikk GRUP principal: project: DOSSER SUBJIVISION, LENNOX HE/ project: DOSSER SUBJIVISION, LENNOX HE/ excavation disensions: 2.0 m long 0.5 yog be been been been been been been been	ADM 056 335 516 engineering log - excavation client: principal: project: DOSSER SUBDIVISION, LENNOX HEAD ptilocation: COSER SUBDIVISION, LENNOX HEAD ptilocation: DOSSER SUBDIVISION, LENNOX HEAD DOS DOS DOS DO	ADN 056 335 516 engineering log - excavation client: BeauLikk GROUP principal: project: DOSSER SUBDIVISION, LENNOX HEAD pti location: REFER FIGURE 1 equipment type and model: CDS-BACKHOE excavation dimensions: 2.0 m long 0.5 m kide texcavation dimensions: 2.	ADM 4066 335 516 engineering log - excavation client: principal: p	ADM 056 335 515 engineering log - excavation client: principal: principa	ADX 056 335 515 engineering log - clian: project: projec	ADI 456 355 316 engineering log - excavation client: principal: princip	MAX 165 335 515 Englineepring log - eXCavation client: Dealts (BRUP principal: priot: priot: DDSSB SABUYISIDE, LEMOX HEAD priot: priot: Samuels: priot: Samuels: priot: Samuels: priot: Samuels: priot: Samuels: priot: Do priot: Do	MAN 65 35 315 Englineering log - englineering log - extent of the second of	MAX KE 305 515 PUIL LAK KEDUP PUIL CARPORT C Liste: BeuLAK KEDUP PUIL CARPORT Protopil: POSCI SEDIVISING LISTON KEDU POSCI SEDIVISING LISTON KEDU POSCI SEDIVISING LISTON KEDU Protopil: POSCI SEDIVISING LISTON KEDU POSCI SEDIVISING LISTON KEDU POSCI SEDIVISING LISTON KEDU POSCI SEDIVISING LISTON KEDU Protopil: POSCI SEDIVISING LISTON KEDU POSCI SEDIVISING LISTON KEDU POSCI SEDIVISING LISTON KEDU POSCI SEDIVISION LISTON KEDU Protopil: POSCI SEDIVISING LISTON KEDU POSCI SEDIVISION LISTON KEDU POSCI SEDIVISION LISTON KEDU POSCI SEDIVISION LISTON KEDU POSCI SEDIVISION LISTON KEDU POSCI SEDIVISION LISTON KEDU POSCI SEDIVISION LISTON KEDU POSCI SEDIVISION LISTON KEDU POSCI SEDIVISION LISTON KEDU POSCI SEDIVISION LISTON KEDU	ANA 455 335 315 Project ing log - excavation Cline: Project: roject: Projec	AND KE 305 515 POID INCEPTING 100 - PITER 10 MC MARPH PITER 1 POID INCEPTING 100 - PITER 10 MC MARPH PITER 1 POID INCEPTING 100 - PITER 10 MC MARPH PITER 1 POID INCEPTING 100 - PITER	AM IES 20 515 Projecting log - excavation Class: Projecting log - excavation Class: Projecting log - exclust GRDP projecting Proj	ARL HE 28 35 15 engineering log - excavation clast: browners

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84.	method	to penetration		samples, tests, etc		depth metres	graphic log	classification symbol	soil	material type:plasticity or particle characteristics , secondary and minor components	ion	consistency/ density index	200 penetro-	
VEASION						-	<u>}</u>	CK		: GRAYELLY CLAY: red-brown, high plasticity coarse size gravel.	и, W —	F		TOPSOIL, BAND OF SILTY CLAY, GREY-100mm THICK
COFEXCA				D		-		CH	CLAY: h mottle,	igh plasticity, red-brown, with orange, gre trace fine to coarse size gravel.	ч : : :	130	X	RESIDUAL pp 300-350kPa
					-	-								pp 300-350kPa
608			ΔΔ	D		1 - - -	00000000000000000000000000000000000000	CH	GRAVELL orange, gravel.	Y CLAY: high plasticity, red-brown and with grey mottle, fine to coarse size	— — — — — — — — — — — — — — — — — — —	•		EW BASALT pockets of wet material numerous water inflows
10 :50 :5						-	000							pp 200-220kPa
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id. 1998	METH N		ral ex	l Josure	PENE	<u>₄</u> Tratio	N			SY!	ASSIFICATIO	 DN SOIL		CONSISTENCY/DENSITY INDEX VS very soft
nces Pty. Lt	X BH B R	exis backi bull	ting e hoe hu dozer	kcavation sket				ittle res anging to ery slow (istance progress	U undisturbed sample (mm) DES D disturbed sample bas 8s bulk sample cla E environmental sample .	SCRIPTION sed on unifi sssification	ed		S soft F firm St stiff VSt very stiff
188-239 (C) Copyright Geosciences Pty. Ltd. 1998	e . Ha . ht . Supp	exca hand hand ORT	vator auger tools		WATE D X V	none not	obsern measurn r level	ed		VS vane shear MO DP dynamic penetrometer D FD field density M WS water sample W	ISTURE dry mois wet	st		H hard Fb friable VL very loose L loose
108-239 (C) Copyr	SH s Nilr RB r	khoring No supp Yockbol	ort	shotcrete	≥li M∆		r outfi r inflo			קא נא	plas	stic lim vid limi		MD medium dense D dense VD very dense

		Coffey (ACN 056			Þty. Ltd.									ſ	פוענ		M		pit no		7
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		excaval	penetracian ip uoi: support		ons: 2 samples, tests, etc	gnot a 0.	graphic log	classification symbol							moisture condition	consistency/ density index	datum punq kPa			SUAFACE structure and nal observations	
Π	IION B4.		34 34					ਿਸ਼ੋ (ਸ	FILL: G	RAVELLY	CLAY: high	plasticity, ron strappir	brown, fin	ne to ces	-3 M	음북 F	<u>888</u>		FILL, some clay	50mm bands of sil	lty
	CA VEASION				D				of char	coal and	ash.	i on an oppir				St	×		pp 150-180	kPa	-
	COFEXCA																×		pp 140-160	kPa	-
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L	608			₽	0	-		СН	CLAY: h to coar	igh pla: se size	sticity, ora gravel.	nge, brown,	trace of	fine	M W ·	St / VSt			RESIDUAL, inflows pp 180-230	numerous water kPa	
	8						Ľ								-				pockets of	wet material	-
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	/. Ltd. 1998	METH N X	natur exist	ing e	posure xcavation	PENETRAT	4	little res	istanre	U		d sample (mm		CLASSI SYMBOL DESCRI	FICATIO S AND S PTION	N OIL			VS v S s	/DENSITY INDEX ery soft oft	
	-239 Coovright Geosciences Ptv. Ltd.	BH B A	bullo	iozer Iozer	cket blade ripper	WATER		ranging to very slow	progress	0 8s E	disturbed : bulk sample environment	e		classif	n unifie fication				St s VSt v	irm tiff ery stiff	
	tht Geosci	E HA HT SUPP	excav hand hand not	auger		.0 n ¥ n	ne obser it measur iter leve	'ed		VS DP FD WS	vane shear dynamic per field dens water samp	ity		MOISTU D M	dry mois	t			FD f VL v	ard riable ery loose oose	
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	13									.			l								

APPENDIX B

ENGINEERING LOGS (BH1 TO BH4)



~	лю;	y u	ieo	scienco	es Pi	ty Lt	i ci ac	CN 056 3	35 516	-	Boreho	le N	0.	BH1
E	ng	in	eel	ring L	.og	- B	ore	eho	e		Sheet Office J	Job I	<u>No.:</u>	1 of 1 NR1059/2
Clie	ent:			GE	OLIN	K Gł	ROU	P			Date sta	arte	d:	NR1059/2 13.2.2002 : 13.2.2002 RW / KU
Prir	ncipa	1:		DM	& Ri	D DO	ssc	R			Date co	ompl	eted	: 13.2.2002
Pro	ject:			DO	sso	R SU	IBDI	Visio	N		Logged	by:		RW/KU
Bor	rehole	e La	catio	n:							Checke	ed by	r.	Ps
	mode		mou	nting:	JACRO	D 350 1	00		Easting: slope: -90*				R.L	Surface: 29.2
	i diam i i i i i no		orm	ation	mm		mat	erial s	Northing bearing:				dati	.m:
method	penetration	summert	water	notes samples, tests, etc		depth	aphic log	classification symbol	material soil type: plasticity or particle characteristics,	moisture condition	consistency/ density index	k	e penetro- meter	structure and additional observation
ADT	12:				-	metres		ठ CH	colour, secondary and minor components. SILTY CLAY: high plasticity, red-brown, with some	E 8 M	VSt	₿ĝ TT	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	
A					_29				basalt, gravel, cobbles and boulders, trace of sand, friable.				×	pp 350kPa POSSIBLE COLLUVIUM
					_28			СН	SANDY CLAY: high plasticity, yellow-brown, fine grained sand, bands of clayey sand.		н			RESIDUAL SOIL
				U ₅₀		-								
					_27	2 -								[≮] pp >500kPa
			_					SC	SILTY CLAYEY SAND: fine to coarse grained, brown,					
			SERVI						fine grained clay of low to medium plasticity.					
RR		N	NOT OBSERVED	U ₅₀	26	2			250mm diameter large cobble.					r pp >500kPa REFUSAL ON BASALT COBI (DIAMOND DRILLED)
	-			D	_25	4			cobble 120mm diameter.					
								СН	CLAY: high plasticity, red-brown, some fine grained sand.		VSt-H			
					_24	D 			grey.					
						6								
	 			U50	23				Borehole BH1 terminated at 6.2m		ļ	,		pp 175kPa
						-								
					_22	<u>7</u> -								
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						8								
meth AS AD RR W CT HA DT B V T *bits	iod shown	a v c b b V T	uger o oller/tr ashb able t and a iatube lank t bit C bit	ool uger	M C	ter 10/1/9/	n eo resista anging to efusa) 8 water 8 water e showi inflow	ievel n	Use undisturbed sample 50mm diameter soil desc Use undisturbed sample 63mm diameter based on D disturbed sample 63mm diameter based on N standard penetration test (SPT) moisture N* SPT - sample recovered moisture NC SPT with solid cone D drg V vane shear (kPa) M mo P pressuremeter W we Bs bulk sample Wp plate Wp plate	ription unified	d classific			consistency/density Index VS very soft S soft F firm St stiff VSt very stiff H hard Fb friable VL very loose L loose MD medium den D dense

(Col	fey	G	eos	clence	s Pl	ty Lt	ici ac	CN 056 3	35 516	-	Boreho	le N	0.	BH2
-	Er		ne	er	ing L		- B			e		Sheet Office			1 of 2 <u>NR1059/2</u> 15.2.2002 15.2.2002 RW/KU DC
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		liame		noun	ung.	mm	5 350 1	00		Easting: -90 Northing bearing:				r.∟ dati	
	_			гта	tion			mat	erial s	ubstance				Gut	
	menna	penetration	support	water	notes samples, tests, etc	RL	depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	ƙ	300 au penetro-	structure and additional observations
100	- 8	123	N			21	metres			SILTY CLAY: medium plasticity, dark grey, some fine	w	s	158	TT TT	RESIDUAL SOIL; SURFACE WATE
Ī	K (200			15/2/02			-		СН	grained sand. SILTY CLAY: high plasticity, grey, yellow mottled, some	M	F-St			
	2000				D	-	-			fine grained gravel.					
	Y					1	<u>1</u>								
						_20									
							-					VSt	1		
					U ₅₀									×	
						_19	2								pp 250kPa
					D	_	-					.			
							-								
							2		СН	SANDY SILTY CLAY: high plasticity, grey to brown	-	н	$\left\{ \left \right \right\}$		EXTREMELY WEATHERED ROCK
					U ₅₀	_18	<u> </u>	ØŊ,		mottled, fine grained sand, with fine to medium grained gravel lenses.					FRIABLE
						-	-								pp >500kPa
							-								U50 REFUSAL ON GRAVEL BAND
	22022					_17	4								
						["	-								
						-	-								
					U ₅₀	-									↓ ¥pp >500kPa
						_16	5								U50 REFUSAL ON GRAVEL BAND
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	etho S	nd d			or out in c*		pport	· · ·	l		fication s escription	ymbols ai	nd	تصاليما	consistency/density index VS very soft
А	DR		at	iger d	crewing* rilling* cone	С	mud casing		N 1111		on unifie	n ed classifi	cation	n	S soft F firm
V C	V		W	ilenuu ashbo ible to	are	pe I	netratio	no resist	ance	N standard penetration test (SPT) N* SPT - sample recovered moistu		· · · ·			St stiff VSt very stiff
С Н D	A		ha	ind au atube	ıger		iter	ranging t refusal	c	Nc SPT with solid cone D	dry moist				H hard Fb friable
B			Ы	ank b bit			10/1/9)8 wate te show	r level	P pressuremeter W	moisi wet plastic lir	mit			VL very loose
Τ		nown	TC	⊃bit				inflow			liquid lim				MD medium dense D dense
e e	oit si .g.	wwr)	oy si Al					outflow	,	is islaat					VD very dense

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	9					ररर	BASALT: dark grey, fine grain		sw		ŦŦ			-	T	H	H	JT, 70°, PL,	RO		
/	NMLC			_15	<u>6</u> - -))))))))) ()))))	BASALT: grey to grey-brown, i with clay filled vesicles. BASALT: dark grey, fine grain		MW					10				JT, 70°, IR, JT, 23°, PL, JT, 33°, PL, JT, 35°, PL 6.10m-6.16	ro Ro Ro		
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Form GEO 5.5 Issue 3 Rev.2	NQ,		, PQ		line core		core recovered - graphic symbols indicate material no core recovered	wa දැ (iu	mplete dr ter press geons) fo arval shor	ure t r de	test r		strength VL v L lo M n H h VH v	ery lo ow nediu ligh ery hi ery hi	w m gh			CU cu UN ur ST st	y anar Irved Idulating epped egular	VN ve	ean ained neer ating

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		pot	penetration	ĮĔ		samples, tests, etc			graphic log	classification symbol	material	tion .	stency fty ind	pocke	penetro meter	structure and additional observations
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(J															
							1									-
							_26	2		CL	SILTY CLAY: medium plasticity, grey.		н			PP >500kPa
									(XI)							
								-		СН	SILTY CLAY: high plasticity, dark red, some fine					
											grained sand.					SMALL IRONSTONE NODULES
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		metho AS AD	bd			crewing* rilling*	M	mud casing	N	nil	notes, samples, tests classifica U ₅₀ undisturbed sample 50mm diameter soil descri- undisturbed sample 62mm diameter	ription				consistency/density index VS very soft
	Rev.2	RR W		rol	ger an Ier/tric Ishbor	cone	рел	casing netration 2 3 4	•		U _{B3} undisturbed sample 63mm diameter based on D disturbed sample system N standard penetration test (SPT)	unified	classifica	ation	1	S soft F firm
	3	СТ НА		cal	ble too nd aug	oi			o resista anging to efusai	лсе	N* SPT - sample recovered moisture Nc SPT with solid cone D dry					St stiff VSt very stiff H hard
	5.3 Issue	DT B		dia	ntube ank bit	-	wat	ter	3 water	laval	V vane shear (kPa) M mo P pressuremeter W we	vist				H hard Fb friable VL very loose
	GEO 5	V T		VE			-	on date	e showr		Bs bulk sample Wp pla	ı Istic limi Jid limit				L ioose MD medium dense
	Form	*bitsl e.g.	hown b	y sul AC				water in water c			R refusal					D dense VD very dense

•	C	ofi	four	Gor	sela		S Pty Ltd ACN 056 335 516											
	U	011	icy		13046 1		5 Fty Ltt ACN 056 335 516								Bo	rehole No.	BH3	
	E	n	gir	iee	ering	j L	og - Cored boreho	le								eet 2 fice Job No.:	of 3 NR1059/	
	CI	ient	t;	_	(GEO	LINK GROUP									ite started:	7.2.2002	¢ Coffey
	Pr	inci	ipal:		I	DM a	& RD DOSSOR								Da	te completed:	7.2.2002	Ť
	Pr	oje	ct:		I	oos	SOR SUBDIVISION								Lo	gged by:	RW /K	
	-			_ocat											Ch	ecked by:	PS	<u> </u>
			odel & amete		iting: JA m		50 100 Drilling fluid:	Easting				slope;		-90°	•	R.L. St		95
		-			nation		terial substance	Northin	y.			bearing		ck m	ass	datum: defects		
						log overv	material		6		mated	ls ₍₅₀₎ MPa		defe spac			defect descripti	on
	method	core-lift	water		depth	graphic log core recoverv	rock type; grain characteristics, colo structure, minor components	our,	weathering atteration	40.	Jigui	D- diam- etral	ROD %	'nr	n		ination, planarity, coating, thicknes	
	3	8	ž	RL	metres	53	Continued from non-cored boreho	le	att	د د کر ۲۰۲	i ± ₹ 8	A- axial	8	a ₽₿₿	₿ĝ	particular		general
	NMLC				-	55	BASALT: brown to yellow-brown and d grey, fine grained, locally grading to han		xw				。				Core highly trac	curea
		H			-		(CH).						┝╌┥╹	H		JT, 15°, PL, R	0	. –
\cap				_23	5	ŞΣ,							4	Ц		Core break		_
\bigcirc		Н				<u> </u>	NO CORE:					4			╨	JT, 45°, PL, R	O, CN	-
		Π			-	555	BASALT: brown to yellow-brown and di grey, fine grained, locally grading to hard		xw			1	0		\dagger	JT, 5°, PL, RC	р,	-
		Ħ		_22	6	<u> </u>	(CH). NO CORE: BASALT: brown to red-brown, fine grai		сw/нw							2 x core break	s	-
						$\langle \rangle \rangle$	with clay filled vesicles, occasional thin o seams along joint planes, occasional zer	lay	HŴ				4			JT, 20°, PL, R	O, CN	-
					-	$\sum_{i=1}^{n}$	amygdales.						4	5		JT, 5°, PL, RC JT, 5°, PL, RC	, CN	_
	ľ	Н	-	_21	7_	<u>}</u> }										Core fracture, JT, 10°, PL, R JT, 30°, PL - C		-
					_	}}										JT, 28°, IR, R	D, CN	-
						$\sum_{i=1}^{n}$							58			JT, 20°, PL - I JT, 20°, PL, R JT, 5°, PL - IR		seam –
				_20	8	$\langle \cdot \rangle \langle$	BASALT: brown-grey to dark grey, fine		- MW							PT, 10°, IR, R Core break		-
					-	$\langle \rangle \langle$	grained, with clay filled vesicles.							ſ		2 x JT, 30°, PL Large vesicles JT, 60°, IR, R(s to 30mm	-
						$\langle \rangle \langle$				3						JT, 20°, PL, R	O, Fe, SN O, Fe, SN	·
	41.00			_19	9	<u>}</u> }							30			JT, 40°, PL - II JT, 90°, PL, R	O, Fe, SN	-
\bigcirc						$\langle \rangle \rangle$										JT, 15°, PL, R JT, 35°, PL - II JT, 43°, PL, R JT, 35°, PL, R	0, Fe, SN R, RO, Fe, SN 0, Fe, SN	
		Ц				>>>	BASALT: dark grey, fine grained.		SW					ų		\\"JT, 30°, PL_R	O, Fe, SN	-
	}			_18										۲,		\dipping 10° =\\JT.CU.60°-9	d fragmented roo 90°, RO	
00 00	, i		Γ		10	$\langle \rangle \langle$							22			JT, 20°, PL, R JT, 70°, PL - C JT, 20°, PL - 2	CU, RO, Fe, SN	,
		Н			-	⋘	BASALT: dark grey to brown-grey grad	ing to	ww							UNJT, 38°, PL, R	O, Fe, SN PL - CU, RO, Fe,	sn –
CODEN BOREHOL E BOREL OAS GDI COCEEN				17		\$ <u>}</u> }	red-grey, fine grained, locally vesicular.									JT, 40°, PL, R	O, Fe, SN O, Fe, SN 0m: Fractured zo	-
			ľ	_17	11	}}		k	iw/sw				0			clay in top 50r	nm R, RO, Fe, SN	
ča G					_	$\langle \rangle \langle$		ŀ	мw							JT, IR, RO, Fe	e, SN O, SL °, PL, RO, Fe, SI	
		Π				<u>}</u> }}							0	Ц		3 × JT, 40°, 60 JT, 20°, PL, R	°, 85°, PL, RO, F O, Fe, SN	
		thod		_16	12	$\frac{22}{1}$	core-lift	water				weatherin		ation		defect type	nted zone	roughness
ç	DT AS AD	;			ube er screwi er dritting		Casing used	▲ 10/1 on d	/98 wate ate sho	er leve wn	t	SW sli	sh ghtly v stinctly	veath	ered there	JT joint PT parti	ng	VR very rough RO rough SO smooth
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	RR	2 1		rolle	er anung n/tricone / or blade		barrel withdrawn	► wate → parti	er inflow ial drill fl		s	XW ex SA sli	tremel ghtly a stinctly	y wea litered	ather i	ed SZ shea SS shea	ared zone ared surface hed seam	SL slickensided
leene v		nlc 1, hc	, PQ	NML	C core line core		graphic log/core recovery	- com				XA ex atrength	tremel	y alte	red	planarity		coating
Eorm GEO & 5 leeue							- graphic symbols indicate material		er pressi			L lov	ry low N edium				ed ulating	CN clean SN stained VN veneer
a Lora Lora							no core recovered		eons) foi val shov			H hig VH ve	gh ry high tremei	ı I <u>y hig</u> l	<u>1</u>	ST step IR irreg	ped ular	CO coating

	CO ,	TTE	¥y	Ge)scie	nces	Fty Ltd ACN 056 335 516								-	Bor	rehole N	0.	BH3	}	A
	Eı	nc	ii	nee	ering	a L(og - Cored boreh	ole								She Off	eșt îce Job I		of 3 NR1(059/2	
	Clie						LINK GROUP										te starte		7.2.2	002	Coffey
	Prir	ncip	al:		l	DM 8	RD DOSSOR									Daf	te compl	eted:	7.2.2	002	Ĩ
	Pro	jeci	Ľ		l	DOS	SOR SUBDIVISION									Log	ged by:		RW /	1ky	R
-				ocat												Che	ecked by	<i>r</i> :	<u>Ps</u>		0
	drill I hole				nting: JA			Eastin Northi	-			siope:		-9	90°				urface:	27.95	
- H-					nation	-	Drilling fluid: terial substance	NORUM	ng:			bearing		ock	ma	155	defects	datum	;		
						yery Very	. material		p.,	estimate strengt		ls ₍₅₀₎ MPa			efec acir		:		defect des	scription	
	method	core-lift	water	RL	depth metres		rock type; grain characteristics, structure, minor componen		weathering alteration	516191		D- diam- etral A- axial	RQD %			-	t particulai		ination, pla coating, th	anarity, roughnes hickness	s, gener
)	NMLC			_15	- - 1 <u>3</u> -		BASALT: dark grey to brown-grey g red-grey, fine grained, locally vesicul (continued) BASALT: dark grey, fine grained, sil vesicular.	ar.	MW/SW				31 18 0				UT, 7/ UT, 5° UT, 83 50mm 3 x JT UT, 42 UT, 42 UT, 20 UT,	0°, PL, F °, PL, R r, PL, R r, clay au f, 40°, 4 break 5°, IR, R 5°, IR, R 0°, PL, F 0°, IR, R	5°, 75°, PL, O, Fe, SN O, Fe, SN O, Fe, SN IR, RO, Fe, N° PI PO	nted rock zone , RO, Fe, SN , SN	
				_14 _13 _12 _11 _10			BH3 terminated at 13.5m										\`JT, 5	5°, PL, F	lO, SS, Fe,	, SW, zeolite infi	-
SUB 3 KBV.Z	meth DT AS AD RR CB NML NQ,	.c	PQ	aug aug rolla clav NM	20 ube ler screwi er drilling er/tricone w or blade LC core ellne core	e bit	core-lift casing used barrel withdrawn graphic log/core recovery core recovered - graphic symbols indicate material no core recovered	→ on wa par cor wa va va va va va va va va va v		wn uid Ioss ill fluid Ios ure test re: r depth	:s sult	SW sli DW di: XW ex SA sli DA di: XA ex strength VL ve L lo M m H hi VH ve	esh Ightly stinc trem ightly stinc trem	/wea tlyw ielyw alte tlyal ielya w m	athe reath red itere	hered there ed	d S S S S S S S S S S S S S S S S S S S	T par M sea Z she S she S cru L pla U cur N uno T ste	t ling ared zone ared surfac shed seam nar	ce	rough h ooth censided n ned eer

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	Co	offey	/ G	eos	clence	s Pl	y Lta	AC	N 056 3	335 516		Boreho	ole N	10.		BH4	因
	E	n ~ 1			ina l	~~~	D	~ * ~	hal			Sheet			4	1 of 3	Coffey E
			ne	er	ing L					e		Office			:	NR1059/2	
	Clie						KGF					Date st				11.2.2002	¥
		ncipa	:									Date co			d:	11.2.2002	
		ject:				sso	RSU	BDN	/ISIO	N .		Logged				RW/K4	X
		ehole mode				IACD	350 1			The Alfred State of the State o		Checke	ed b			<u>/ </u>	<u> </u>
		diame		moum	ung:	mm	3350 1	υü		Easting: -90 Northing bearing:	-				.L. S aturr	Surface: 34.9 n:	
	<u> </u>	illing		orma	tion			mat	erial s	ubstance						······································	
	method	5 penetration	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	H	300 % penetro-		structure and additional observatio	ns
	ADT		N					/)(/)	СН	SILTY CLAY: high plasticity, brown, trace of fine grained sand.		н	<u> </u>		4	RESIDUAL SOIL pp >500kPa	
	4						-	///		red-brown						3p >500kra	_
							_	M									-
\sim						_34	1	NO				VSt					_
\bigcirc							-	M	СН	SILTY CLAY: high plasticity, with some fine grained sand.	-						-
					Usa	1		h		Sano.							_
						_33	2	\square						Ť	,	pp 300kPa	-
								X		decrease in sand content							
							-	X									-
								M									
				-	 11.	_32	3	ID									_
					U _{\$0}				СН	SILTY CLAY: high plasticity, grey, with bands of sandy clay.	1	н			×.	pp >500kPa	-
				RVE			-	ID		out.						BANDS OF EXTREMELY WEATHERED BASALT	_
				OBSERVED		_31	4	M				·				NCREASE IN MOISTURE	-
				NOT			-	XD		increase in frequency of banding grading to extremely						JONIEN	• -
					U ₅₀			1XI)		weathered basalt.						U50 REFUSAL	_
						_30				Borehole BH4 continued as cored hole			\square				
							<u>5</u>										
																	-
10							-										-
BOREHOLE BORELOGS GPJ COFFEY GDT						_29	6										_
C C							-										4
S.GPJ																	
ELO G						_28	,- ,-										-
BOR							7										_
HOLE																	-
BORE																	_
Ļ	meth					_27	8 port			bates samples tests	lant'				Ц	*a tattattat	
	AS AD	54			rewing* illing*	м	mud casing	N	nil	U ₅₀ undisturbed sample 50mm diameter soll de	scription	symbols ar n ed classifi		n		consistency/density index VS very soft S soft	
	RR		rol	ler/trio ashbo	cone		etration	1		D disturbed sample system N standard penetration test (SPT)			0010			S Son F firm St stiff	
sue 31	CT HA		ca	ble to nd au	ol			o resista anging to stusal	nce	N* SPT - sample recovered moistu Nc SPT with solid cone D	re dry					VSt very stiff H hard	
5.3 Iss	DT B		dia bla	atube ank bi	-	wa'	10/1/98	3 water	level	V vane shear (kPa) M P pressuremeter W	moist wet					Fb friable VL very loose	
Form GEO 5.3 Issue 3 Rev.2	V T		то	bit > bit		<u> </u>	on date	show	ו	E environmental sample WL	plastic li iquid lin					L loose MD medium de	nse
Form	*bits e.g.	hown	by su A[water i water c			R refusal						D dense VD very dense	

	Cof	fey	Geo	scier	ces	Pty Ltd ACN 056 335 516							В	orehole	No.	BH4	Ø
	_			*		.							s	heet	2	2 of 3	
-	En	gi	nee			og - Cored borel	lole						С	ffice Jo	b No.:	NR1059/2	Coffey
	Clien												_	ate star		11.2.2002	
	Princ	•				RD DOSSOR									pleted:	11.2.2002	5
	Proje				JOS:	SOR SUBDIVISION								ogged b	-	RW KY PS	0
Г				on: ing: JA(CRO 3	50, 100	Eastir			slope:			30°	hecked		Surface: 34.9	
	hole d			g. or .mr		Drilling fluid:	Northi	•		bearin	g:				datum		
ŀ	drill	ing i	nforn	nation		erial substance material		<u>, , , ,</u>		T	rc	ock	mas	s defec	:ts	defect description	·
	7				graphic log core recovery	rock type; grain characteristics,	colour.	gring Ho	estimated strength	Is ₍₅₀₎ MPa	%	sp	efect acing mm		type, inc	lination, planarity, roughr	1855,
	method	water	DI	depth	iraphic ore re	structure, minor componer		weathering alteration	. –	D-diam- etral r A-axial	RQD %	ĺ	285 285 1010	3	-, -	coating, thickness	
		, s	RL _30	metres					₹ᠴॾॻऄ			88	- - - - - - - - - - - - - - - - - - -	g partic	ular	··· · · · · · · · · · · · · · · · · ·	general
	NMLC		_30	5_	$\langle \rangle \langle$	BASALT: brown to grey-brown, me grained.	aium	нw			23]	5.	00m - 5.40	RO, Fe, SN m: Fractured zone with	-
		4			$\langle \langle \rangle \rangle$	BASALT: brown-grey to grey, medi		XW				Ľ		—JT	, 10°, PL, I	eathered basalt RO, Fe, SN	-
\frown				-	$\langle \rangle \rangle$	grained. BASALT: grey to dark grey speckle		SW						⊥∖ர		RO, Fe, SN RO, Fe, SN tures	•
J			_29	· <u>6</u>	$\langle \rangle \langle$	grained.					8				', 60°, PL, I ', 45°, IR, C	RO, Fe, SN CU, RO, Fe, SN	-
					$\langle \rangle \langle$,	25°, PL, RO, Fe, SN	•
		1		-	<u>}</u> }								וא	ΓL—–	, 70°, PL,	IR, RO, Fe, SN RO, Fe, SN IR, RO, Fe, SN	
			_28	7	$\langle \rangle \rangle$						56			[~л	, 30°, PL, I	RO, Fe, SN RO, Fe, SN	_
	┝	+		-	\sum	BASALT: grey-brown, fine to media grained.		MW			┡				85°, PL,	RO, Fe, SN RO, Fe, SN	•
				-	$\langle \rangle \langle$	BASALT: grey to dark grey speckle grained.	a, meaium	SW						LVU	, 60°, PL,	nd irregular fractures RO, Fe, SN nd 25°, PL, RO, Fe, SN	
			_27	8	\$\$\$						8			\JI	, 10°, PL,	RO, Fe, SN RO, Fe, SN	
				-	$\langle \rangle \langle$	BASALT: grey to brown-grey, fine g	grained,									30°, PL, RO, Fe, SN RO, Fe, SN	-
		1		-	\rightarrow	vesicular. BASALT: grey-brown to red-brown	with clay	-IW/MW			0			8.		m: Fractured zone along	
	F	1	_26		$\langle \rangle \langle$	filled vesicles.	, which enay				F			8.	75m - 8.82	m: Fractured zone	
				9	$\langle \rangle \langle$						39	r				RO, Fe, SN sture, 20° - 45°	-
8				-							۳.			[—]	-	RO, Fe, SN	
03.0					$\langle \rangle \rangle$											RO, Fe, SN	
			_25	10	$\langle \rangle \rangle$									J"	, 88°, PL,	RO, Fe, SN RO, Fe, SN RO, Fe, SN	-
DFFEY				-	$\langle \rangle \langle$						4			\r	", 50°, IR, I	RO, Fe, SN RO, Fe, SN 55°, PL, RO, Fe, SN	
50				-	$\langle \rangle \langle$.90m: core fracture along	
068.6		$\frac{1}{2}$	_24	11	555						⊢	╎╟				RO, Fe, SN	-
CORED BOREHOLE BORELOGS.GPJ COFFEY.GD					$\langle \rangle \langle$									1	r, 55°, PL,	RO, Fe, SN RO, Fe, SN IR, RO, Fe, SN	
OLE B					\sum						3]			\1 ⁺		.85m: 6 x irregular core	
OREH			_23	12										2	x core bre	aks	-
ED B($\langle \rangle \rangle$	BASALT: dark grey to red-grey, fin	e orained.	MWISW					וא		x core bre ore fractur	aks e, 30° - 40°	
ğ					$\langle \rangle \rangle$	with zeolite and clay filled vesicles.	- <u>-</u> ,				68				2.50m - 12)°, 55°	.60m: 4 x core fractures :	at 5°,
	meth DT	od		tube		core-lift	water	1		weatheri FR fr	ng/al resh	teral	ion	<u></u>	defect ty		iness /ery rough
27	AS AD		aug	jer screw Jer drilling		casing used	<u> </u>)/1/98 wal h date sho	wn	SW s DW d	light listin	ctly 🗤	ather veath weath	ered	PT pa SM se	arting RO : sam SO :	rough smooth slickensided
e 3 Rev.	RR CB	_	rolle clav	er/tricone w or blad		graphic log/core recovery	- P	ater inflow artial drill 1	luid loss	DA d	ilight Iistin	ly alt ctly a	ered altered	l	SS sh	neared zone SL : neared surface ushed seam	SIICKENSIGEO
5 Issue 3	NML NQ, I	C HQ, P		LC core eline core	;	core recovered		omplete di	ill fluid loss	strength		-	altere	a		anar CN	clean
3EO 5.5						- graphic symbols indicate material		•	ure test resu	lt M T	ow nedil				CU cu UN ur	uved SN adulating VN	stained veneer coating
Form GEO						no core recovered		ugeons) fo terval sho	-	VH V	nigh very f	igh	high			egular 00	

	Co	off	ey	Geo	scie	nces	Pty Ltd ACN 056 335 516								В	orehole	No.	BH4	- 8	
	Ε	no	air	iee	rinc	a Lo	og - Cored bore	hole								neet fice Jo		of 3 NR1059		
		ent:					LINK GROUP									ate star		11.2.200	— Л	
	Pri	ncij	bal:		1	DM 8	RD DOSSOR								Da	ate com	pleted:	11.2.200	02	
	Pro				I	oos	SOR SUBDIVISION								La	gged b	v:	RW /K	ч О	
	Borehole Location:																-	Ps	Ϊ 🖸	
	drill model & mounting: JACRO 350 100							Eastir	ng:			slope:		-90° R.L. St			R.L.S		1,9	٦
	hole diameter: mm Drilling fluid:						Drilling fluid:	Northi	-			bearin					datum			
	dr	illi:	ng i	nforn	nation		erial substance material		1				rc	ock I	mass	s defec		defect descrip		-
	method	core-lift	water	RL	depth metres	graphic log core recovery	rock type; grain characteristic structure, minor compone		weathering alteration	5	stimated strength	Is ₍₅₀₎ MPa D- diam- etral A- axial	RQD %	spa n	afect acing nm	partice	type, incl	ination, planarit coating, thickn	y, roughness,	al
	NMLC			_22	13	555	BASALT: dark grey to red-grey, fi with zeolite and clay filled vesicles	ne grained, (continued)	MW/SW							í	, 15°, Fe, S	IN, RO		-
	Ż				' <u>-</u>	$\langle \rangle \rangle$,					68					l core break		
		Ц			ļ _		BASALT: dark grey to grey speck	ed fine to	SWIFt								ore break JT, 10°, PL,	80		-
\sim					-	$\langle \rangle \langle$	medium grained.										,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	NO		-
I				_21	14_									║┢	4		, 20°, PL, F			1
					-	$\langle \langle \langle$							80				, 30°, PL, F pre break	<i>.</i> 0		-
					-	$\left \right\rangle$														
				_20	15	$\langle \langle \rangle$									╔┛		ore fracture , 20°, PL, F			_
					, <u>s</u>		BASALT: dark grey, fine grained,		-								, 20 , FL, P pre fracture , 35°, PL - I	, 35°		
					-												, 45°, PL, F			_
					-	$\langle \rangle \langle$							76				, 10°, PL, F			-
				_19	1 <u>6</u>	555										L11	, 30°, PL, F			1
					-	$\langle \rangle \langle$								╏┛		$\Gamma \sqrt{1}$, 60°, PL - , 35°, PL, F , 15°, PL -	20		_
		$\left \right $			-	555							-	וו		[−_1	45°, PL, F			
				_18	-	$\langle \rangle \rangle$										— л	re fracture , 30°, PL, F			-
					17_	$\langle \langle \langle \langle$	BASALT: dark grey, fine grained,	with zeolite	-				76	╽┟╢		\JT	, 50°, PL - I 50°, PL - I	IR, RO, SL		
2						$\langle \rangle \rangle$	and filled vesicles.										, 70°, PL, F pre fracture			1
00000					-	$\langle \rangle \langle$								<u>ןן</u>	1	-JT	, 25°, PL, F , 60° - 70°	20		
\ <u>L</u>		Π		_17	18	$\langle \rangle \rangle$							72		1	->J	5° PL R 5° 7° Pl	D, SL		_
FEY.G		Ц			-	$\langle \rangle \rangle$]	Ĺ			<u></u>	, 20°, PL, F , 60° - 70°	CU, RO		_
COFI						$\langle \rangle \rangle$			sw									, 45°, 75°, PL, F 34m: Fractured		-
CORED BOREHOLE BORELOGS.GPJ COFFEY.GD				_16			BASALT: dark grey to brown-grey						43]			, 85°, PL, F	C Artical, zeolite v	ein	_
100 100					19	$\langle \rangle \langle$	grained, with large pale green zeo dipping 85° - 90°.						4			L/JI	, 15°, PL, F , 22°, PL, F	20		_
BOR					-									╽╽┛		E JI	ore fracture , 18°, PL, F	20		_
HOLE		\square				77,	BH4 terminated at 19.58m			╞╌┼╸	┥╌ ^{╔╗} ╼┤╸		┢	┝┤┛┼		T\\JT	, 60°, PL, F	20 20, Fe, SN 20, Fe, SN		
BORE				_15	20												, 30 , FC, F	(O, F8, 014		_
RED I															:					_
8																				_
	met DT	thod	 	diat	tubo		core-lift	water	water water 10/1/98 water jevel				ng/ali resh	g/alteration		<u> </u>	defect typ JT join		roughness VR very rough	
v.2	AS			aug	er screw er drilling		casing used	- <u>≭</u> on	ı date sho	wn		SW si DW d	lightly	tly we	therec	ed	PT par SM sea	ting m	RO rough SO smooth	
3 Rei	RR CB			rolle	v or blad	·	barre! withdrawn	-⊲ pa	ater inflow artial drill f	fluid		SA s	lightly	rely v y aite tly ali		rea	SS she	ared zone ared surface shed seam	SL slickensided	i
i Issue	NM NC	ILC), HC	2, PC		LC core atine core		graphic log/core recovery	co	mplete di	rill fl	uid loss	XA e strength	xtrem	nely a	ltered		planarity		coating	
EO 5.5						- graphic symbols						L k	ery lo ow nediu				PL pla: CU cur UN unc		CN clean SN stained VN veneer	
Form GEO 5,5 Issue 3 Rev.2							no core recovered	き (こ	geons) fo terval sho	or de		H h VH v	iigh ery hl	igh	11		ST ste	pped gular	CO coating	
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APPENDIX C

RISK ASSESSMENT TERMS, DESCRIPTIONS AND DISCUSSION



For the purposes of the risk assessment presented in this report, the terms and descriptions provided in Appendix G of AGS 2000 have been used and are summarised below.

TABLE 3:	QUALITATIVE MEASURES OF LIKELIHOOD
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Level	Descriptor	Description	Indicative Annual Probability
А	Almost Certain	The event is expected to occur	>~10-1
В	Likely	The event will probably occur under adverse conditions	~10-2
С	Possible	The event could occur under adverse conditions	~10-3
D	Unlikely	The event might occur under very adverse circumstances	~10-4
E	Rare	The event is conceivable but only under exceptional circumstances	~10 ⁻⁵
F	Not credible	The event is inconceivable or fanciful	<~10 ⁻⁶

TABLE 4: QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

Level	Descriptor	Description
1	Catastrophic	Structure completely destroyed or large scale damage requiring major engineering works for stabilisation
2	Major	Extensive damage to most of the structure, or extending beyond site boundaries requiring significant stabilisation works
3	Medium	Moderate damage to some of the structure, or significant part of the site requiring large stabilisation works
4	Minor	Limited damage to part of the structure, or part of the site requiring some reinstatement/stabilisation works
5	Insignificant	Little damage

TABLE 5: QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

Likelihood	Consequences to Property									
	1	2	3	4	5					
А	VH	VH	Н	Н	М					
В	VH	Н	Н	М	L-M					
С	Н	Н	М	L-M	VL-L					
D	M-H	М	L-M	VL-L	VL					
E	M-L	L-M	VL-L	VL	VL					
F	VL	VL	VL	VL	VL					

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Notes: Risk levels - VH = Very High, H = High, M = Moderate, L = Low, VL = Very Low.

A discussion of the assessed likelihood and consequences used to assess the risk of slope instability at the site is shown below:

- Hazard 1: Shallow seated instability of the natural and altered slopes in the vicinity of the proposed developments.
 - The consequences of shallow seated instability were assessed to be minor for all zones. Shallow seated instability would likely cause limited damage to part of residential dwellings and other residential structures, or part of the site may require some reinstatement/stabilisation works.
 - The likelihood of shallow seated instability will increase with increasing slope angle. Signs of soil creep were evident in Zones 2 and 3, indicating that very slow down slope movement of soils has taken place on the upper site slopes. Development of the site in accordance with the above recommendations for development may actually decrease the likelihood of shallow seated failures.
- Hazard 2: Deep seated instability of the natural and altered slopes in the vicinity of the proposed developments.
 - The consequences of deep seated instability were assessed to be major for all zones. Deep seated instability would likely cause extensive damage to residential dwellings and other residential structures. In addition, the instability may extend beyond allotment and/or the site boundaries, and will likely require significant stabilisation works
 - The likelihood of deep seated instability will in part be driven by slope angle, though site earthworks such as cut and fill, groundwater and the subsurface conditions play a much more significant role than for shallow seated instability. No signs of existing deep seated instability were observed at the site. General geotechnical conditions at the site comprise stiff to hard residual soils overlying weathered rock. No weak layers or zones which could trigger instability were observed in boreholes cored through the rock. As part of the recommendations for development, cut and fill has been limited in Zones 2 and 3, and recommendations for filling are provided in this report and on the attached hillside construction information documents. Groundwater seepages were observed in zone 2, however recommendations for the treatment of groundwater in this area and where encountered elsewhere on the site have been provided. On this basis, the likelihood of deep seated instability has been assessed as between Not Credible and Rare for the

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three zones.

- Hazard 3: Instability of appropriately battered and treated slopes or failure of engineer designed retaining walls.
 - The consequences of instability of engineered slopes and retaining walls were assessed to be medium to major for all zones. This could require reconstruction of some or all of the retaining wall and large to significant site stabilisation works. As retaining walls are often located near allotment boundaries, instability may extend beyond allotment boundaries.
 - The likelihood of instability of engineered slopes and retaining walls is assessed to be rare, in that the engineering design should have an adequate factor of safety in all but exceptional circumstances.

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