Proposed Community Infrastructure Depot - Geotechnical Assessment

Lot 1 DP819014, No. 252 Coal Road, Muswellbrook

NEW22P-0092-AB
29 June 2022

LABORATORY (NSW) PTY LTD

GEOTECHNICAL I LABORATORY I EARTHWORKS I QUARRY I CONSTRUCTION MATERIAL TESTING

29 June 2022

Muswellbrook Shire Council
60-82 Bridge Street
MUSWELLBROOK NSW 2300

Attention: Mr Joseph Thurairatnam

Dear Joseph

RE: PROPOSED COMMUNITY INFRASTRUCTURE DEPOT
No. 252 COAL ROAD, MUSWELLBROOK NSW
GEOTECHNICAL ASSESSMENT

Please find enclosed our Geotechnical Assessment report for the proposed Community Infrastructure Depot, located at Lot 1 DP819014, No. 252 Coal Road, Muswellbrook NSW.

The report includes recommendations on pavement design and construction for internal access roads and carparks, preliminary site classification in accordance with AS2870-2011, "*Residential Slabs and Footings*", foundations design parameters, and earthworks including suitability of existing materials for re-use.

If you have any questions regarding this report, please do not hesitate to contact Ben Edwards, Shannon Kelly or the undersigned.

For and on behalf of Qualtest Laboratory (NSW) Pty Ltd

Jason Lee

Jason Lee
Principal Geotechnical Engineer

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Attachments:

Figure AB1:	Site Plan and Approximate Test Locations
Appendix A:	Results of Field Investigations
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1.0 Introduction

Qualtest Laboratory NSW Pty Ltd (Qualtest) is pleased to present this geotechnical report to Muswellbrook Shire Council (MSC), for the proposed Community Infrastructure Depot to be located at no. 252 Coal Road, Muswellbrook NSW.

Based on the brief and drawings provided in subsequent emails dated from 18 April 2022, It is understood that Council proposes to construct a Community Infrastructure Depot, which will comprise industrial sheds, with associated hardstand and car parking, and a future leachate basin. The site is approximately 2.6ha in area, and comprises part Lot 1 DP819014.

Layout of the proposed development and borehole locations are shown on the attached Figure AB1.

The scope of work for the geotechnical investigation included providing discussion and recommendations on the following:

- Site preparation;
- Excavation conditions and depth to rock (if encountered);
- The suitability of the site soils for use as fill and on fill construction procedures;
- Preliminary Site Classification to AS2870-2011, "*Residential Slabs and Footings*";
- Recommendations on suitable footing types, founding levels and foundation design parameters (within depth of investigation);
- Pavement design and construction recommendations in general accordance with Muswellbrook Shire Council design guidelines;
- Leachate basin ground conditions;
- Special requirements for construction procedures and or site drainage;

This report presents the results of the field work investigations and laboratory testing, and provides recommendations for the scope outlined above.

2.0 Field Work

Field work investigations were carried out on 18 May 2022 and comprised of:

- DBYD search and scanning of proposed test locations using an accredited professional cable locator to check for the presence of underground services;
- Site walkover to make observations of surface features at the property and in the immediate surrounding area;
- Excavation of 9 boreholes (BH01 to BH09) using a 2.7 tonne excavator equipped with a 300mm diameter auger. Boreholes were terminated at depths of between 0.30m and 2.60m;
- Bulk disturbed samples, undisturbed samples (U50 tubes), and small bag samples were taken for subsequent laboratory testing; and,
- Boreholes were backfilled with the excavation spoil and compacted using the excavator auger and tracks.
- Additional sampling of Stockpile locations (S01 to S03) located fronting Muswellbrook Waste Management Facility for potential re-use as lining and bulk filling for the proposed Leachate basin construction and for onsite fill, as shown on Figure AB1.

Investigations were carried out by an experienced Geotechnical Engineer from Qualtest who located the boreholes, carried out the testing and sampling, produced field logs of the boreholes, and made observations of the site surface conditions.

Engineering logs of the borehole are presented in Appendix A.

Approximate borehole locations are shown on the attached Figure AB1. Boreholes were located in the field by handheld GPS and relative to existing site features including topographic features, lot boundaries, existing developments and trees.

3.0 Site Description

3.1 Surface Conditions

The site is approximately 2.6ha in area, and comprises part Lot 1 DP819014. The site is located in the south-western and western areas of the lot, as shown on Figure AB1.

The site was formerly part of an open cut coal mine operation. Historic filling was observed during site investigations, including two large fill stockpiles located on the southern side of the lot: 'Stockpile 1' - up to 5.5m in height and about 200m long; and, 'Stockpile 2' - up to 5m in height and about 120m long. Fill platforms were observed in places generally located along the powerline easement, with a few small dam areas generally located in the western area.

Trafficability was judged to be good by way of 4WD vehicle along the existing access tracks.

Photographs of the site taken on the day of the site investigations are shown below.

Photograph 1: From near BH04, facing southwest. Fill mound just visible in background behind tree line.

Photograph 2: From near BH04, facing west.

Photograph 3: From near BH04, facing east. Showing existing recycling sheds in background.

Photograph 4: From top of existing fill mound ('stockpile 1' – approximately 5.5m in height), approximately 15m south of BH04, facing northwest.

Photograph 5: From near BH02, facing east.

Photograph 6: From near BH02, facing southeast.

Photograph 7: From near BH07, facing south.

Photograph 8: From near BH07, facing west.

Photograph 9: From near BH09, facing east.

Photograph 10: From base of (Clay) Fill stockpile, located east of the site.

3.2 Subsurface Conditions

Reference to the 1:100,000 Hunter Coalfields Regional Geology map indicates the site to be underlain by the Rowan Formation of the Greta Coal Measures, which are characterised by coal seams, sandstone, and siltstone rock types.

Table 1 presents a summary of the typical soil types encountered at borehole locations during the field investigation, divided into representative geotechnical units.

Table 2 contains a summary of the distribution of the above geotechnical units at the borehole locations.

TABLE 1 – SUMMARY OF GEOTECHNICAL UNITS AND SOIL TYPES

Unit	Soil Type	Description
1A	FILL-TOPSOIL	Sandy CLAY – low plasticity, brown, fine to coarse grained sand, trace fine to medium grained angular to sub-angular gravel, root affected.
1B	FILL	Sandy GRAVEL – generally fine to coarse grained angular to sub-rounded, colour combinations of grey, dark grey-brown, pale brown to brown, and orange, fine to coarse grained sand, trace fines of low plasticity, trace coal chitter in places. Silty Sandy GRAVEL – fine to coarse grained angular, dark grey to dark brown, fine grained sand, fines of low plasticity, trace angular cobbles. Silty SAND – fine grained, generally dark grey to black, fines of low plasticity. Gravelly CLAY – medium to high plasticity, colour combinations of red-brown, dark grey, brown, pale brown and pale grey, fine to medium grained angular to sub-angular gravel, trace fine to coarse grained sand.
2	TOPSOIL	Gravelly Silty SAND – fine to coarse grained, grey-brown, fine to coarse grained angular gravel, root affected.
3	SLOPEWASH	Gravelly Silty SAND – fine to coarse grained, grey-brown, fine to coarse grained angular gravel, root affected.
4	RESIDUAL SOIL	CLAY – medium to high plasticity, generally pale grey, with pale orange, trace silt, trace extremely weathered rock pockets in places. Silty CLAY / Gravelly Silty CLAY / Clayey GRAVEL – medium plasticity, pale grey to white, trace pale brown, with some fine to medium grained angular gravel, with some fine to medium grained sand in places. Sandy GRAVEL – fine to medium grained angular, pale brown with some pale grey, fine to coarse grained sand, with some fines of low plasticity.
5	EXTREMELY WEATHERED (XW) ROCK with soil properties	Siltstone; breaks down into Silty Gravelly CLAY / Clayey GRAVEL – medium plasticity, pale grey to white, trace pale brown, with some fine to medium grained angular gravel, with highly weathered pockets in places. Sandy Siltstone; breaks down into Silty Sandy GRAVEL – fine to medium grained angular, pale brown, trace pale grey, fine to coarse grained sand, fines of low plasticity, trace Sandy CLAY / Silty CLAY bands in places.
6	MODERATLEY WEATHERED (MW) TO HIGHLY WEATHERED (HW) ROCK	SILTSTONE, Sandy SILTSTONE – pale grey to grey, trace orange, varying rock strength of estimated low to high (generally estimated medium to high strength).

TABLE 2 – SUMMARY OF GEOTECHNICAL UNITS ENCOUNTERED AT BOREHOLE LOCATIONS

Location	**Unit 1A Fill-Topsoil**	**Unit 1B Fill**	**Unit 2 Topsoil**	**Unit 3 Slopewash**	**Unit 4 Residual Soil**	**Unit 5 XW Rock**	**Unit 6 HW to MW Rock**
	Depth in metres (m)						
BH01	-	-	0.00 - 0.15	0.15 - 0.35	0.35 - 2.10	2.10 - 2.60	-
BH02	-	0.00 - 0.15	-	-	-	-	0.15 - 0.30*
BH03	-	0.00 - 1.70	-	-	1.70 - 2.60	-	-
BH04	-	0.00 - 0.55	-	-	0.55 - 0.60	0.60 - 2.60	-
BH05	0.00 - 0.10	0.10 - 0.60	-	-	0.60 - 1.20	1.20 - 1.50	1.50 - 1.70*
BH06	-	-	0.00 - 0.10	-	0.10 - 0.50	-	0.50 - 055*
BH07	0.00 - 0.05	0.05 - 0.65#	-	-	-	-	-
BH08	-	0.00 - 1.70	-	-	-	-	1.70 - 1.80*
BH09	-	0.00 - 1.40#	-	-	-	-	-
Notes:	* = Practical refusal or refusal of 2.7 tonne excavator met on Highly Weathered Rock. # = Refusal of 2.7 tonne excavator met on possible Weathered Rock.						

No water inflows or groundwater levels were encountered in the borehole during the limited time that they remained open during the day of the field investigations.

It should be noted that groundwater conditions can vary due to rainfall and other influences including regional groundwater flow, temperature, permeability, recharge areas, surface condition, and subsoil drainage.

4.0 Laboratory Testing

Samples collected during the field investigations were returned to our NATA accredited Newcastle Laboratory for testing which comprised of:

- (5 no.) California Bearing Ratio (CBR, 4 day soaked) & Standard Compaction tests;
- (6 no.) Atterberg Limits tests;
- (3 no.) Particle Size Distribution (Grading) tests.
- (1 no.) Emerson Dispersion test.

Proposed shrink/swell testing for the two undisturbed samples (U50 tubes) taken were replaced by Atterberg Limits classification tests due to the friable nature of the site soils.

Results of the laboratory testing are presented in Appendix B, with a summary of the test results presented in Tables 3 and 4.

TABLE 3 – SUMMARY OF CBR TESTING RESULTS

Location	Sample Depth (m)	Field Moisture Content (%)	Optimum Moisture Content (%)	Relationship of Field MC to OMC (%)	CBR (%)
BH01	0.35 – 0.60	20.5	22.7	2.2 Dry	2.5
BH03	0.50 – 0.90	13.6	21.1	7.5 Dry	6
BH07	0.20 – 0.50	17.6	18.0	0.4 Dry	4
Fill Stockpile (General Fill)					
Stockpile 1 - S01		11.7	13.4	1.7 Dry	7
Stockpile 2 - S02		12.4	15.1	2.7 Dry	20

TABLE 4 - SUMMARY OF LABORATORY TEST RESULTS

Location and Depth (m)	Material Description	Grading		Atterberg Limits			Emerson Class
		Sieve (mm)	% Pass	Liquid Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	
BH01 0.35 – 0.60	CLAY	37.5	-	44	25	11.5	-
		19.0	-				
		2.36	-				
		0.075	-				
BH05 0.60 – 0.75	CLAY	37.5	-	50	31	14.0	-
		19.0	-				
		2.36	-				
		0.075	-				
BH06 0.10 – 0.30	CLAY	37.5	-	59	33	15.5	-
		19.0	-				
		2.36	-				
		0.075	-				
Stockpile 1 - S01	Clayey Sandy GRAVEL	37.5	90	25	11	5.0	-
		19.0	75				
		2.36	43				
		0.075	19				
Stockpile 1 - S02	Gravelly Silty SAND / Gravelly Sandy CLAY	37.5	100	37	19	9.0	-
		19.0	91				
		2.36	62				
		0.075	36				
Stockpile 2 - S03	Sandy Gravelly CLAY	37.5	95	36	19	9.0	2
		19.0	84				
		2.36	60				
		0.075	41				

The results of the Atterberg Limits laboratory testing indicate that the residual soils tested from the site generally contain fines of medium to high plasticity.

5.0 Discussion and Recommendations

5.1 Preliminary Site Classification to AS2870-2011

Site Classification to AS2870 is not strictly applicable to this site due to proposed development including administration / industrial buildings and store / workshop structures rather than a residential development. However, the principles of footing design and site maintenance presented therein may be taken into account for buildings such as those proposed for the site.

Based on the results of the field work and laboratory testing, the site of the proposed administration, internal store and workshop buildings to be located at the Community Infrastructure Depot at Muswellbrook, in the vicinity of BH01, BH04, BH05 and BH06 as shown on Figure AA1, is classified in its current condition in accordance with AS2870-2011 '*Residential Slabs and Footings*', as **Class 'P'**.

The site is classified as **Class 'P'** due to the presence or inferred presence of fill associated with the construction of the access track, to depths of greater than 0.4m encountered within boreholes BH04 and BH05 (along the northern section of the proposed structure footprint). No records of the placement or compaction of the fill material have been provided; therefore, it has been assessed to be uncontrolled fill.

If the depth and extent of fill needs to be known more accurately for planning, design or other purposes, then it should be investigated further.

It is recommended that the extent of Fill is investigated further during or prior to construction works, and that fill is removed or replaced as controlled fill to 'Level 1' criteria as defined in Clause 8.2 – Section 8, of AS3798-2007, where shallow footings or settlement sensitive structures are proposed.

It is envisaged that if uncontrolled fill, topsoil and slopewash depths are reduced to less than 0.4m, witnessed and documented by a geotechnical authority, then it is likely that those areas could be re-classified. This should be confirmed by the geotechnical authority following fill / topsoil removal.

If site re-grading works involving cutting or filling are performed after the date of this assessment the classification may change and further advice should be sought.

As a preliminary guide, potential site classification following site regrade may include:

- Areas stripped of uncontrolled fill (where applicable) and topsoil, then filled with site won Residual Soil or similar material, carried out to 'Level 1' criteria as defined in Clause 8.2 – Section 8, of AS3798-2007, are likely to be re-classified as **Class 'H2-D'** or **Class 'E-D'**. A classification of **Class 'H1-D'** may be achievable in some places if specific engineering measures are undertaken such as (to be confirmed): placing a very low to non-reactive fill or topsoil layer to depths of about 0.30m from finish surface level; and, rock depth of about 1m or less or filling to sufficient depths (to be confirmed) with less reactive materials (e.g. Sandy or Gravelly materials generally from deeper in the existing profile with I_{ss} of about 2.0% or less).
- Areas of residual soil, or cut into residual soil or extremely weathered rock are likely to be re-classified as **Class 'H1-D',** or possibly **Class 'H2-D'** in some areas if deeper or higher reactivity soil is encountered. A classification of **Class 'M-D'** may apply to some areas if favourable conditions are encountered (e.g. possibly areas where the full footprint comprises residual soil overlying bedrock at depths of less than about 1.0m).

If earthworks measures targeting site classification of **Class 'H1-D' or 'H2-D'** are proposed, then further engineering advice should be sought. Due to possible variability in reactivity of site won materials, it is recommended that Shrink/Swell testing of lower layers of controlled fill is undertaken during construction so that the suitability and required thickness of the proposed overlying lower reactivity fill can be reassessed.

Final site classification will be dependent on a number of factors, including depth of topsoil, depth of cut / fill, reactivity of the natural soil and any fill material placed, depth to rock, and the level of supervision carried out. Re-classification should be confirmed by the geotechnical authority at the time of construction following any site re-grade works.

A characteristic free surface movement of 20mm to 40mm is estimated for areas classified as **Class 'M-D'**.

A characteristic free surface movement of 40mm to 60mm is estimated for areas classified as **Class 'H1-D'**.

A characteristic free surface movement of 60mm to 75mm is estimated for areas classified as **Class 'H2-D'**.

A characteristic free surface movement of greater than 75mm is estimated for areas classified as **Class 'E-D'**.

The effects of changes to the soil profile by additional cutting and filling and the effects of past and future trees should be considered in selection of the design value for differential movement.

Footings for the proposed development should be designed and constructed in accordance with the requirements of AS2870-2011.

The classification presented above assumes that:

- All footings are founded in controlled fill (if applicable) or in the residual clayey soils or rock below all non-controlled fill, topsoil material and root zones, and fill under slab panels meets the requirements of AS2870-2011, in particular, the root zone must be removed prior to the placement of fill materials beneath slabs;
- The performance expectations set out in Appendix B of AS2870-2011 are acceptable, and that site foundation maintenance is undertaken to avoid extremes of wetting and drying;
- Footings are to be founded outside of or below all zones of influence resulting from existing or future service trenches;
- The constructional and architectural requirements for reactive clay sites set out in AS2870-2011 are followed;
- Adherence to the detailing requirement outlined in Section 5 of AS2870-2011 '*Residential Slabs and Footings*' is essential, in particular Section 5.6, '*Additional requirements for Classes M, H1, H2 and E sites*' including architectural restrictions, plumbing and drainage requirements; and,
- Site maintenance complies with the provisions of CSIRO Sheet BTF 18*, "Foundation Maintenance and Footing Performance: A Homeowner's Guide*", a copy of which is attached in Appendix C.

All structural elements on all lots should be supported on footings founded beneath all uncontrolled fill, layers of inadequate bearing capacity, soft/loose, wet or other potentially deleterious material.

If any areas of uncontrolled fill of depths greater than 0.4m are encountered during construction, footings should be designed in accordance with engineering principles for Class 'P' sites.

5.2 Foundations

5.2.1 Shallow Footings

Footings should be founded below any existing uncontrolled fill, topsoil, deleterious material, or very soft to firm / loose material.

Shallow footings founded on stiff or better residual clay, dense or better sand, or approved controlled fill (placed under Level 1 supervision in accordance with AS3798-2007) may be proportioned for a maximum allowable bearing pressure of 100kPa.

Shallow footings founded on very stiff or better residual clay, or approved controlled fill (compacted to a minimum density ratio of 98% Standard Compaction placed under Level 1 supervision in accordance with AS3798-2007) may be proportioned for a maximum allowable bearing pressure of 150kPa.

Shallow footings founded on Extremely Weathered Rock without clay layers may be proportioned for a maximum allowable bearing pressure of 300kPa.

Shallow footings founded in Highly Weathered Rock (Class V Sandstone or better, without clay or extremely weathered layers) may be proportioned for a maximum allowable bearing pressure of 600kPa.

The recommended allowable bearing pressures assume that elastic settlements will be less than about 1% of least footing width; although, relevant ground movements related to reactive clay soils would also apply.

5.2.2 Deep Footings

Piled foundation options are expected to include bored piles. Table 5 presents a summary of founding parameters for deep footings (founding depth greater than 3 times maximum footing width) that have been adopted for the relevant materials.

Increased capacity may be achieved in rock of medium strength or better; however, due to the investigations being limited to boreholes rather than rock coring, and potential for low strength layers to be present, it is recommended that the values provided in Table 5 are adopted for Unit 6 rock unless further investigations are carried out to confirm or otherwise the presence of medium strength rock over the depth of proposed pile socket and below the base depth of proposed piles.

TABLE 5 – SUMMARY OF DEEP FOOTING DESIGN PARAMETERS

Soil Description	Serviceability (Allowable) End Bearing Capacity (kPa)	Serviceability (Allowable) Shaft Adhesion (kPa)	Serviceability (Allowable) Lateral Bearing Capacity (kPa)	Ultimate End Bearing Capacity (kPa)	Ultimate Shaft Adhesion (kPa)
Uncontrolled Fill, Topsoil, Slopewash	-	-	-	-	-
Unit 4 – Residual Soil (stiff or better)	150	25	50	450	50
Unit 5 - Extremely Weathered Rock	300	25	100	900	50
Unit 6 - Highly Weathered Rock (Class V Shale or better)	700	50	250	2100	100

Notes:

1) Design should not allow for any geotechnical strength from the upper 0.5m of embedded foundation depth.
2) Ultimate values occur at large settlements (>5% of minimum footing dimensions).
3) The ultimate pile parameters presented should be used in limit state pile design in accordance with Australian Standard AS 2159-2009, *Piling – Design and Installation*.
4) A geotechnical strength reduction factor should be adopted for use with the above ultimate soil and rock parameters. A geotechnical strength reduction factor of 0.45 is recommended based on available information at this stage.
5) Where the founding stratum is underlain by a weaker layer, the pile toe should be located at least three pile diameters above the top of the weaker layer.
6) Piles should be no closer than 2.5 pile diameters apart.
7) It is expected that the settlement of deep footings proportioned as recommended above should be less than about 1% of the effective pile diameter.

The design parameters for rock sockets assume the socket is clean and rough. Sockets should be checked to confirm appropriate cleanliness prior to pouring of concrete.

The base of piles should be cleaned using a suitable bucket to remove spoil, as open flight augers usually cannot remove sufficient spoil to expose the majority of the pile base. A suitably experienced geotechnical engineer should inspect the pile excavations prior to pouring concrete.

Contingency should be made for localised use of casing if collapse of the side walls due to water inflows or granular soils is encountered. If groundwater is encountered, then piles will require dewatering prior to the pouring of concrete or else tremmie methods should be used to ensure concrete can be placed effectively to the base of the pile.

5.3 Pavement Design

5.3.1 Design Subgrade CBR Values

Subgrade laboratory CBR test results from the current investigation at the site ranged from 2.0% to 7%. Based on the results of the field work and laboratory testing, and previous experience in the surrounding area, the following design California Bearing Ratio (CBR) values have been adopted for pavement thickness design.

TABLE 6 – DESIGN SUBGRADE CBR VALUES

Road Section	Design Subgrade	Design CBR (%)
To Be Confirmed	Residual Clay, Controlled Fill - (low CBR soils where encountered)	2.5
To Be Confirmed	Residual Clay, Controlled Fill - (higher CBR soils where encountered)	4.0
To Be Confirmed	Weathered Rock	8

Notes:

1) Design subgrade CBR values should be confirmed at the time of construction by the geotechnical authority for each relevant road section.
2) Fill placed at road subgrade level should be assessed by the geotechnical authority. If the fill is assessed to have CBR different to that of the design CBR, then a revised pavement design will be required for that section.

Based upon the test results from the site, is anticipated that:

- **Design subgrade CBR of 2.5% may apply to the majority of road sections in residual soil where shallow cuts do not expose weathered rock, and most areas filled with site won Residual Soil or similar material;**
- Design subgrade CBR of 4.0% may apply to some road sections if residual clay soil or fill with CBR of 4.0% or higher forms the subgrade for new pavements; and,
- Design subgrade CBR of 8% may apply to some localised areas in deeper cuts which expose weathered rock, provided that the ripped and re-compacted weathered rock is confirmed to have a design CBR $\geq$ 8%.

Subgrade should be prepared in accordance with the site preparation requirements presented in Section 5.5. Subgrade should be compacted in accordance with the recommendations of this report.

5.3.2 Design Traffic Loadings

The proposed development is understood to be a private facility with pavement areas expected to include the access roads to the proposed structures and car parks, with commercial and heavy vehicle traffic, and possibly car park areas with no large commercial or heavy vehicle traffic.

In the absence of detailed traffic data for the site, estimates of design traffic have been made based on the anticipated use of the site by limited heavy vehicles such as delivery trucks, plus separate areas for car parking, with options for increased heavy vehicles / industrial road if required.

Design Traffic is provided in terms of equivalent standard axles (ESA's), with respect to Muswellbrook Shire Council (MSC) specifications. A summary of the design traffic loadings adopted for the proposed pavements is provided in Table 7.

TABLE 7 – PAVEMENT DESIGN TRAFFIC LOADING

Road Section	Equivalent Classification (Muswellbrook Shire Council)	Design Traffic (ESA's)
Car park	Urban Residential – Access Street	6×10^4
Access Roads – Option 1	Urban Residential – Local Street	3×10^5
Access Roads – Option 2	Urban Residential – Collector Street	1×10^6
TBC	Commercial and Industrial	5×10^6

Based upon a 25 year design life, car park areas estimated traffic of 6×10^4 ESA's generally allows for regular light vehicle traffic, up to about 10 small (two axle) heavy vehicles per day and 1 to 2 medium sized heavy vehicles (e.g. delivery / garbage truck) per day.

The estimated traffic of 3×10^5 ESA's comprises an average of about 32 ESA's per day if it is assumed that the site operates 7 days per week. Based on an assumption of about 2.5 ESA's per heavy vehicle; the design traffic could be equated to about 10 heavy vehicles per day plus a number of small (two axle) heavy vehicles and regular traffic of light vehicles (i.e. private vehicles of staff / visitors) per day.

The estimated traffic of 1×10^6 ESA's comprises an average of about 110 ESA's per day if the site were to operate 7 days per week. Based on an assumption of about 2.5 ESA's per heavy vehicle; the design traffic could be equated to about 30 to 40 heavy vehicles per day plus regular small (two axle) heavy vehicles and light vehicles.

Design based upon the traffic loading from MSC specifications for Commercial and Industrial pavements is provided in case it is required. It is noted that this is for subdivision roads as opposed to internal pavements, therefore is likely to be significantly higher than proposed site usage.

Rigid pavement design to Austroads is based on design traffic in terms of Heavy Vehicle Axle Groups (HVAG). Muswellbrook Shire Council requires design traffic based on a 40 year design life for rigid pavements compared to a 25 year design life for flexible pavements. Based on an adopted ESA per heavy vehicle axle group of approximately 0.3, the design traffic in terms of HVAG is assessed to be as provided in Table 8.

TABLE 8 – RIGID PAVEMENT DESIGN TRAFFIC LOADING

Road Section	Equivalent Classification (Muswellbrook Shire Council)	Design Traffic (HVAG)
Car park	Urban Residential – Access Street	3.0×10^5
Access Roads – Option 1	Urban Residential – Local Street	1.5×10^6
Access Roads – Option 2	Urban Residential – Collector Street	5.0×10^6
TBC	Commercial and Industrial	2.5×10^7

In the event that a different design traffic loading is applicable, then the pavement thickness designs presented in this report should be reviewed; in particular, if heavy vehicle movements may exceed those described above, or if the site is to be trafficked by vehicles which exceed normal road load limits.

5.3.3 Flexible Pavement Thickness Design

Flexible pavement thickness design has been based on the procedures outlined in:

- Muswellbrook Shire Council – Development Design Specification, AUS-SPEC (Cot 09), 0042 Pavement Design, Rev 2_2013;
- Muswellbrook Shire Council – Construction Specification, AUS-SPEC (Cot 09), 1141 Flexible Pavements, Version 01;
- Austroads, "Guide to Pavement Technology, Part 2: Pavement Structural Design";

Flexible Pavement Thickness Designs are presented in Tables 9 to 12.

Pavement Material Specification and Compaction Requirements are presented in Table 13.

It is recommended that each construction length be boxed out to the minimum subgrade level required by the relevant pavement thickness design. Prior to pavement construction, the exposed subgrade should be assessed by the geotechnical authority to confirm the pavement thickness requirement for that section.

Select fill or bridging layer should be allowed for beneath the pavement in any areas where poor, wet or saturated subgrade conditions are encountered. This is discussed in Section 7.5.

Pavements should not be constructed on the existing fill. Uncontrolled fill should be removed and replaced as controlled fill.

If rock subgrade materials are encountered, the rock should be ripped and re-compacted for a minimum depth of 300mm to break-up preferential drainage paths and provide a dense homogenous surface on which to construct the pavement.

TABLE 9 – FLEXIBLE PAVEMENT THICKNESS DESIGN SUMMARY - CAR PARK

Road Classification (MSC)	**Access Street**	Access Street	Access Street
Design Traffic Loading (ESA's)	**6×10^4**	6×10^4	6×10^4
Subgrade Material	**Natural CLAY / Approved FILL**	Natural CLAY / Approved FILL	Weathered ROCK
Design Subgrade CBR (%)	**2.5**	4.0	8.0
Wearing Course (mm)	**30 AC10**	30 AC10	30 AC10
Base Course (mm)	**100**	100	100
Subbase (mm)	**270**	180	100
Select Fill (mm)		-	-
Total Thickness (mm)	**410**	320	230

Notes:

1) A 7mm primer should be placed over the base course prior to placement of the asphaltic concrete.
2) A two coat seal may be adopted in general accordance with MSC specification; however, the pavement subbase and total thickness specified above is increased by 30mm.
3) An allowance for subgrade replacement should be anticipated in any areas where poor, wet or saturated subgrade conditions are encountered.
4) The requirement for, and depth and extent of any subgrade replacement / select filling, should be confirmed by the geotechnical authority at the time of construction.
5) If rock subgrade materials are encountered, the rock should be ripped and re-compacted for a minimum depth of 300mm to break-up preferential drainage paths and provide a dense homogenous surface on which to construct the pavement.
6) Prior to pavement construction, the exposed subgrade should be assessed by the geotechnical authority to confirm the pavement thickness requirement for that section.

TABLE 10 – FLEXIBLE PAVEMENT THICKNESS DESIGN SUMMARY – ACCESS ROADS (OPTION 1)

Road Classification (MSC)	**Local Street**	Local Street	Local Street
Design Traffic Loading (ESA's)	**3 x 10^5**	3 x 10^5	3 x 10^5
Subgrade Material	**Natural CLAY / Approved FILL**	Natural CLAY / Approved FILL	Weathered ROCK
Design Subgrade CBR (%)	**2.5**	4.0	8.0
Wearing Course (mm)	**30 AC10**	30 AC10	30 AC10
Base Course (mm)	**120**	120	120
Subbase (mm)	**340**	240	110
Select Fill (mm)	**-**	-	-
Total Thickness (mm)	**490**	390	260

Notes:

1) A 7mm primer should be placed over the base course prior to placement of the asphaltic concrete.
2) A two coat seal may be adopted in general accordance with MSC specification; however, the pavement subbase and total thickness specified above is increased by 30mm.
3) An allowance for subgrade replacement should be anticipated in any areas where poor, wet or saturated subgrade conditions are encountered.
4) The requirement for, and depth and extent of any subgrade replacement / select filling, should be confirmed by the geotechnical authority at the time of construction.
5) If rock subgrade materials are encountered, the rock should be ripped and re-compacted for a minimum depth of 300mm to break-up preferential drainage paths and provide a dense homogenous surface on which to construct the pavement.
6) Prior to pavement construction, the exposed subgrade should be assessed by the geotechnical authority to confirm the pavement thickness requirement for that section.

TABLE 11 – FLEXIBLE PAVEMENT THICKNESS DESIGN SUMMARY – ACCESS ROADS (OPTION 2)

Road Classification (MSC)	**Collector Street**	Collector Street	Collector Street
Design Traffic Loading (ESA's)	**1×10^6**	1×10^6	1×10^6
Subgrade Material	**Natural CLAY / Approved FILL**	Natural CLAY / Approved FILL	Weathered ROCK
Design Subgrade CBR (%)	**2.5**	4.0	8.0
Wearing Course (mm)	**40 AC10**	40 AC10	40 AC10
Base Course (mm)	**140**	140	140
Subbase (mm)	**390**	270	120
Select Fill (mm)	**-**	-	-
Total Thickness (mm)	**570**	450	300

Notes:

1) A 7mm primer should be placed over the base course prior to placement of the asphaltic concrete.
2) An allowance for subgrade replacement should be anticipated in any areas where poor, wet or saturated subgrade conditions are encountered.
3) The requirement for, and depth and extent of any subgrade replacement / select filling, should be confirmed by the geotechnical authority at the time of construction.
4) If rock subgrade materials are encountered, the rock should be ripped and re-compacted for a minimum depth of 300mm to break-up preferential drainage paths and provide a dense homogenous surface on which to construct the pavement.
5) Prior to pavement construction, the exposed subgrade should be assessed by the geotechnical authority to confirm the pavement thickness requirement for that section.

TABLE 12 – FLEXIBLE PAVEMENT THICKNESS DESIGN SUMMARY – COMMERCIAL/INDUSTRIAL

Road Classification (MSC)	**Commercial and Industrial**	Commercial and Industrial	Commercial and Industrial
Design Traffic Loading (ESA's)	**5×10^6**	5×10^6	5×10^6
Subgrade Material	**Natural CLAY / Approved FILL**	Natural CLAY / Approved FILL	Weathered ROCK
Design Subgrade CBR (%)	**2.5**	4.0	8.0
Wearing Course (mm)	**40 AC10**	40 AC10	40 AC10
Base Course (mm)	**150**	150	150
Subbase (mm)	**480**	340	160
Select Fill (mm)	**-**	-	-
Total Thickness (mm)	**670**	530	350

Notes:

1) A 7mm primer should be placed over the base course prior to placement of the asphaltic concrete.
2) An allowance for subgrade replacement should be anticipated in any areas where poor, wet or saturated subgrade conditions are encountered.
3) The requirement for, and depth and extent of any subgrade replacement / select filling, should be confirmed by the geotechnical authority at the time of construction.
4) If rock subgrade materials are encountered, the rock should be ripped and re-compacted for a minimum depth of 300mm to break-up preferential drainage paths and provide a dense homogenous surface on which to construct the pavement.
5) Prior to pavement construction, the exposed subgrade should be assessed by the geotechnical authority to confirm the pavement thickness requirement for that section.

TABLE 13 – PAVEMENT MATERIAL SPECIFICATION AND COMPACTION REQUIREMENTS

Pavement Course	**Material Specification**	**Compaction Requirements**
Wearing Course (AC)	Muswellbrook Shire Council Specification	Muswellbrook Shire Council Specification.
Base Course	CBR ≥ 80%, PI ≤ 6%	98% Modified (AS1289 5.2.1)
Subbase	CBR ≥ 30%, PI ≤ 12%	95% Modified (AS1289 5.2.1)
Select Fill	Select, CBR ≥ 15%, PI ≤ 15%, max particle size 75mm Or 2% cement stabilised subbase material	95% Modified (AS1289 5.2.1)
Subgrade (top 300mm)	Minimum CBR = 2.5%	100% Standard (AS1289 5.1.1)
Subgrade / Fill Below	Minimum CBR = 2.5%	95% Standard (AS1289 5.1.1)

Notes:

1) All flexible road pavement materials shall be supplied to comply with requirements of Muswellbrook Shire Council, Construction Specification 1141, Flexible Pavements, for unbound base and unbound sub base.
2) CBR = California Bearing Ratio, PI = Plasticity Index.
3) Select Fill adopted will be dependent on subgrade moisture conditions.

5.3.4 Rigid (Concrete) Pavement Thickness Design

Rigid (concrete) pavement design has been carried out in accordance with:

- Muswellbrook Shire Council - Development Design Specification - 0042 Pavement Design, Rev_2 2013;
- Austroads, "Guide to Pavement Technology, Part 2: Pavement Structural Design";

Rigid Pavement Thickness Designs are presented in Tables 14 to 17.

Pavement Material Specification and Compaction Requirements are presented in Table 18.

It is recommended that each construction length be boxed out to the minimum subgrade level required by the relevant pavement thickness design. Prior to pavement construction, the exposed subgrade should be assessed by the geotechnical authority to confirm the pavement thickness requirement for that section.

Concrete Base:

The design assumes steel reinforced concrete. Dowels are required at all transverse contraction joints which should be designed by an experienced structural engineer.

In general accordance with Austroads, for areas with 1 x 10^6 HVAG or more (access roads and driveways) the base should comprise concrete with a 28-day characteristic compressive strength of not less than 40 MPa, and flexural strength of not less than 4.5MPa.

In Car Park areas with less than 1 x 10^6 HVAG the base should comprise concrete with a 28-day characteristic compressive strength of not less than 32 MPa, and flexural strength of not less than 4.0MPa.

Areas with odd-shaped and acute cornered slabs requiring increased resistance to cracking should be designed for construction with fibre-reinforced concrete base. The base should be of flexural strength of not less than 5.5MPa, with a minimum 50kg/m^3 of steel fibre.

Subbase:

The concrete should be constructed over lightly bound sub-base (5% cement or equivalent). It would be preferred to have a lightly bound sub-base in all areas; however, unbound sub-base may be considered for lightly trafficked car park areas (less than 10^6 HVAG), provided the risk of reduced performance at joints is understood and accepted. Alternatively, the sub-base layer may be replaced by 100mm thickness of Lean Concrete Sub-base (LCS). The Commercial and Industrial road classification if adopted requires 150mm of LCS as specified in the design.

TABLE 14 – RIGID PAVEMENT THICKNESS DESIGN SUMMARY - CAR PARK

Road Classification	Car Park / Access Street					
Design Traffic Loading (HVAG)	3 x 10^5		3 x 10^5		3 x 10^5	
With Shoulder or No Shoulder	With	No	With	No	With	No
Design Subgrade CBR (%)	2.5		4.0		8	
Concrete Base (mm)	155	175	150	170	150	165
Sub-base (mm)	125 bound	125 bound	125 bound	125 bound	125 bound	125 bound
Total Thickness (mm)	280	300	275	295	275	290

Notes:

1) Where design is based on the option of "with" shoulder, the concrete shoulder must be either integral or structural in accordance with the requirements of Austroads.
2) The requirement for, and extent of any subgrade replacement / select filling, should be confirmed by the geotechnical authority at the time of construction.
3) The 125mm bound sub-base layer may be replaced by unbound subbase in car park areas where the risk of reduced performance at joints is understood and accepted provided that the thickness of Concrete Base and the total is increased by 20mm.

TABLE 15 – RIGID PAVEMENT THICKNESS DESIGN SUMMARY - ACCESS ROADS (OPTION 1)

Road Classification	Access Roads / Local Street		
Design Traffic Loading (HVAG)	1.5×10^6	1.5×10^6	1.5×10^6
Design Subgrade CBR (%)	2.5	4.0	8
Concrete Base (mm)	180	175	170
Sub-base (mm)	150 bound	150 bound	150 bound
Total Thickness (mm)	330	325	320

Notes:

1) The requirement for, and extent of any subgrade replacement / select filling, should be confirmed by the geotechnical authority at the time of construction.
2) The 150mm bound sub-base layer may be replaced by 125mm thickness of Lean Concrete Sub-base (LCS), with total thickness reduced accordingly where applicable.

TABLE 16 – RIGID PAVEMENT THICKNESS DESIGN SUMMARY - ACCESS ROADS (OPTION 2)

Road Classification	Access Roads / Collector Street		
Design Traffic Loading (HVAG)	5×10^6	5×10^6	5×10^6
Design Subgrade CBR (%)	2.5	4.0	8
Concrete Base (mm)	185	180	175
Sub-base (mm)	150 bound	150 bound	150 bound
Total Thickness (mm)	335	330	325

Notes:

1) The requirement for, and extent of any subgrade replacement / select filling, should be confirmed by the geotechnical authority at the time of construction.
2) The 150mm bound sub-base layer may be replaced by 125mm thickness of Lean Concrete Sub-base (LCS), with total thickness reduced accordingly where applicable.

TABLE 17 – RIGID PAVEMENT THICKNESS DESIGN SUMMARY - COMMERCIAL/INDUSTRIAL

Road Classification	Commercial and Industrial		
Design Traffic Loading (HVAG)	2.5×10^7	2.5×10^7	2.5×10^7
Design Subgrade CBR (%)	2.5	4.0	8
Concrete Base (mm)	190	185	185
Sub-base (mm)	150 LCS	150 LCS	150 LCS
Total Thickness (mm)	340	335	335

Notes:

1) The requirement for, and extent of any subgrade replacement / select filling, should be confirmed by the geotechnical authority at the time of construction.
2) The 150mm bound sub-base layer may be replaced by 125mm thickness of Lean Concrete Sub-base (LCS), with total thickness reduced accordingly where applicable.

TABLE 18 – RIGID PAVEMENT MATERIAL SPECIFICATION AND COMPACTION REQUIREMENTS

Pavement Course	**Material Specification**	**Compaction Requirements**
Concrete Base – Steel Reinforced Concrete Pavement with dowelled joints.	Concrete with minimum characteristic compressive strength, fc = 40 MPa. Reinforced with SL92 (Access Roads), SL82 (Car Parks), or steel fibre reinforcement as specified in Section 5.3.4.	Muswellbrook Shire Council / AUS-SPEC Specification
Lean Concrete Sub-base (LCS)	Concrete with minimum characteristic compressive strength, fc = 5 MPa (with fly ash) or 7MPa (without fly ash).	Muswellbrook Shire Council / AUS-SPEC Specification
Bound Sub-base	Conforming to ARRB SR41, CBR > 30%, PI < 12%, bound with 5% cementitious binder	95% Modified (AS1289 5.2.1)
Unbound Sub-base	Conforming to ARRB SR41, CBR ≥ 30%, PI ≤ 12%	95% Modified (AS1289 5.2.1)
Select Fill / Stabilised Subgrade	2% cement stabilised subbase material Or Select, CBR ≥ 15%, PI ≤ 15%, max particle size 75mm	95% Modified (AS1289 5.2.1)
Subgrade (top 300mm)	Minimum CBR = As per design	100% Standard (AS1289 5.1.1)
Subgrade / Fill Below	Minimum CBR = As pre design	95% Standard (AS1289 5.1.1)

5.4 Excavation Conditions and Depth to Rock

The depths of fill, topsoil, alluvium/colluvium, residual soils and weathered rock, together with depths of practical refusal of the 2.7 tonne excavator where encountered are summarised in Table 2.

In terms of excavation conditions, site materials can generally be divided into:

- Clayey and Granular Soils (Units 1, 2, 3, & 4). It is anticipated that these materials could be excavated by a conventional excavator or backhoe bucket;
- Weathered Rock (Unit 5 & 6). Rippability is dependent on rock strength, depth, degree of weathering and number of defects within the rock mass which can vary significantly.

It is anticipated that the Weathered Rock (Unit 5 & 6) material encountered could be excavated at least to the depths indicated on the appended borehole logs.

It is expected that material below the depth of 2.7 tonne excavator auger practical refusal or refusal will be excavatable by use of large machinery and ripping to some greater depth, although this has not been assessed as part of the current investigation.

Based upon our previous experience, refusal of the 300mm diameter auger on a 2.7 tonne excavator is roughly equivalent to refusal of a 20 tonne excavator with 450mm bucket equipped with tiger teeth; therefore, it is anticipated that excavators with toothed buckets may achieve limited depths of excavation into the bedrock below depths of refusal / practical refusal.

The use of hydraulic rock hammers or other methods may be required where hard layers of weathered rock are encountered and for deep confined excavations such as for service trenches.

It is recommended that targeted investigations (e.g. cored boreholes or excavation trials) are carried out if significant excavations are proposed where bedrock depth or excavatability is important to design or construction.

Groundwater may exist at localised areas of the site such as within the topsoil / colluvium profile, from water perched above the residual clay / bedrock profile, or in areas of former drainage channels. It is possible that slow water inflow may be encountered from such layers, particularly if earthworks are carried out during or following periods of wet weather. If groundwater is encountered, it is generally expected to be manageable by de-watering by sump and pump methods.

Excavations should be supported by properly designed and constructed retaining walls or else battered at 1V:2H or flatter and protected from erosion.

Temporary excavations should be battered at 1V:1H or flatter in cohesive soils, or 1V:1.5H or flatter in granular soils, and protected from erosion. Steeper excavations may be supported by means of temporary shoring.

Temporary excavations to depths of up to 1.2m in competent compact material with sufficient cohesion, such as clay of stiff consistency or better may be battered vertically, subject to inspection during excavation by the geotechnical authority.

The safe working procedures of Work Cover NSW Excavation work code of practice, dated January 2020 should be followed.

Care should be taken not to disturb or destabilise existing underground services or structures.

5.5 Site Preparation

Site preparation and earthworks suitable for pavement support and site re-grading should consist of:

- Following bulk excavation to proposed subgrade level, all areas of proposed pavement construction or site re-grading should be stripped to remove all existing uncontrolled fill, vegetation, topsoil, root affected or other potentially deleterious materials;
- Stripping is generally expected to be required to depths of about 0.05 to 0.35 to remove topsoil and root affected material.
- Stripping of greater depths of uncontrolled fill material in addition to topsoil and root affected material is expected to be required in some areas, including areas of fill encountered in the boreholes.
- Additional stripping may be required in any areas where poor, wet or saturated subgrade conditions are encountered, for example in the vicinity of gullies and dams, or following wet weather;
- Following stripping, the exposed subgrade should be proof rolled (minimum 10 tonne static roller), to identify any wet or excessively deflecting material. Any such areas should be over excavated and backfilled with an approved select material;
- The moisture content of the subgrade materials and therefore the need for moisture conditioning or over-excavation and replacement, will be largely dependent on pre-existing and prevailing weather conditions at the time of construction;
- Subgrade preparation should be carried out using a tracked excavator equipped with a smooth sided (‘gummy’) bucket to minimise the risk of over-disturbance of soils;
- Protect the area after subgrade preparation to maintain moisture content as far as practicable. The placement of subbase gravel would normally provide adequate protection; and,
- Site preparation should include provision of drainage and erosion control as required, as well as sedimentation control measures.

It should be anticipated that some moisture conditioning of the subgrade may be necessary prior to compaction and placement of fill materials.

At the time of the field investigations, moisture content for the subgrade material tested varied from 7.5% dry to 0.4% dry of standard Optimum Moisture Content (OMC). It should be anticipated that moisture conditioning of the subgrade may be necessary prior to compaction and placement of pavement materials.

The required time period to prepare the subgrade is likely to be dependent on the prevailing weather conditions at the time of construction.

If over-wet subgrades exist at the time of construction or deleterious materials are encountered at subgrade level, these materials should be over-excavated and be replaced with a minimum depth of 300mm of well graded granular select material with CBR of 15% or greater, or a 2% cement stabilised subbase material. The requirement for, and extent of subgrade replacement / select filling, should be confirmed at the time of construction.

5.6 Fill Construction Procedures

Earthworks for pavement construction or support of foundations should consist of the following measures:

- Approved fill beneath structures and pavements should be compacted in layers not exceeding 300mm loose thickness;
- Approved fill for pavements should be compacted to the compaction requirements provided in Section 5.3;
- Approved fill beneath pavements should be compacted to a minimum density ratio of 95% Standard Compaction within ±2% of OMC in cohesive soils;
- The top 300mm of natural subgrade below pavements or the final 300mm of road subgrade fill should be compacted to a minimum density ratio of 100% Standard Compaction within the moisture range of 60% to 90% of Optimum Moisture Content (OMC);
- Site fill beneath structures should be compacted to a minimum density ratio of 98% Standard Compaction within ±2% of OMC in cohesive soils;
- All fill should be supported by properly designed and constructed retaining walls or else battered at 1V:2H or flatter and protected against erosion;
- Where fill is to be placed on slopes in excess of 1V:8H (7°), a prepared surface should be benched or stepped into the natural slope; and,
- Earthworks should be carried out in accordance with the recommendations outlined in AS3798-2007 'Guidelines for Earthworks for Commercial and Residential Developments'.

5.7 Suitability of Site Materials for Re-Use as Fill

The following comments are made with respect to suitability of site materials for re-use as fill:

- Unit 1A – Fill Topsoil materials are expected to be suitable for landscaping purposes only;
- Unit 1B - Fill materials may be variable. Some fill material may be suitable for landscaping purposes only due to the presence of roots and organics. If fill material is not affected by roots or other deleterious material, it is generally expected to be suitable for re-use as general fill for engineering purposes. Suitability for re-use should be confirmed prior to, or at the time of construction;
- Unit 2 – Topsoil materials are expected to be suitable for landscaping purposes only;
- Unit 3 – Slopewash may be suitable for re-use as general fill for engineering purposes except where root affected. Blending of material in a suitable ratio with cohesive material is recommended to reduce potential for moisture ingress.
- Unit 4 - Residual Soils are generally expected to be suitable for re-use as general fill for engineering purposes;
- Unit 5 - Extremely Weathered Rock is generally expected to be suitable for re-use as general fill for engineering purposes; and,
- Unit 6 - Highly Weathered Rock are generally expected to be suitable for re-use as general fill for engineering purposes. These materials may require sorting or processing by crushing / screening depending upon excavation methods, source material characteristics and proposed uses.

As requested on the day of the field investigations, limited sampling and testing of two existing stockpiles was conducted. Preliminary discussion of results presented below:

Stockpile 1 – (Variable Sand, Gravel & Clay mixtures):

Stockpile 2 – (Variable Sandy Gravelly CLAY):

- Based on the 3 samples tested, material is assessed to be Unit 1B Fill. As noted above, Unit 1B - Fill materials may be variable. Based on the laboratory testing results, if fill material is not affected by roots or other deleterious material, it is generally expected to be suitable for re-use as general fill for engineering purposes only.
- Potential for re-use in Pavements:
  - Laboratory testing results of all 3 samples indicate that the materials do not meet requirements for pavement basecourse or subbase material specifications.
- Potential for re-use in Leachate Basin Embankments:
  - Laboratory testing results for Stockpile 2 – S03, indicates that the material may need to be modified if proposed to be used in Leachate Basins or similar, noting:
  - The sample tested is likely to meet typical basin embankment specifications based on Plasticity Index and Particle Size.
  - Where clay content is greater than 30%, the material is likely to be of relatively low permeability and suited to dam / basin embankment construction, however specific permeability testing should be undertaken if it is important to design.
  - Results of the Emerson test indicates that the material may be susceptible to dispersion. If the CLAY material from the Stockpiles is to be used in applications where low susceptibility to dispersion is desirable, then it is recommended that soil with Emerson Class ≤ 3 should be blended with other materials, or alternatively be stabilised with addition of 1% to 2% gypsum added to the soil and blended prior to usage in embankments. It is recommended that any blended or gypsum treated material be tested to confirm suitable Emerson Class prior to placement.
  - It should be noted that only very limited discrete sampling of the large stockpiles (i.e. 'Stockpile 1' - up to 5.5m in height and about 200m long; and, 'Stockpile 2' - up to 5m in height and about 120m long) has been carried out. Further investigation, sampling and testing of stockpiles should be conducted to confirm suitability for any proposed re-use prior to, or at the time of construction.

Final selection of fill materials should consider properties such as reactivity which is typically moderate to high for site won Unit 4 Residual Soils, and expected to be low for site won Unit 5 Extremely Weathered Rock and Unit 6 Highly Weathered Rock.

If coal, chitter or other potentially combustible material is encountered within material proposed for re-use at the site, it is recommended that that such materials are thoroughly mixed with inert fill such that no layer contains more than 10% potentially combustible materials.

The suitability of material for re-use should be assessed and confirmed by the geotechnical authority at the time of construction. The materials may require some moisture conditioning.

5.8 Proposed Leachate Basins

As requested by client during time of field investigation, two additional boreholes (BH08 and BH09) were undertaken within the footprint of proposed Leachate Basin location, to assess existing ground conditions and the feasibility of the proposed Leachate Basin location.

Deep fill material was encountered in both boreholes (BH08 and BH09), overlying weathered rock at depths of 1.8m and 1.4m, respectively. Limited bulk samples of the fill material have been taken and stored at our Newcastle office for testing for potential reuse on site if required, and/or if design advice for leachate basin construction is requested.

5.9 Special Construction Requirements and Site Drainage

The enclosed pavement thickness designs assume the provision of adequate surface and subsurface drainage of the pavement and adjacent areas. As a minimum, it is recommended that subsoil drains be installed:

- Along the high side of roads aligned across site slopes; and,
- Along both sides of roads aligned down slope.

It is recommended that surface and subsoil drainage be installed in line with the above advice, and in accordance with Muswellbrook Shire Council specifications.

Adequate surface and subsurface drainage should be installed and connected to the stormwater disposal system.

Inspection should be carried out by a geotechnical authority during construction to confirm the conditions assumed in this report and in the design.

6.0 Limitations

The findings presented in the report and used as the basis for recommendations presented herein were obtained using normal, industry accepted geotechnical design practices and standards. To our knowledge, they represent a reasonable interpretation of the general conditions of the site.

The extent of testing associated with this assessment is limited to discrete test locations. It should be noted that subsurface conditions between and away from the test locations may be different to those observed during the field work and used as the basis of the recommendations contained in this report.

If subsurface conditions encountered during construction differ from those given in this report, further advice should be sought without delay.

Data and opinions contained within the report may not be used in other contexts or for any other purposes without prior review and agreement by Qualtest. If this report is reproduced, it must be in full.

If you have any further questions regarding this report, please do not hesitate to contact Ben Edwards, Shannon Kelly, or the undersigned.

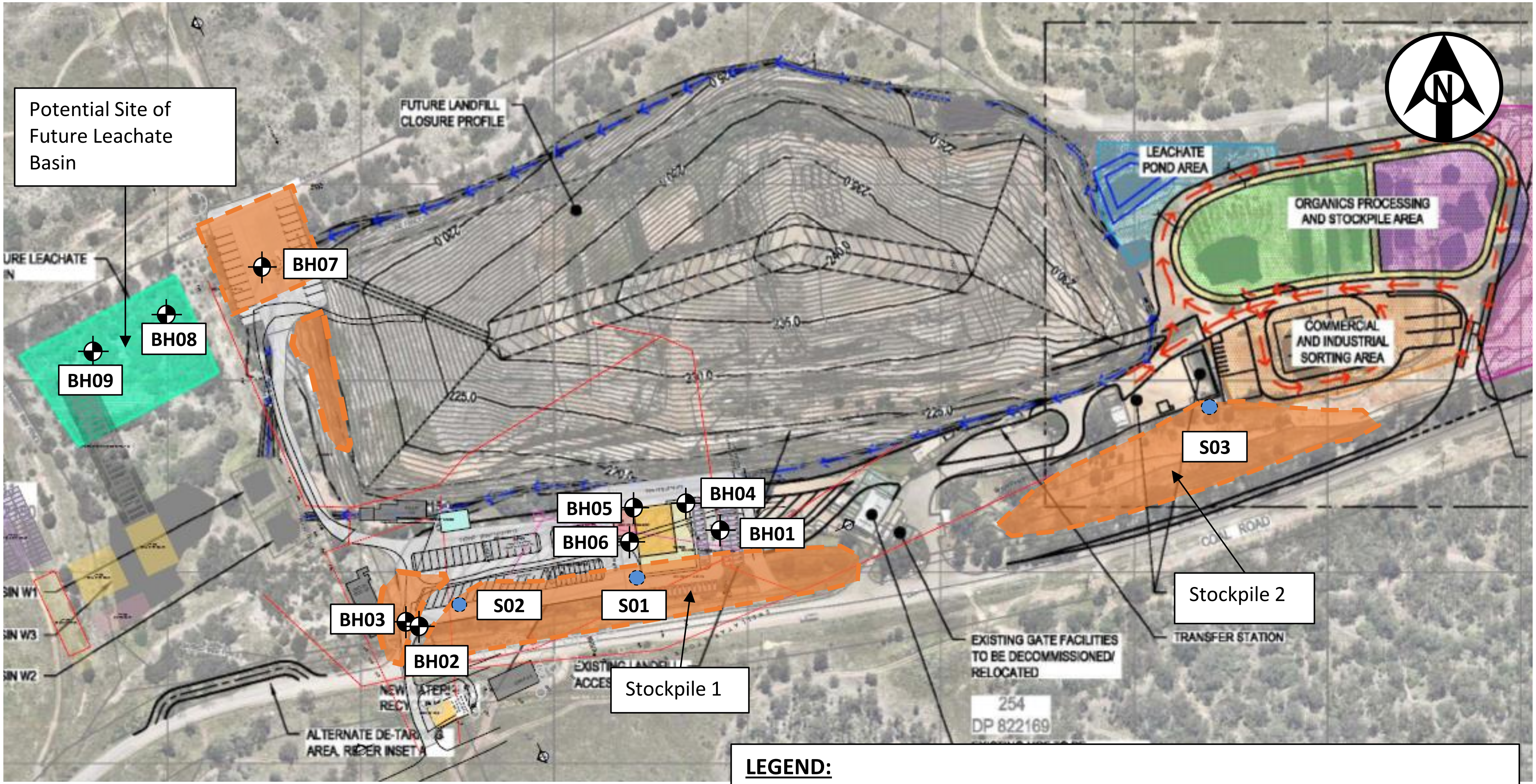
For and on behalf of Qualtest Laboratory (NSW) Pty Ltd.

Jason Lee

Jason Lee
Principal Geotechnical Engineer

FIGURE AB1:

Site Plan and Approximate Test Locations



Based on drawing provided by client (Ref: Job no: 22-18709, Rev No: A, dated: April 2017, by GHD).

LEGEND:

⊕	Approximate borehole location.
●	Approximate stockpile sample location.
▨	Approximate location of observed fill mounds / platforms and stockpiles.

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Client:	MUSWELLBROOK SHIRE COUNCIL	Drawing No:	FIGURE AB1
Project:	PROPOSED COMMUNITY INFRASTRUCTURE DEPOT	Project No:	NEW22P-0092
Location:	COAL ROAD, MUSWELLBROOK	Scale:	NOT TO SCALE
Title:	SITE PLAN & APPROXIMATE TEST LOCATIONS	Date:	29/06/2022

APPENDIX A:

Results of Field Investigations

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ENGINEERING LOG - BOREHOLE

CLIENT:	MUSWELLBROOK SHIRE COUNCIL	**BOREHOLE NO:**	**BH01**
PROJECT:	COMMUNITY INFRASTRUCTURE DEPOT	**PAGE:**	1 OF 1
LOCATION:	COAL ROAD, MUSWELLBROOK	**JOB NO:**	NEW22P-0092
		LOGGED BY:	BE
		DATE:	18/5/22

DRILL TYPE: 2.7 TONNE EXCAVATOR WITH AUGER ATTACHMENT **SURFACE RL:**
BOREHOLE DIAMETER: 300 mm **DATUM:**

Drilling and Sampling					Material description and profile information					Field Test		
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
E	Not Encountered					SM	TOPSOIL: Gravelly Silty SAND - fine to coarse grained, grey-brown, fines of low plasticity, fine to coarse grained angular gravel.	D - M				TOPSOIL
		0.35m				SM	0.15m Gravelly Silty SAND - fine to coarse grained, grey, fines of low plasticity, fine to coarse grained, angular gravel.					SLOPE WASH / POSSIBLE FILL
		D 0.60m		0.5		CH	0.35m CLAY - medium to high plasticity, pale grey, with pale orange, trace silt.	M > W$_P$	VSt	HP HP HP	300 390 220	RESIDUAL SOIL
				1.0 1.5		CI	0.60m Silty CLAY - medium plasticity, pale grey to white, trace pale brown, with some fine to medium grained angular gravel, with some fine to coarse grained sand.		VSt / Fb			
				2.0		CI	1.70m Silty Gravelly CLAY / Clayey GRAVEL - medium plasticity, pale grey to white, trace pale brown, fine to medium grained angular gravel.	M < W$_P$	H			RESIDUAL SOIL / EXTREMELY WEATHERED ROCK
				2.5		CI	2.10m Extremely weathered Siltstone with soil properties: breaks down into Silty Gravelly CLAY / Clayey GRAVEL - medium plasticity, pale grey to white, trace pale brown, fine to medium grained angular gravel, with highly weathered rock pockets.					EXTREMELY TO HIGHLY WEATHERED ROCK
							2.60m Hole Terminated at 2.60 m					

LEGEND:

Water
- Water Level (Date and time shown)
- ▶ Water Inflow
- ◀ Water Outflow

Strata Changes
- — — Gradational or transitional strata
- —— Definitive or distict strata change

Notes, Samples and Tests

U$_{50}$	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		**UCS (kPa)**
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W$_p$	Plastic Limit
W$_L$	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

ENGINEERING LOG - BOREHOLE

CLIENT:	MUSWELLBROOK SHIRE COUNCIL	**BOREHOLE NO:**	**BH02**
PROJECT:	COMMUNITY INFRASTRUCTURE DEPOT	**PAGE:**	1 OF 1
LOCATION:	COAL ROAD, MUSWELLBROOK	**JOB NO:**	NEW22P-0092
		LOGGED BY:	BE
		DATE:	18/5/22

DRILL TYPE: 2.7 TONNE EXCAVATOR WITH AUGER ATTACHMENT **SURFACE RL:**

BOREHOLE DIAMETER: 300 mm **DATUM:**

Drilling and Sampling					Material description and profile information					Field Test		Structure and additional observations
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	
E	Not Encountered					GP	0.15m FILL: Sandy GRAVEL - fine to coarse grained angular to sub-rounded, grey, fine to coarse grained sand, trace fines of low plasticity.	M				FILL
							0.30m SILTSTONE - pale grey to grey, trace orange, estimated medium to high strength.	D				MODERATELY WEATHERED ROCK
							Hole Terminated at 0.30 m Refusal					
				0.5								
				1.0								
				1.5								
				2.0								
				2.5								

LEGEND:

Water

▼	Water Level (Date and time shown)
►—	Water Inflow
—◄	Water Outflow

Strata Changes

— — —	Gradational or transitional strata
——	Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		**UCS (kPa)**
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

ENGINEERING LOG - BOREHOLE

CLIENT:	MUSWELLBROOK SHIRE COUNCIL
PROJECT:	COMMUNITY INFRASTRUCTURE DEPOT
LOCATION:	COAL ROAD, MUSWELLBROOK
BOREHOLE NO:	**BH03**
PAGE:	1 OF 1
JOB NO:	NEW22P-0092
LOGGED BY:	BE
DATE:	18/5/22

DRILL TYPE: 2.7 TONNE EXCAVATOR WITH AUGER ATTACHMENT

SURFACE RL:

BOREHOLE DIAMETER: 300 mm

DATUM:

Drilling and Sampling					Material description and profile information					Field Test		
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
E	Not Encountered					GP	FILL: Sandy GRAVEL - fine to medium grained angular to sub-angular, grey to dark grey, with some brown to pale grey, trace black, fine to coarse grained sand, trace fines of low plasticity.	D - M				FILL
		0.50m CBR 0.90m		0.5 1.0 1.5		SM	0.50m FILL: Silty SAND - fine grained, dark grey to black, fines of low plasticity. Grey to dark grey. Dark grey to black.	M				
				2.0 2.5		GP	1.70m Sandy GRAVEL - fine to medium grained angular, pale brown with some pale grey, fine to coarse grained, with some fines of low plasticity.	D - M	MD			RESIDUAL SOIL
							2.60m Hole Terminated at 2.60 m					

LEGEND:

Water

- Water Level (Date and time shown)
- Water Inflow
- Water Outflow

Strata Changes

- — — Gradational or transitional strata
- ——— Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		**UCS (kPa)**
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

ENGINEERING LOG - BOREHOLE

CLIENT:	MUSWELLBROOK SHIRE COUNCIL
PROJECT:	COMMUNITY INFRASTRUCTURE DEPOT
LOCATION:	COAL ROAD, MUSWELLBROOK
BOREHOLE NO:	**BH04**
PAGE:	1 OF 1
JOB NO:	NEW22P-0092
LOGGED BY:	BE
DATE:	18/5/22

DRILL TYPE:	2.7 TONNE EXCAVATOR WITH AUGER ATTACHMENT	**SURFACE RL:**	
BOREHOLE DIAMETER:	300 mm	**DATUM:**	

Drilling and Sampling					Material description and profile information					Field Test		
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
E	Not Encountered					GP	FILL: Sandy GRAVEL - fine to medium grained angular, dark grey-brown, fine to coarse grained sand, trace fines of low plasticity.	D - M				FILL
				0.10m		GP	FILL: Sandy GRAVEL - fine to medium grained, angular, grey, pale brown to brown, trace orange, with fines of low plasticity. Trace coal chitter between 0.15 to 0.18m.					
				0.5 0.55m		CH	CLAY - medium to high plasticity, pale grey, with pale orange.	M > W_P	VSt	HP	320	RESIDUAL SOIL
				0.60m		GM	Extremely weathered Sandy Siltstone with soil properties: breaks down into Silty Sandy GRAVEL - fine to medium grained angular, pale brown, trace pale grey, fine to coarse grained sand, fines of low plasticity.	D - M	D			EXTREMELY WEATHERED ROCK
				1.0			Sandy CLAY band - approximately 100mm thick. Assessed to be of Hard consistency.			HP	420	
				1.5 2.0			Silty CLAY band - approximately 200mm thick. Assessed to be of Hard consistency.			HP	>600	
				2.5 2.60m								
							Hole Terminated at 2.60 m					

LEGEND:

Water

- ▼ Water Level (Date and time shown)
- ▶ Water Inflow
- ◀ Water Outflow

Strata Changes

- — — Gradational or transitional strata
- —— Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		UCS (kPa)
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

Qualtest
LABORATORY (NSW) PTY LTD

ENGINEERING LOG - BOREHOLE

CLIENT:	MUSWELLBROOK SHIRE COUNCIL	**BOREHOLE NO:**	**BH05**
PROJECT:	COMMUNITY INFRASTRUCTURE DEPOT	**PAGE:**	1 OF 1
LOCATION:	COAL ROAD, MUSWELLBROOK	**JOB NO:**	NEW22P-0092
		LOGGED BY:	BE
		DATE:	18/5/22

DRILL TYPE:	2.7 TONNE EXCAVATOR WITH AUGER ATTACHMENT	**SURFACE RL:**	
BOREHOLE DIAMETER:	300 mm	**DATUM:**	

Drilling and Sampling					Material description and profile information					Field Test		
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
E	Not Encountered			0.10m		CL	FILL-TOPSOIL: Sandy CLAY - low plasticity, dark grey to dark brown, fine to coarse grained sand, trace fine to medium grained gravel, root affected.	$M < W_P$				FILL: TOPSOIL
				0.5 0.60m		GM	FILL: Silty Sandy GRAVEL - fine to coarse grained angular to sub-angular, grey to pale brown, with dark grey, trace orange to red-brown, fine to coarse grained sand, fines of low plasticity.	D - M				FILL
		0.60m U50 0.75m				CH	CLAY - medium to high plasticity, pale grey, with pale brown, trace red-brown.	$M > W_P$	VSt	HP HP HP	300 400 450	RESIDUAL SOIL
				1.0 1.20m			Trace extremely weathered rock pockets.	$M < W_P$	H			
				1.5 1.50m		GM	Extremely weathered Sandy Siltstone with soil properties: breaks down into Silty Sandy GRAVEL - fine to medium grained angular, pale brown, trace pale grey, fine to coarse grained sand, fines of low plasticity.	D - M	D			EXTREMELY WEATHERED ROCK
				1.70m			Sandy SILTSTONE - pale grey, with pale brown, fine grained sand in rock matrix, estimated low to high (generally of low to medium) rock strength.	D				HIGHLY TO MODERATELY WEATHERED ROCK
				2.0 2.5			Hole Terminated at 1.70 m Refusal					

LEGEND:

Water

▼	Water Level (Date and time shown)
►—	Water Inflow
—◄	Water Outflow

Strata Changes

— — —	Gradational or transitional strata
———	Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		**UCS (kPa)**
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

ENGINEERING LOG - BOREHOLE

CLIENT:	MUSWELLBROOK SHIRE COUNCIL	**BOREHOLE NO:**	**BH06**
PROJECT:	COMMUNITY INFRASTRUCTURE DEPOT	**PAGE:**	1 OF 1
LOCATION:	COAL ROAD, MUSWELLBROOK	**JOB NO:**	NEW22P-0092
		LOGGED BY:	BE
		DATE:	18/5/22

DRILL TYPE: 2.7 TONNE EXCAVATOR WITH AUGER ATTACHMENT **SURFACE RL:**
BOREHOLE DIAMETER: 300 mm **DATUM:**

Drilling and Sampling					Material description and profile information						Field Test		
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
E	Not Encountered	0.10m				CL	TOPSOIL: Sandy CLAY - low plasticity, brown, fine grained sand, trace fine grained sub-rounded gravel, root affected.	M < W_P				TOPSOIL
		U50 0.30m				CH	0.10m CLAY - medium to high plasticity, brown.		H	HP	>600	RESIDUAL SOIL
						GC	0.30m Clayey GRAVEL - fine to medium grained angular, brown, with pale grey and pale orange, fines of medium plasticity.	M	D			
				0.5			0.50m Sandy SILTSTONE - fine grained sand in rock matrix, pale grey, with pale brown, estimated medium to high rock strength.	D				HIGHLY TO MODERATELY WEATHERED ROCK
							0.55m Hole Terminated at 0.55 m Refusal					
				1.0								
				1.5								
				2.0								
				2.5								

LEGEND:

Water

- Water Level (Date and time shown)
- Water Inflow
- Water Outflow

Strata Changes

- — — Gradational or transitional strata
- —— Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		**UCS (kPa)**
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

Qualtest
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ENGINEERING LOG - BOREHOLE

CLIENT: MUSWELLBROOK SHIRE COUNCIL
PROJECT: COMMUNITY INFRASTRUCTURE DEPOT
LOCATION: COAL ROAD, MUSWELLBROOK

BOREHOLE NO: BH07
PAGE: 1 OF 1
JOB NO: NEW22P-0092
LOGGED BY: BE
DATE: 18/5/22

DRILL TYPE: 2.7 TONNE EXCAVATOR WITH AUGER ATTACHMENT
BOREHOLE DIAMETER: 300 mm
SURFACE RL:
DATUM:

Drilling and Sampling					Material description and profile information					Field Test		
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
E	Not Encountered	0.20m CBR 0.50m		0.5	▨	CL	0.05m FILL-TOPSOIL: Sandy CLAY - low plasticity, brown, fine to coarse grained sand, trace fine to medium grained angular to sub-angular gravel, root affected.	$M > W_P$		HP	350	FILL: TOPSOIL
					▨	CH	FILL: Gravelly CLAY - medium to high plasticity, red-brown, fine to medium grained angular to sub-angular gravel, trace fine to coarse grained sand. Dark grey. Brown, with pale brown to pale grey. 0.65m	$M < W_P$		HP HP	>600 >600	FILL
				1.0 1.5 2.0 2.5			Hole Terminated at 0.65 m Refusal on possible weathered rock.					

LEGEND:

Water
- Water Level (Date and time shown)
- ▶— Water Inflow
- —◀ Water Outflow

Strata Changes
- — — Gradational or transitional strata
- —— Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		UCS (kPa)
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

ENGINEERING LOG - BOREHOLE

CLIENT:	MUSWELLBROOK SHIRE COUNCIL	**BOREHOLE NO:**	**BH08**
PROJECT:	COMMUNITY INFRASTRUCTURE DEPOT	**PAGE:**	1 OF 1
LOCATION:	COAL ROAD, MUSWELLBROOK	**JOB NO:**	NEW22P-0092
		LOGGED BY:	BE
		DATE:	18/5/22

DRILL TYPE:	2.7 TONNE EXCAVATOR WITH AUGER ATTACHMENT	**SURFACE RL:**	
BOREHOLE DIAMETER:	300 mm	**DATUM:**	

Drilling and Sampling					Material description and profile information					Field Test		
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
E	Not Encountered			0.0 – 1.70m	▨	GM	FILL: Silty SANDY GRAVEL - fine to coarse grained angular, dark grey to dark brown, fine grained sand, fines of low plasticity, trace angular cobbles.	M				FILL
				1.70m – 1.80m			Sandy SILTSTONE - fine grained sand in rock matrix, pale grey, with pale brown, estimated medium to high rock strength.	D				HIGHLY TO MODERATELY WEATHERED ROCK
							Hole Terminated at 1.80 m Refusal					

LEGEND:

Water

- Water Level (Date and time shown)
- Water Inflow
- Water Outflow

Strata Changes

- Gradational or transitional strata
- Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		**UCS (kPa)**
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

ENGINEERING LOG - BOREHOLE

CLIENT: MUSWELLBROOK SHIRE COUNCIL
PROJECT: COMMUNITY INFRASTRUCTURE DEPOT
LOCATION: COAL ROAD, MUSWELLBROOK

BOREHOLE NO: **BH09**
PAGE: 1 OF 1
JOB NO: NEW22P-0092
LOGGED BY: BE
DATE: 18/5/22

DRILL TYPE: 2.7 TONNE EXCAVATOR WITH AUGER ATTACHMENT
BOREHOLE DIAMETER: 300 mm
SURFACE RL:
DATUM:

Drilling and Sampling					Material description and profile information					Field Test		
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
E	Not Encountered			0.5 1.0	▨	GM	FILL: Silty SANDY GRAVEL - fine to coarse grained angular, dark grey to dark brown, fine grained sand, fines of low plasticity, trace angular cobbles. 1.40m	D - M				FILL
				1.5 2.0 2.5			Hole Terminated at 1.40 m Refusal on possible weathered rock.					

LEGEND:

Water

- Water Level (Date and time shown)
- ▶— Water Inflow
- —◀ Water Outflow

Strata Changes

- — — Gradational or transitional strata
- ——— Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		UCS (kPa)
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

APPENDIX B:

Results of Laboratory Testing

QUALTEST Laboratory (NSW) Pty Ltd (20708)
2 Murray Dwyer Circuit, Mayfield West, NSW 2304
T: 02 4968 4468
F: 02 4960 9775
E: admin@qualtest.com.au
W: www.qualtest.com.au
ABN: 98 153 268 896

Report No: CBR:NEW22W-1552-S04
Issue No: 1

California Bearing Ratio Test Report

Client:	Muswellbrook Shire Council 157 New England Hwy Muswellbrook NSW 2333
Project No.:	NEW22P-0092
Project Name:	New CI Depot - Alternate Site
Project Location:	Muswellbrook, NSW

Accredited for compliance with ISO/IEC 17025-Testing.
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.
Results provided relate only to the items tested or sampled.

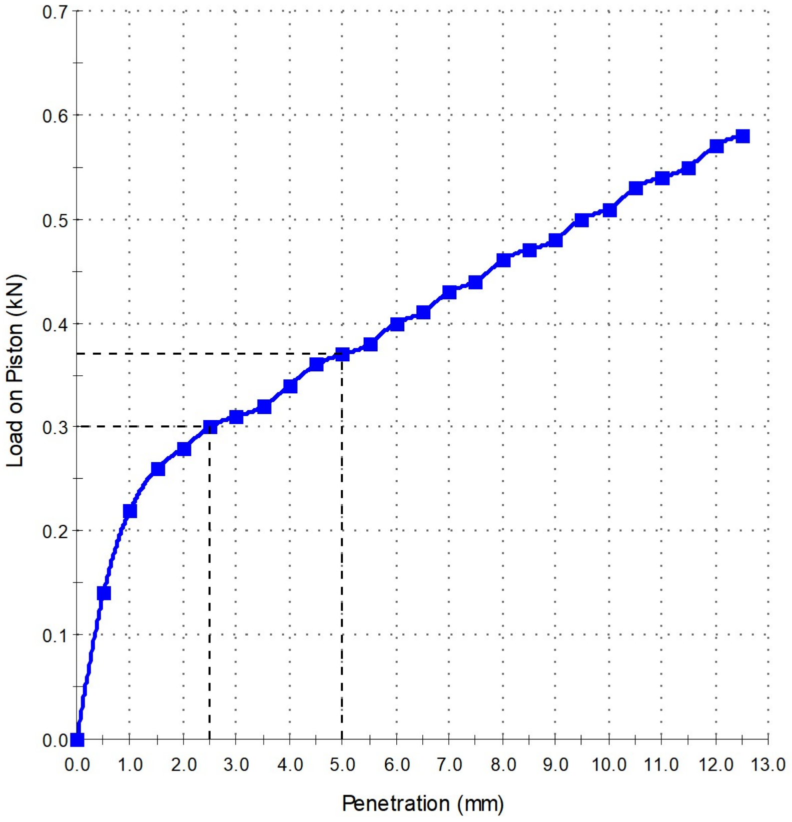
NATA
WORLD RECOGNISED ACCREDITATION

B. Cullen
Approved Signatory: Brent Cullen
(Engineering Geologist)
NATA Accredited Laboratory Number: 18686
Date of Issue: 7/06/2022

Sample Details

Sample ID:	NEW22W-1552-S04	**Date Sampled:**	18/05/2022
Sampling Method:	The results outlined below apply to the sample as received		
Specification:	No Specification	**Source:**	On-Site Insitu
Location:	BH01 - (0.35 - 0.6m)	**Material:**	Clay
Date Tested:	3/06/2022		

Load vs Penetration



Test Results

AS 1289.6.1.1

CBR at 2.5mm (%):	**2.5**
Maximum Dry Density(t/m³):	1.57
Optimum Moisture Content(%):	22.7
Dry Density before Soaking (t/m³):	1.57
Density Ratio before Soaking (%):	100.0
Moisture Content before Soaking (%):	23.0
Moisture Ratio before Soaking (%):	101.0
Dry Density after Soaking (t/m³):	1.50
Density Ratio after Soaking (%):	95.0
Swell (%):	5.0
Moisture Content of Top 30mm (%):	30.6
Moisture Content of Remaining Depth (%):	24.7
Compaction Hammer Used:	Standard AS 1289.5.1.1
Surcharge Mass (kg):	9.00
Period of Soaking (Days):	4
Retained on 19 mm Sieve (%):	0
CBR Moisture Content Method:	AS 1289.2.1.1
Sample Curing Time (h):	96
Plasticity Determination Method:	Visual/Tactile

——— AS1289.2.1.1 ———

In Situ (Field) Moisture Content (%):	20.5

Comments

QUALTEST Laboratory (NSW) Pty Ltd (20708)
2 Murray Dwyer Circuit, Mayfield West, NSW 2304
T: 02 4968 4468
F: 02 4960 9775
E: admin@qualtest.com.au
W: www.qualtest.com.au
ABN: 98 153 268 896

California Bearing Ratio Test Report

Report No: CBR:NEW22W-1552-S05
Issue No: 1

Client:	Muswellbrook Shire Council 157 New England Hwy Muswellbrook NSW 2333
Project No.:	NEW22P-0092
Project Name:	New CI Depot - Alternate Site
Project Location:	Muswellbrook, NSW

NATA WORLD RECOGNISED ACCREDITATION

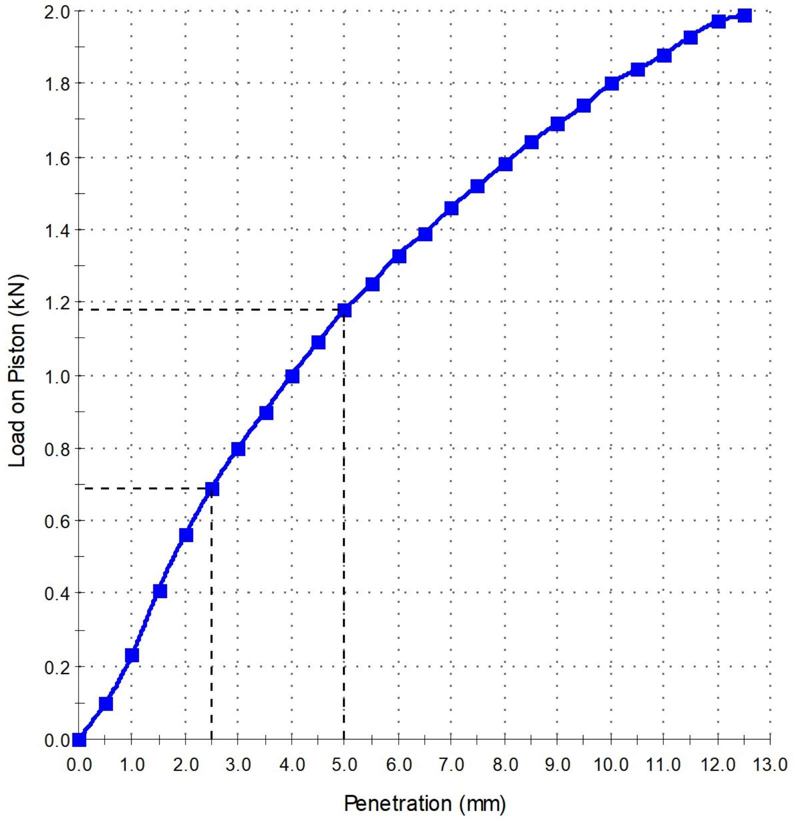
Accredited for compliance with ISO/IEC 17025-Testing.
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.
Results provided relate only to the items tested or sampled.

B. Cullen
Approved Signatory: Brent Cullen
(Engineering Geologist)
NATA Accredited Laboratory Number: 18686
Date of Issue: 20/06/2022

Sample Details

Sample ID:	NEW22W-1552-S05	**Date Sampled:**	18/05/2022
Sampling Method:	The results outlined below apply to the sample as received		
Specification:	No Specification	**Source:**	On-Site Insitu
Location:	BH03 - (0.5 - 0.9m)	**Material:**	Sand
Date Tested:	2/06/2022		

Load vs Penetration



Test Results

AS 1289.6.1.1

CBR at 5.0mm (%):	**6**
Maximum Dry Density(t/m^3):	1.46
Optimum Moisture Content(%):	21.1
Dry Density before Soaking (t/m^3):	1.46
Density Ratio before Soaking (%):	100.0
Moisture Content before Soaking (%):	20.9
Moisture Ratio before Soaking (%):	99.0
Dry Density after Soaking (t/m^3):	1.42
Density Ratio after Soaking (%):	97.0
Swell (%):	3.0
Moisture Content of Top 30mm (%):	32.3
Moisture Content of Remaining Depth (%):	27.7
Compaction Hammer Used:	Standard AS 1289.5.1.1
Surcharge Mass (kg):	9.00
Period of Soaking (Days):	4
Retained on 19 mm Sieve (%):	8
CBR Moisture Content Method:	AS 1289.2.1.1
Sample Curing Time (h):	72
Plasticity Determination Method:	Visual/Tactile

——— AS1289.2.1.1 ———

In Situ (Field) Moisture Content (%):	13.6

Comments

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ABN: 98 153 268 896

California Bearing Ratio Test Report

Report No: CBR:NEW22W-1552-S06
Issue No: 1

Client:	Muswellbrook Shire Council 157 New England Hwy Muswellbrook NSW 2333
Project No.:	NEW22P-0092
Project Name:	New CI Depot - Alternate Site
Project Location:	Muswellbrook, NSW

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Results provided relate only to the items tested or sampled.

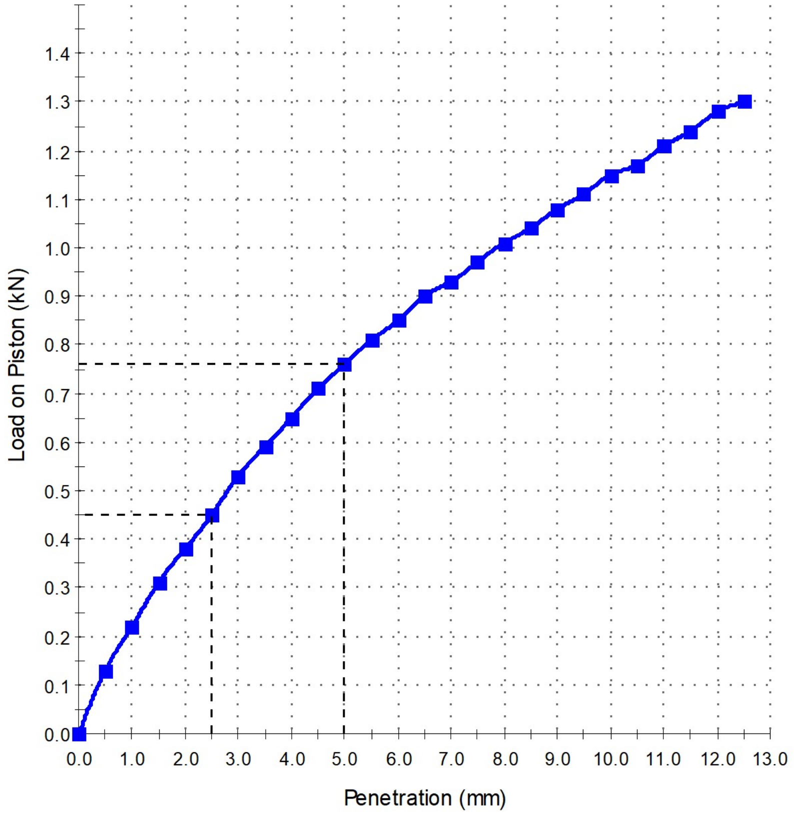
B. Cullen

Approved Signatory: Brent Cullen
(Engineering Geologist)
NATA Accredited Laboratory Number: 18686
Date of Issue: 7/06/2022

Sample Details

Sample ID:	NEW22W-1552-S06	**Date Sampled:**	18/05/2022
Sampling Method:	The results outlined below apply to the sample as received		
Specification:	No Specification	**Source:**	On-Site Insitu
Location:	BH07 - (0.2 - 0.5m)	**Material:**	Gravelly Clay
Date Tested:	3/06/2022		

Load vs Penetration



Test Results

AS 1289.6.1.1

CBR at 5.0mm (%):	**4.0**
Maximum Dry Density(t/m³):	1.73
Optimum Moisture Content(%):	18.0
Dry Density before Soaking (t/m³):	1.74
Density Ratio before Soaking (%):	100.5
Moisture Content before Soaking (%):	17.6
Moisture Ratio before Soaking (%):	98.0
Dry Density after Soaking (t/m³):	1.75
Density Ratio after Soaking (%):	101.0
Swell (%):	-0.5
Moisture Content of Top 30mm (%):	20.6
Moisture Content of Remaining Depth (%):	19.0
Compaction Hammer Used:	Standard AS 1289.5.1.1
Surcharge Mass (kg):	9.00
Period of Soaking (Days):	4
Retained on 19 mm Sieve (%):	4
CBR Moisture Content Method:	AS 1289.2.1.1
Sample Curing Time (h):	96
Plasticity Determination Method:	Visual/Tactile

——— AS1289.2.1.1 ———

In Situ (Field) Moisture Content (%):	17.6

Comments

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Report No: MAT:NEW22W-1552-S01
Issue No: 1

Material Test Report

Client: Muswellbrook Shire Council
157 New England Hwy
Muswellbrook NSW 2333

Project No.: NEW22P-0092
Project Name: New CI Depot - Alternate Site
Project Location: Muswellbrook, NSW

Accredited for compliance with ISO/IEC 17025-Testing.
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Results provided relate only to the items tested or sampled.

B. Cullen

Approved Signatory: Brent Cullen
(Engineering Geologist)
NATA Accredited Laboratory Number: 18686
Date of Issue: 3/06/2022

Sample Details

Sample ID: NEW22W-1552-S01
Date Sampled: 18/05/2022
Date Received: 24/05/2022
Source: On-Site Insitu
Material: Clay
Specification: No Specification
The results outlined below apply to the sample as received
Sample Location: BH01 - (0.35 - 0.6m)

Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	11.5	
Mould Length (mm)		250	
Crumbling		No	
Curling		Yes	
Cracking		No	
Liquid Limit (%)	AS 1289.3.1.1	44	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	19	
Plasticity Index (%)	AS 1289.3.3.1	25	
Date Tested		2/06/2022	

Comments

N/A

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Report No: MAT:NEW22W-1552-S02
Issue No: 1

Material Test Report

Client: Muswellbrook Shire Council
157 New England Hwy
Muswellbrook NSW 2333

Project No.: NEW22P-0092
Project Name: New CI Depot - Alternate Site
Project Location: Muswellbrook, NSW

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B. Cullen

Approved Signatory: Brent Cullen
(Engineering Geologist)
NATA Accredited Laboratory Number: 18686
Date of Issue: 10/06/2022

Sample Details

Sample ID: NEW22W-1552-S02
Date Sampled: 18/05/2022
Date Received: 24/05/2022
Source: On-Site Insitu
Material: Clay
Specification: No Specification
The results outlined below apply to the sample as received
Sample Location: BH05 - (0.6 - 0.75m)

Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	14.0	
Mould Length (mm)		250	
Crumbling		No	
Curling		Yes	
Cracking		No	
Liquid Limit (%)	AS 1289.3.1.1	50	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	19	
Plasticity Index (%)	AS 1289.3.3.1	31	
Date Tested		8/06/2022	

Comments

N/A

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Report No: MAT:NEW22W-1552-S03
Issue No: 1

Material Test Report

Client: Muswellbrook Shire Council
157 New England Hwy
Muswellbrook NSW 2333

Project No.: NEW22P-0092
Project Name: New CI Depot - Alternate Site
Project Location: Muswellbrook, NSW

Accredited for compliance with ISO/IEC 17025-Testing.
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.
Results provided relate only to the items tested or sampled.

B. Cullen
Approved Signatory: Brent Cullen
(Engineering Geologist)
NATA Accredited Laboratory Number: 18686
Date of Issue: 20/06/2022

Sample Details

Sample ID: NEW22W-1552-S03
Date Sampled: 18/05/2022
Date Received: 24/05/2022
Source: On-Site Insitu
Material: Clay
Specification: No Specification
The results outlined below apply to the sample as received
Sample Location: BH06 - (0.1 - 0.3m)

Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	15.5	
Mould Length (mm)		250	
Crumbling		No	
Curling		Yes	
Cracking		No	
Liquid Limit (%)	AS 1289.3.1.1	59	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	26	
Plasticity Index (%)	AS 1289.3.3.1	33	
Date Tested		8/06/2022	

Comments

N/A

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Report No: CBR:NEW22W-1573-S01
Issue No: 1

California Bearing Ratio Test Report

Client: Muswellbrook Shire Council
157 New England Hwy
Muswellbrook NSW 2333

Project No.: NEW22P-0092
Project Name: New CI Depot - Alternate Site
Project Location: Muswellbrook, NSW

Accredited for compliance with ISO/IEC 17025-Testing.
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Results provided relate only to the items tested or sampled.

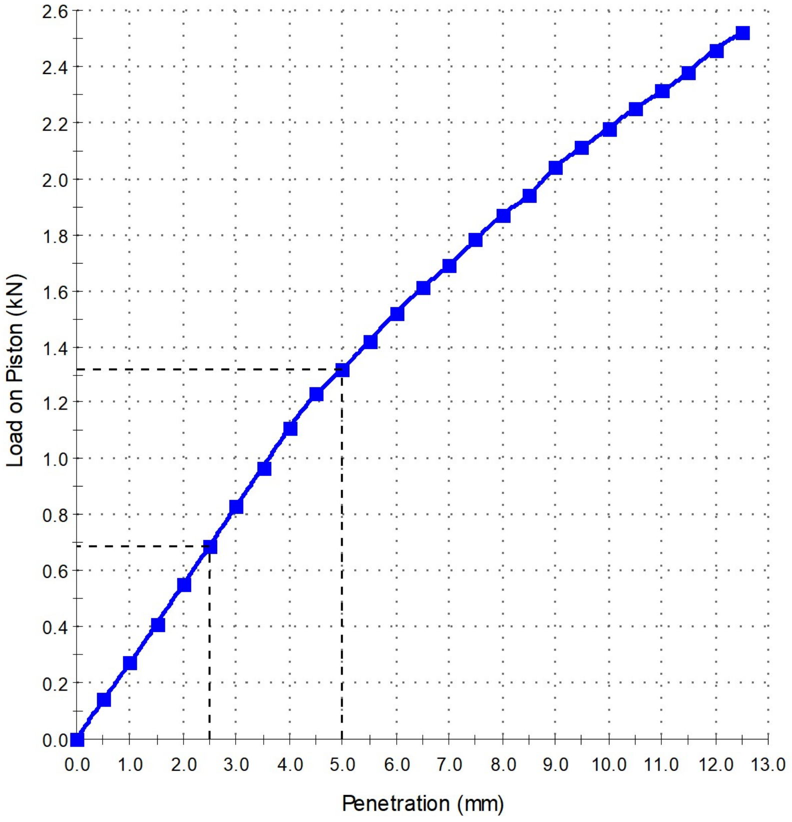
B. Cullen

Approved Signatory: Brent Cullen
(Engineering Geologist)
NATA Accredited Laboratory Number: 18686
Date of Issue: 7/06/2022

Sample Details

Sample ID: NEW22W-1573-S01
Date Sampled: 18/05/2022
Sampling Method: The results outlined below apply to the sample as received
Specification: No Specification
Source: On-Site Stockpile
Location: Stockpile 1
Material: Clayey Sandy Gravel
Date Tested: 3/06/2022

Load vs Penetration



Test Results

AS 1289.6.1.1

CBR at 5.0mm (%):	**7**
Maximum Dry Density(t/m³):	1.86
Optimum Moisture Content(%):	13.4
Dry Density before Soaking (t/m³):	1.89
Density Ratio before Soaking (%):	101.0
Moisture Content before Soaking (%):	13.7
Moisture Ratio before Soaking (%):	102.0
Dry Density after Soaking (t/m³):	1.89
Density Ratio after Soaking (%):	101.5
Swell (%):	0.0
Moisture Content of Top 30mm (%):	15.4
Moisture Content of Remaining Depth (%):	14.3
Compaction Hammer Used:	Standard AS 1289.5.1.1
Surcharge Mass (kg):	9.00
Period of Soaking (Days):	4
Retained on 19 mm Sieve (%):	7
CBR Moisture Content Method:	AS 1289.2.1.1
Sample Curing Time (h):	96
Plasticity Determination Method:	AS 1289.3.1.1

——— AS1289.2.1.1 ———

In Situ (Field) Moisture Content (%):	11.7

Comments

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ABN: 98 153 268 896

California Bearing Ratio Test Report

Report No: CBR:NEW22W-1573-S02
Issue No: 2
This report replaces all previous issues of report no 'CBR:NEW22W-1573-S02'.

Client:	Muswellbrook Shire Council 157 New England Hwy Muswellbrook NSW 2333
Project No.:	NEW22P-0092
Project Name:	New CI Depot - Alternate Site
Project Location:	Muswellbrook, NSW

Accredited for compliance with ISO/IEC 17025-Testing.
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.
Results provided relate only to the items tested or sampled.

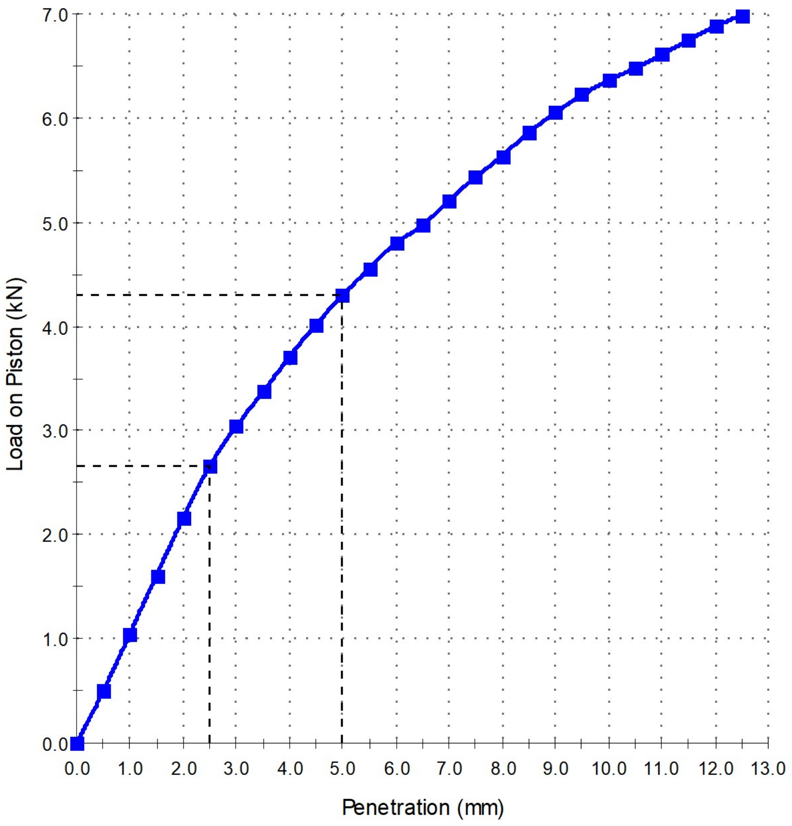
B. Cullen

Approved Signatory: Brent Cullen
(Engineering Geologist)
NATA Accredited Laboratory Number: 18686
Date of Issue: 29/06/2022

Sample Details

Sample ID:	NEW22W-1573-S02	**Date Sampled:**	18/05/2022
Sampling Method:	The results outlined below apply to the sample as received		
Specification:	No Specification	**Source:**	On-Site Stockpile
Location:	Stockpile 1	**Material:**	Gravelly Silty Sand
Date Tested:	3/06/2022		

Load vs Penetration



Test Results

AS 1289.6.1.1

CBR at 5.0mm (%):	**20**
Maximum Dry Density(t/m³):	1.75
Optimum Moisture Content(%):	15.1
Dry Density before Soaking (t/m³):	1.75
Density Ratio before Soaking (%):	100.0
Moisture Content before Soaking (%):	15.3
Moisture Ratio before Soaking (%):	101.5
Dry Density after Soaking (t/m³):	1.72
Density Ratio after Soaking (%):	98.5
Swell (%):	1.5
Moisture Content of Top 30mm (%):	18.3
Moisture Content of Remaining Depth (%):	15.9
Compaction Hammer Used:	Standard AS 1289.5.1.1
Surcharge Mass (kg):	9.00
Period of Soaking (Days):	4
Retained on 19 mm Sieve (%):	12
CBR Moisture Content Method:	AS 1289.2.1.1
Sample Curing Time (h):	96
Plasticity Determination Method:	AS 1289.3.1.1

——— AS1289.2.1.1 ———

In Situ (Field) Moisture Content (%):	12.4

Comments

Report re-issued due to amendment of Stockpile number

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Material Test Report

Report No: MAT:NEW22W-1573-S01
Issue No: 1

Client:	Muswellbrook Shire Council 157 New England Hwy Muswellbrook NSW 2333
Project No.:	NEW22P-0092
Project Name:	New CI Depot - Alternate Site
Project Location:	Muswellbrook, NSW

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Results provided relate only to the items tested or sampled.

B. Cullen
Approved Signatory: Brent Cullen
(Engineering Geologist)
NATA Accredited Laboratory Number: 18686
Date of Issue: 3/06/2022

Sample Details

Sample ID:	NEW22W-1573-S01
Date Sampled:	18/05/2022
Date Received:	26/05/2022
Source:	On-Site Stockpile
Material:	Clayey Sandy Gravel
Specification:	No Specification The results outlined below apply to the sample as received
Sample Location:	Stockpile 1

Other Test Results

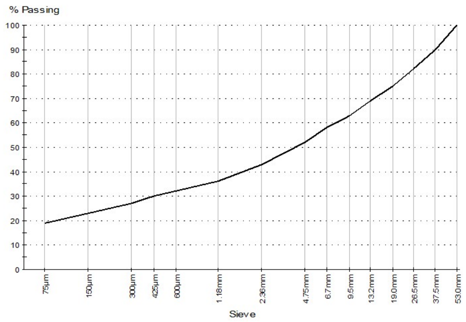
Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	5.0	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Cracking		No	
Liquid Limit (%)	AS 1289.3.1.1	25	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	14	
Plasticity Index (%)	AS 1289.3.3.1	11	
Date Tested		2/06/2022	

Particle Size Distribution

Method:	AS 1289.3.6.1
Drying by:	Oven
Date Tested:	1/06/2022
Note:	Sample Washed

Sieve Size	% Passing	Limits
53.0mm	100	
37.5mm	90	
26.5mm	82	
19.0mm	75	
13.2mm	69	
9.5mm	63	
6.7mm	58	
4.75mm	52	
2.36mm	43	
1.18mm	36	
600µm	32	
425µm	30	
300µm	27	
150µm	23	
75µm	19	

Chart



Comments

N/A

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Report No: MAT:NEW22W-1573-S02
Issue No: 2
This report replaces all previous issues of report no 'MAT:NEW22W-1573-S02'.

Material Test Report

Client: Muswellbrook Shire Council
157 New England Hwy
Muswellbrook NSW 2333

Project No.: NEW22P-0092
Project Name: New CI Depot - Alternate Site
Project Location: Muswellbrook, NSW

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B. Cullen
Approved Signatory: Brent Cullen
(Engineering Geologist)
NATA Accredited Laboratory Number: 18686
Date of Issue: 29/06/2022

Sample Details

Sample ID:	NEW22W-1573-S02
Date Sampled:	18/05/2022
Date Received:	26/05/2022
Source:	On-Site Stockpile
Material:	Gravelly Silty Sand
Specification:	No Specification The results outlined below apply to the sample as received
Sample Location:	Stockpile 1

Other Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	9.0	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Cracking		No	
Liquid Limit (%)	AS 1289.3.1.1	37	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	18	
Plasticity Index (%)	AS 1289.3.3.1	19	
Date Tested		3/06/2022	

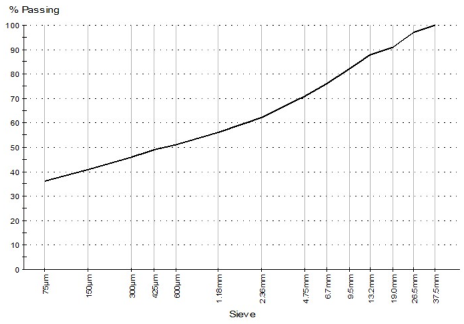
Particle Size Distribution

Method: AS 1289.3.6.1
Drying by: Oven
Date Tested: 1/06/2022

Note: Sample Washed

Sieve Size	% Passing	Limits
37.5mm	100	
26.5mm	97	
19.0mm	91	
13.2mm	88	
9.5mm	82	
6.7mm	76	
4.75mm	71	
2.36mm	62	
1.18mm	56	
600µm	51	
425µm	49	
300µm	46	
150µm	41	
75µm	36	

Chart



Comments

Report re-issued due to amendment of Stockpile number

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ABN: 98 153 268 896

Material Test Report

Report No: MAT:NEW22W-1573-S03
Issue No: 2
This report replaces all previous issues of report no 'MAT:NEW22W-1573-S03'.

Client:	Muswellbrook Shire Council 157 New England Hwy Muswellbrook NSW 2333
Project No.:	NEW22P-0092
Project Name:	New CI Depot - Alternate Site
Project Location:	Muswellbrook, NSW

Accredited for compliance with ISO/IEC 17025-Testing.
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Results provided relate only to the items tested or sampled.

B. Cullen
Approved Signatory: Brent Cullen
(Engineering Geologist)
NATA Accredited Laboratory Number: 18686
Date of Issue: 29/06/2022

Sample Details

Sample ID:	NEW22W-1573-S03
Date Sampled:	18/05/2022
Date Received:	26/05/2022
Source:	On-Site Stockpile
Material:	Sandy Clay
Specification:	No Specification
	The results outlined below apply to the sample as received
Sample Location:	Stockpile 2

Other Test Results

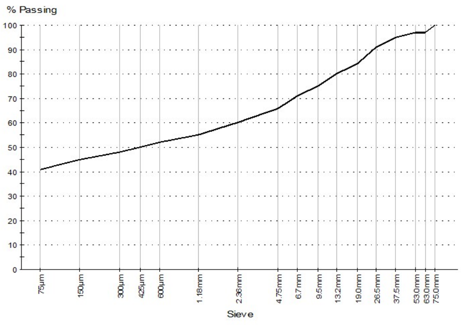
Description	**Method**	**Result**	**Limits**
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	9.0	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Cracking		No	
Liquid Limit (%)	AS 1289.3.1.1	36	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	17	
Plasticity Index (%)	AS 1289.3.3.1	19	
Date Tested		10/06/2022	
Emerson Class Number	AS 1289.3.8.1	2	
Soil Description		Sandy Clay	
Type of Water		Distilled	
Date Tested		2/06/2022	

Particle Size Distribution

Method:	AS 1289.3.6.1
Drying by:	Oven
Date Tested:	1/06/2022
Note:	Sample Washed

Sieve Size	**% Passing**	**Limits**
75.0mm	100	
63.0mm	97	
53.0mm	97	
37.5mm	95	
26.5mm	91	
19.0mm	84	
13.2mm	80	
9.5mm	75	
6.7mm	71	
4.75mm	66	
2.36mm	60	
1.18mm	55	
600µm	52	
425µm	50	
300µm	48	
150µm	45	
75µm	41	

Chart



Comments

Report re-issued due to amendment of Stockpile number

APPENDIX C:

CSIRO Sheet BTF 18

Foundation Maintenance and Footing Performance: A Homeowner’s Guide

Foundation Maintenance and Footing Performance:

A Homeowner's Guide

CSIRO

BTF 18
replaces
Information
Sheet 10/91

Buildings can and often do move. This movement can be up, down, lateral or rotational. The fundamental cause of movement in buildings can usually be related to one or more problems in the foundation soil. It is important for the homeowner to identify the soil type in order to ascertain the measures that should be put in place in order to ensure that problems in the foundation soil can be prevented, thus protecting against building movement.

This Building Technology File is designed to identify causes of soil-related building movement, and to suggest methods of prevention of resultant cracking in buildings.

Soil Types

The types of soils usually present under the topsoil in land zoned for residential buildings can be split into two approximate groups – granular and clay. Quite often, foundation soil is a mixture of both types. The general problems associated with soils having granular content are usually caused by erosion. Clay soils are subject to saturation and swell/shrink problems.

Classifications for a given area can generally be obtained by application to the local authority, but these are sometimes unreliable and if there is doubt, a geotechnical report should be commissioned. As most buildings suffering movement problems are founded on clay soils, there is an emphasis on classification of soils according to the amount of swell and shrinkage they experience with variations of water content. The table below is Table 2.1 from AS 2870, the Residential Slab and Footing Code.

Causes of Movement

Settlement due to construction

There are two types of settlement that occur as a result of construction:

- Immediate settlement occurs when a building is first placed on its foundation soil, as a result of compaction of the soil under the weight of the structure. The cohesive quality of clay soil mitigates against this, but granular (particularly sandy) soil is susceptible.
- Consolidation settlement is a feature of clay soil and may take place because of the expulsion of moisture from the soil or because of the soil's lack of resistance to local compressive or shear stresses. This will usually take place during the first few months after construction, but has been known to take many years in exceptional cases.

These problems are the province of the builder and should be taken into consideration as part of the preparation of the site for construction. Building Technology File 19 (BTF 19) deals with these problems.

Erosion

All soils are prone to erosion, but sandy soil is particularly susceptible to being washed away. Even clay with a sand component of say 10% or more can suffer from erosion.

Saturation

This is particularly a problem in clay soils. Saturation creates a bog-like suspension of the soil that causes it to lose virtually all of its bearing capacity. To a lesser degree, sand is affected by saturation because saturated sand may undergo a reduction in volume – particularly imported sand fill for bedding and blinding layers. However, this usually occurs as immediate settlement and should normally be the province of the builder.

Seasonal swelling and shrinkage of soil

All clays react to the presence of water by slowly absorbing it, making the soil increase in volume (see table below). The degree of increase varies considerably between different clays, as does the degree of decrease during the subsequent drying out caused by fair weather periods. Because of the low absorption and expulsion rate, this phenomenon will not usually be noticeable unless there are prolonged rainy or dry periods, usually of weeks or months, depending on the land and soil characteristics.

The swelling of soil creates an upward force on the footings of the building, and shrinkage creates subsidence that takes away the support needed by the footing to retain equilibrium.

Shear failure

This phenomenon occurs when the foundation soil does not have sufficient strength to support the weight of the footing. There are two major post-construction causes:

- Significant load increase.
- Reduction of lateral support of the soil under the footing due to erosion or excavation.
- In clay soil, shear failure can be caused by saturation of the soil adjacent to or under the footing.

GENERAL DEFINITIONS OF SITE CLASSES

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites with only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which can experience moderate ground movement from moisture changes
H	Highly reactive clay sites, which can experience high ground movement from moisture changes
E	Extremely reactive sites, which can experience extreme ground movement from moisture changes
A to P	Filled sites
P	Sites which include soft soils, such as soft clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise

Tree root growth

Trees and shrubs that are allowed to grow in the vicinity of footings can cause foundation soil movement in two ways:

- Roots that grow under footings may increase in cross-sectional size, exerting upward pressure on footings.
- Roots in the vicinity of footings will absorb much of the moisture in the foundation soil, causing shrinkage or subsidence.

Unevenness of Movement

The types of ground movement described above usually occur unevenly throughout the building's foundation soil. Settlement due to construction tends to be uneven because of:

- Differing compaction of foundation soil prior to construction.
- Differing moisture content of foundation soil prior to construction.

Movement due to non-construction causes is usually more uneven still. Erosion can undermine a footing that traverses the flow or can create the conditions for shear failure by eroding soil adjacent to a footing that runs in the same direction as the flow.

Saturation of clay foundation soil may occur where subfloor walls create a dam that makes water pond. It can also occur wherever there is a source of water near footings in clay soil. This leads to a severe reduction in the strength of the soil which may create local shear failure.

Seasonal swelling and shrinkage of clay soil affects the perimeter of the building first, then gradually spreads to the interior. The swelling process will usually begin at the uphill extreme of the building, or on the weather side where the land is flat. Swelling gradually reaches the interior soil as absorption continues. Shrinkage usually begins where the sun's heat is greatest.

Effects of Uneven Soil Movement on Structures

Erosion and saturation

Erosion removes the support from under footings, tending to create subsidence of the part of the structure under which it occurs. Brickwork walls will resist the stress created by this removal of support by bridging the gap or cantilevering until the bricks or the mortar bedding fail. Older masonry has little resistance. Evidence of failure varies according to circumstances and symptoms may include:

- Step cracking in the mortar beds in the body of the wall or above/below openings such as doors or windows.
- Vertical cracking in the bricks (usually but not necessarily in line with the vertical beds or perpends).

Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

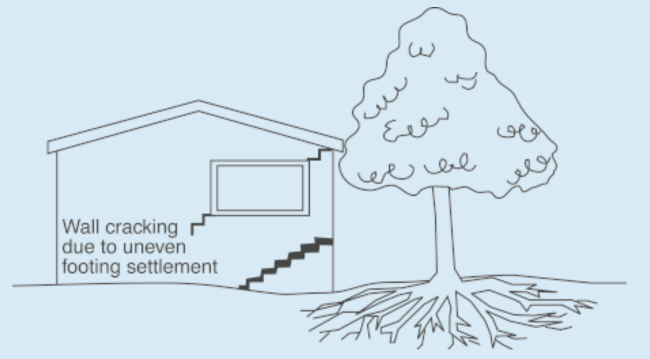
Seasonal swelling/shrinkage in clay

Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends to create a dish effect, because the external footings are pushed higher than the internal ones.

The first noticeable symptom may be that the floor appears slightly dished. This is often accompanied by some doors binding on the floor or the door head, together with some cracking of cornice mitres. In buildings with timber flooring supported by bearers and joists, the floor can be bouncy. Externally there may be visible dishing of the hip or ridge lines.

As the moisture absorption process completes its journey to the innermost areas of the building, the internal footings will rise. If the spread of moisture is roughly even, it may be that the symptoms will temporarily disappear, but it is more likely that swelling will be uneven, creating a difference rather than a disappearance in symptoms. In buildings with timber flooring supported by bearers and joists, the isolated piers will rise more easily than the strip footings or piers under walls, creating noticeable doming of flooring.

Trees can cause shrinkage and damage



As the weather pattern changes and the soil begins to dry out, the external footings will be first affected, beginning with the locations where the sun's effect is strongest. This has the effect of lowering the external footings. The doming is accentuated and cracking reduces or disappears where it occurred because of dishing, but other cracks open up. The roof lines may become convex.

Doming and dishing are also affected by weather in other ways. In areas where warm, wet summers and cooler dry winters prevail, water migration tends to be toward the interior and doming will be accentuated, whereas where summers are dry and winters are cold and wet, migration tends to be toward the exterior and the underlying propensity is toward dishing.

Movement caused by tree roots

In general, growing roots will exert an upward pressure on footings, whereas soil subject to drying because of tree or shrub roots will tend to remove support from under footings by inducing shrinkage.

Complications caused by the structure itself

Most forces that the soil causes to be exerted on structures are vertical – i.e. either up or down. However, because these forces are seldom spread evenly around the footings, and because the building resists uneven movement because of its rigidity, forces are exerted from one part of the building to another. The net result of all these forces is usually rotational. This resultant force often complicates the diagnosis because the visible symptoms do not simply reflect the original cause. A common symptom is binding of doors on the vertical member of the frame.

Effects on full masonry structures

Brickwork will resist cracking where it can. It will attempt to span areas that lose support because of subsided foundations or raised points. It is therefore usual to see cracking at weak points, such as openings for windows or doors.

In the event of construction settlement, cracking will usually remain unchanged after the process of settlement has ceased.

With local shear or erosion, cracking will usually continue to develop until the original cause has been remedied, or until the subsidence has completely neutralised the affected portion of footing and the structure has stabilised on other footings that remain effective.

In the case of swell/shrink effects, the brickwork will in some cases return to its original position after completion of a cycle, however it is more likely that the rotational effect will not be exactly reversed, and it is also usual that brickwork will settle in its new position and will resist the forces trying to return it to its original position. This means that in a case where swelling takes place after construction and cracking occurs, the cracking is likely to at least partly remain after the shrink segment of the cycle is complete. Thus, each time the cycle is repeated, the likelihood is that the cracking will become wider until the sections of brickwork become virtually independent.

With repeated cycles, once the cracking is established, if there is no other complication, it is normal for the incidence of cracking to stabilise, as the building has the articulation it needs to cope with the problem. This is by no means always the case, however, and monitoring of cracks in walls and floors should always be treated seriously.

Upheaval caused by growth of tree roots under footings is not a simple vertical shear stress. There is a tendency for the root to also exert lateral forces that attempt to separate sections of brickwork after initial cracking has occurred.

The normal structural arrangement is that the inner leaf of brickwork in the external walls and at least some of the internal walls (depending on the roof type) comprise the load-bearing structure on which any upper floors, ceilings and the roof are supported. In these cases, it is internally visible cracking that should be the main focus of attention, however there are a few examples of dwellings whose external leaf of masonry plays some supporting role, so this should be checked if there is any doubt. In any case, externally visible cracking is important as a guide to stresses on the structure generally, and it should also be remembered that the external walls must be capable of supporting themselves.

Effects on framed structures
Timber or steel framed buildings are less likely to exhibit cracking due to swell/shrink than masonry buildings because of their flexibility. Also, the doming/dishing effects tend to be lower because of the lighter weight of walls. The main risks to framed buildings are encountered because of the isolated pier footings used under walls. Where erosion or saturation cause a footing to fall away, this can double the span which a wall must bridge. This additional stress can create cracking in wall linings, particularly where there is a weak point in the structure caused by a door or window opening. It is, however, unlikely that framed structures will be so stressed as to suffer serious damage without first exhibiting some or all of the above symptoms for a considerable period. The same warning period should apply in the case of upheaval. It should be noted, however, that where framed buildings are supported by strip footings there is only one leaf of brickwork and therefore the externally visible walls are the supporting structure for the building. In this case, the subfloor masonry walls can be expected to behave as full brickwork walls.

Effects on brick veneer structures
Because the load-bearing structure of a brick veneer building is the frame that makes up the interior leaf of the external walls plus perhaps the internal walls, depending on the type of roof, the building can be expected to behave as a framed structure, except that the external masonry will behave in a similar way to the external leaf of a full masonry structure.

Water Service and Drainage

Where a water service pipe, a sewer or stormwater drainage pipe is in the vicinity of a building, a water leak can cause erosion, swelling or saturation of susceptible soil. Even a minuscule leak can be enough to saturate a clay foundation. A leaking tap near a building can have the same effect. In addition, trenches containing pipes can become watercourses even though backfilled, particularly where broken rubble is used as fill. Water that runs along these trenches can be responsible for serious erosion, interstrata seepage into subfloor areas and saturation.

Pipe leakage and trench water flows also encourage tree and shrub roots to the source of water, complicating and exacerbating the problem.
Poor roof plumbing can result in large volumes of rainwater being concentrated in a small area of soil:

- Incorrect falls in roof guttering may result in overflows, as may gutters blocked with leaves etc.
- Corroded guttering or downpipes can spill water to ground.
- Downpipes not positively connected to a proper stormwater collection system will direct a concentration of water to soil that is directly adjacent to footings, sometimes causing large-scale problems such as erosion, saturation and migration of water under the building.

Seriousness of Cracking

In general, most cracking found in masonry walls is a cosmetic nuisance only and can be kept in repair or even ignored. The table below is a reproduction of Table C1 of AS 2870.

AS 2870 also publishes figures relating to cracking in concrete floors, however because wall cracking will usually reach the critical point significantly earlier than cracking in slabs, this table is not reproduced here.

Prevention/Cure

Plumbing
Where building movement is caused by water service, roof plumbing, sewer or stormwater failure, the remedy is to repair the problem. It is prudent, however, to consider also rerouting pipes away from the building where possible, and relocating taps to positions where any leakage will not direct water to the building vicinity. Even where gully traps are present, there is sometimes sufficient spill to create erosion or saturation, particularly in modern installations using smaller diameter PVC fixtures. Indeed, some gully traps are not situated directly under the taps that are installed to charge them, with the result that water from the tap may enter the backfilled trench that houses the sewer piping. If the trench has been poorly backfilled, the water will either pond or flow along the bottom of the trench. As these trenches usually run alongside the footings and can be at a similar depth, it is not hard to see how any water that is thus directed into a trench can easily affect the foundation's ability to support footings or even gain entry to the subfloor area.

Ground drainage
In all soils there is the capacity for water to travel on the surface and below it. Surface water flows can be established by inspection during and after heavy or prolonged rain. If necessary, a grated drain system connected to the stormwater collection system is usually an easy solution.

It is, however, sometimes necessary when attempting to prevent water migration that testing be carried out to establish watertable height and subsoil water flows. This subject is referred to in BTF 19 and may properly be regarded as an area for an expert consultant.

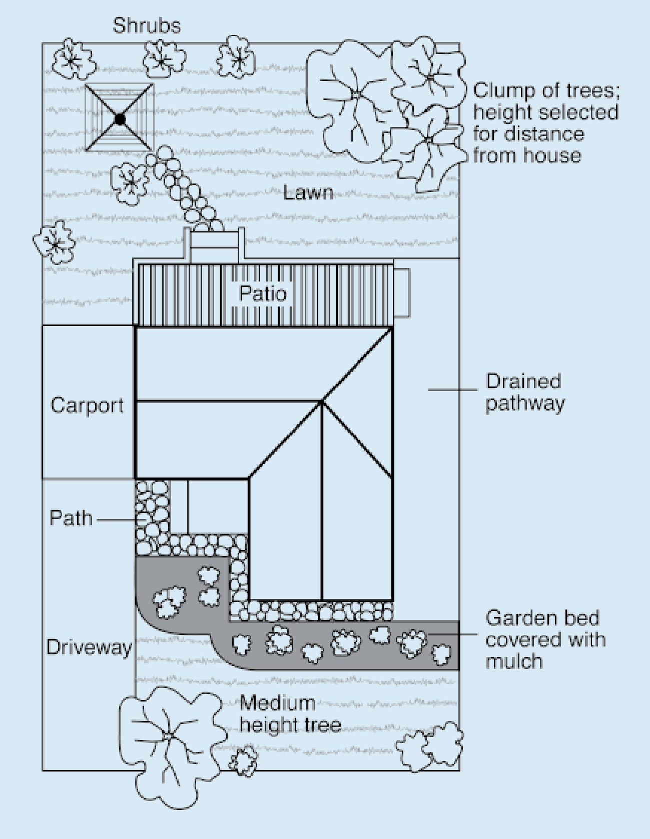
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

For this reason, particularly where problems exist or are likely to occur, it is recommended that an apron of paving be installed around as much of the building perimeter as necessary. This paving

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

Description of typical damage and required repair	Approximate crack width limit (see Note 3)	Damage category
Hairline cracks	<0.1 mm	0
Fine cracks which do not need repair	<1 mm	1
Cracks noticeable but easily filled. Doors and windows stick slightly	<5 mm	2
Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weathertightness often impaired	5–15 mm (or a number of cracks 3 mm or more in one group)	3
Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window and door frames distort. Walls lean or bulge noticeably, some loss of bearing in beams. Service pipes disrupted	15–25 mm but also depend on number of cracks	4

Gardens for a reactive site



should extend outwards a minimum of 900 mm (more in highly reactive soil) and should have a minimum fall away from the building of 1:60. The finished paving should be no less than 100 mm below brick vent bases.

It is prudent to relocate drainage pipes away from this paving, if possible, to avoid complications from future leakage. If this is not practical, earthenware pipes should be replaced by PVC and backfilling should be of the same soil type as the surrounding soil and compacted to the same density.

Except in areas where freezing of water is an issue, it is wise to remove taps in the building area and relocate them well away from the building – preferably not uphill from it (see BTF 19).

It may be desirable to install a grated drain at the outside edge of the paving on the uphill side of the building. If subsoil drainage is needed this can be installed under the surface drain.

Condensation

In buildings with a subfloor void such as where bearers and joists support flooring, insufficient ventilation creates ideal conditions for condensation, particularly where there is little clearance between the floor and the ground. Condensation adds to the moisture already present in the subfloor and significantly slows the process of drying out. Installation of an adequate subfloor ventilation system, either natural or mechanical, is desirable.

Warning: Although this Building Technology File deals with cracking in buildings, it should be said that subfloor moisture can result in the development of other problems, notably:

- Water that is transmitted into masonry, metal or timber building elements causes damage and/or decay to those elements.
- High subfloor humidity and moisture content create an ideal environment for various pests, including termites and spiders.
- Where high moisture levels are transmitted to the flooring and walls, an increase in the dust mite count can ensue within the living areas. Dust mites, as well as dampness in general, can be a health hazard to inhabitants, particularly those who are abnormally susceptible to respiratory ailments.

The garden

The ideal vegetation layout is to have lawn or plants that require only light watering immediately adjacent to the drainage or paving edge, then more demanding plants, shrubs and trees spread out in that order.

Overwatering due to misuse of automatic watering systems is a common cause of saturation and water migration under footings. If it is necessary to use these systems, it is important to remove garden beds to a completely safe distance from buildings.

Existing trees

Where a tree is causing a problem of soil drying or there is the existence or threat of upheaval of footings, if the offending roots are subsidiary and their removal will not significantly damage the tree, they should be severed and a concrete or metal barrier placed vertically in the soil to prevent future root growth in the direction of the building. If it is not possible to remove the relevant roots without damage to the tree, an application to remove the tree should be made to the local authority. A prudent plan is to transplant likely offenders before they become a problem.

Information on trees, plants and shrubs

State departments overseeing agriculture can give information regarding root patterns, volume of water needed and safe distance from buildings of most species. Botanic gardens are also sources of information. For information on plant roots and drains, see Building Technology File 17.

Excavation

Excavation around footings must be properly engineered. Soil supporting footings can only be safely excavated at an angle that allows the soil under the footing to remain stable. This angle is called the angle of repose (or friction) and varies significantly between soil types and conditions. Removal of soil within the angle of repose will cause subsidence.

Remediation

Where erosion has occurred that has washed away soil adjacent to footings, soil of the same classification should be introduced and compacted to the same density. Where footings have been undermined, augmentation or other specialist work may be required. Remediation of footings and foundations is generally the realm of a specialist consultant.

Where isolated footings rise and fall because of swell/shrink effect, the homeowner may be tempted to alleviate floor bounce by filling the gap that has appeared between the bearer and the pier with blocking. The danger here is that when the next swell segment of the cycle occurs, the extra blocking will push the floor up into an accentuated dome and may also cause local shear failure in the soil. If it is necessary to use blocking, it should be by a pair of fine wedges and monitoring should be carried out fortnightly.

This BTF was prepared by John Lewer FAIB, MIAMA, Partner, Construction Diagnosis.

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