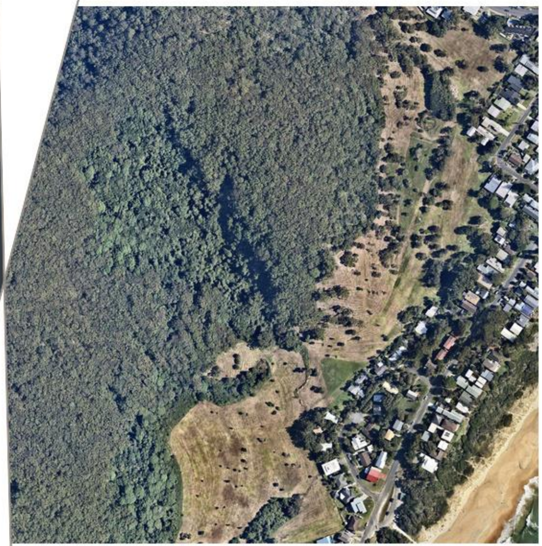
Report on Geotechnical Investigation

Blueys Beach Residential Development

50522033-001.1



Prepared for

Addenbrooke Pty Ltd

25 August 2022

Cardno

now

Stantec

Contact Information

Stantec Australia Pty Ltd
ABN 17 007 820 322

559 Hunter Street
Newcastle West NSW 2302
Australia

www.cardno.com
www.stantec.com
Phone +61 2 4965 4555
Fax +61 2 4965 4666

Document Information

Prepared for	Addenbrooke Pty Ltd
Project Name	Blueys Beach Residential Development
File Reference	Report on Geotechnical Investigation – Blueys Beach Residential Development
Job Reference	50522033-001.1
Date	25 August 2022
Version Number	2

Author(s):

Kosta Sykiotis
Geotechnical Engineer

Effective Date 25/08/2022

Approved By:

Ian Piper
Technical Services Manager, Geotechnical

Date Approved 25/08/2022

Document History

Version	Effective Date	Description of Revision	Prepared by	Reviewed by
0	8/06/2022	Draft Issue	KS	IGP
1	12/08/2022	Layout Revision	KS	IGP
2	25/08/2022	Development Application	KS	IGP

Our report is based on information made available by the client. The validity and comprehensiveness of supplied information has not been independently verified and, for the purposes of this report, it is assumed that the information provided to Stantec is both complete and accurate. Whilst, to the best of our knowledge, the information contained in this report is accurate at the date of issue, changes may occur to the site conditions, the site context or the applicable planning framework. This report should not be used after any such changes without consulting the provider of the report or a suitably qualified person.

Table of Contents

Appendices

Tables

Figures

1 Introduction

This report presents the findings of a geotechnical investigation undertaken by Stantec Australia Pty Ltd (Stantec) for the proposed Blueys Beach Residential Subdivision located on Boomerang Drive, Blueys Beach NSW. The investigation was commissioned by Addenbrooke Pty Ltd (the Client).

1.1 Proposed Development

Stantec have prepared the following plans for the Site:

> Concept layout design plans titled "Blueys Beach Development – Overall General Arrangement Plan", referenced 50522033-C-1004, revision B, dated 9th May 2022 [1]; and

> Concept bulk earthworks plan titled "Blueys Beach Development – Isopach", referenced 50522033-C-1008, revision A, dated 9th May 2022 [2].

Based on the concept design plan, it is understood the development is proposed to comprise:

- Creation of 73 residential allotments (Lots A1-A6, B1-B8, C1-C8, D1-D30, E1-E6, F1-F6, G1-G6);
- Creation of a potential commercial allotment (Lots Z1 and Z2);
- Construction of internal roads (Roads 1-4) and associated infrastructure;
- Construction of a proposed roundabout at the intersection of Croll Street, View Street and the Site; and
- Construction of two proposed basins in the eastern (Y2) and southern (Y3) portions of the Site.

The proposed development layout is shown overlaid over Nearmap imagery on Figure 1 in Appendix A.

1.2 Objectives

The purpose of the investigation was to obtain geotechnical information on subsurface conditions as a basis for the following comments and recommendations:

- Preliminary acid sulfate soil assessment.
- Recommendations for earthwork procedures and guidelines.
- Preliminary site classifications of the proposed lots in accordance with AS 2870-2011 [3].
- Comment on founding conditions for residential structures.
- Retaining wall design parameters.
- Pavement thickness design for the proposed internal road sections.
- Pavement design for proposed roundabout.
- Recommendations for basin construction.
- Description on subsurface conditions within the existing Croll Street pavement.

2 Site Identification

The proposed subdivision is an irregular parcel of land identified as Lot 23 DP 537919, located on Boomerang Drive, Blueys Beach NSW (the Site). The Site is bounded by:

> Residential and commercial allotments, and Boomerang Drive to the north;

> Residential housing along the eastern and southeastern boundary of the Site;

> Residential housing and undeveloped land to the south of the Site; and

> Densely vegetated land to the west of the Site.

2.1 Site Description

Topographically the Site is located on the eastern face of a northwest to southeast trending ridgeline. Site slopes vary, generally characterised as east to west and are shown through contours shown on Figures 2 attached in Appendix A. The Site topography is also characterised by gully lines trending from the northwest of the Site to the eastern portion of the Site, in southern portion of the Site trending west to east, and in the south-eastern portion of the Site trending north west.

The following features were observed at the time of investigation:

> Vegetation comprised maintained pasture with scattered mature trees across the Site. A higher density of mature trees was noted in the north-western and far southern portion of the Site, and tall reeds noted in the gully line in the southern portion of the Site.

> Surface drainage appears to comprise surface runoff, with flows directed towards gully lines and leading to the eastern portion of the Site.

> Mulch stockpiles were noted in the central northern portion of the Site.

> Existing basins were noted in the central northern and central eastern portions of the Site.

> An overland drainage path was noted trending northwest to southeast through the Site towards the basin in the central-eastern portion of the Site.

> A swale drainage line along the eastern boundary of the Site heading towards the south of the Site.

3 Investigation Methodology

3.1 Desktop Review

Prior to geotechnical investigation at the Site, desktop review of published data was undertaken to inform on potential conditions encountered at the Site. The desktop review comprised review of the following:

> Geological mapping in the area.

> Acid sulphate soil mapping in the area.

Results of the desktop review are included in Section 4 below.

3.2 Site Investigation

Geotechnical investigation at the Site was undertaken on 24th January 2022 and comprised the following:

> A site walkover by a geotechnical engineer from Stantec, including visual appraisal and recording of salient site conditions and features.

> Excavation of 17 test pits and logging of subsurface conditions within the proposed allotment areas and future road alignments. Test pits were excavated utilising a 13.5-tonne excavator fitted with an 900mm toothed bucket to depths ranging from 0.95-3.5 m below existing ground level (bgl), with refusal (including slow progress termination) in the underlying weathered rock encountered in test pits TP002-TP004, TP008-TP012, TP014 and TP015. Test pit locations are shown on Figures 1-4 attached in Appendix A.

> Drilling of three (3) test bores (TB001-TB003) in adjacent Croll Street to assess the existing pavement profile. Test bores were extended using a ute mounted drill rig fitted with a 300 mm bulk auger, extended to depths of 1.2 m bgl with refusal on weathered rock encountered in TB002 at depths of 1.1 m bgl. Test bore locations are shown on Figure 5 attached in Appendix A.

> Dynamic cone penetrometer tests (DCP) were conducted at all excavated test pits and test bores to aid in the assessment of subsurface strength conditions.

> Thin wall tube (50mm diameter) and disturbed geotechnical/environmental samples of natural materials were collected for subsequent laboratory testing.

> All test pits backfilled with excavated spoil upon completion.

All fieldwork including logging of subsurface profiles and collection of samples was carried out by a geotechnical engineer from Stantec. Test locations were located using a kml file generated by overlaying proposed test locations onto the supplied development extents and then output to a compatible handheld tablet. It is expected that test pit accuracy would be in the range of +/- 5m.

Test locations are shown overlaid on georeferenced aerial imagery and client supplied preliminary layout plans on Figures 1-5 attached in Appendix A.

3.3 Laboratory Testing

Laboratory testing on selected samples recovered during the current investigation comprised the following:

> Four (4) Shrink Swell tests to measure soil volume change over an extreme soil moisture content range.

> Five (5) California Bearing Ratio (CBR) test to assess proposed subgrade strength.

> Two (2) Atterberg limits tests to classify soil plasticity.

> Two (2) Emerson Class tests to classify soil dispersion.

> Four (4) detailed acid sulfate soil tests using the Chromium Reducible Sulphur (SCr) method.

Geotechnical laboratory testing was conducted at NATA accredited construction materials testing laboratory and the environmental testing was conducted at an external NATA accredited chemical testing laboratory. Results of laboratory testing are detailed in the report sheets attached in Appendix C.

4 Investigation Findings

4.1 Published Data

4.1.1 Geology Maps

Review of the New South Wales Seamless Geology dataset [4] indicates the Site is underlain by the following formations:

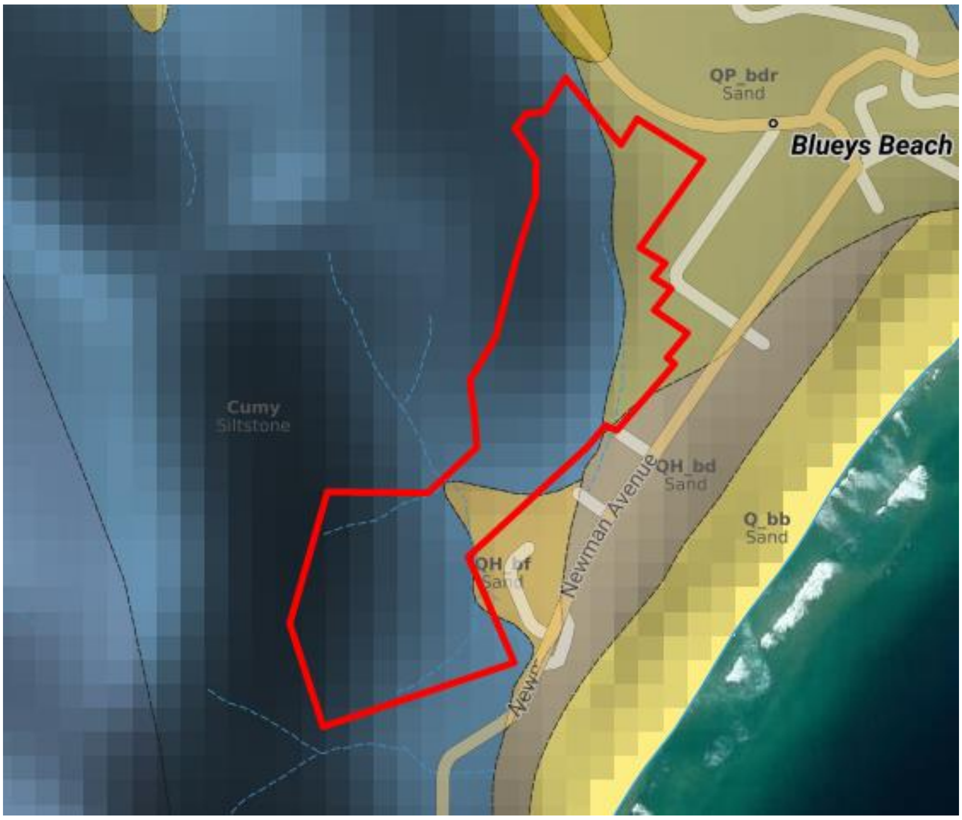
> The western portion of the Site is underlain by the Yagon Siltstone formation (Cumy), of the Myall Block Units, known to comprise fossiliferous dark siltstone, with interbedded of mudstone and sandstone, and residual soils formed by the weathering of these rocks.

> The north-eastern portion of the Site is underlain by Coastal Deposits (QP_bdr) known to comprise marine deposited and Aeolian reworked fine to coarse grained sand.

> The south-eastern portion of the Site is underlain by Coastal Deposits (QP_bf) known to comprise fine to medium grained sand, indurated sand, silt, gravel, clay and organic mud/peat.

The proposed development has been overlain over the seamless geology to show the extents in Figure 4-1 below.

Figure 4-1 Proposed Development over Seamless Geology.



4.2 Subsurface Conditions

4.2.1 Croll Street Pavement

A summary of subsurface conditions has been provided below, with depths of encountered material provided in Table 4-1 below. The subsurface conditions encountered within the Croll Street investigation generally comprised:

> WEARING COURSE: Sprayed seal comprising a 7/14 mm blend of thickness varying from 0.02-0.03 m. Evidence of previous overlays was noted at the Site.

> PAVEMENT: Clayey Sandy GRAVEL generally fine to coarse gravels up to cobble sized angular to sub-angular siltstone and sandstone, light brown, dry, encountered in all test bores to depths of 0.2-0.25 m BGL.
> FILL:
  - Gravelly Sandy CLAY generally low to medium plasticity, brown, fine to coarse gravels up to cobble sized angular to sub-angular siltstone and sandstone, with moisture content less than plastic limit, encountered in test bores TB001 and TB003 to depths of 0.32-0.45 m bgl.
  - Silty CLAY of medium to high plasticity, dark brown, generally of firm consistency and moisture content greater than plastic limit, encountered to depths of 0.37 m BGL in TB002 only.
> ALLUVIAL: SAND generally fine to medium grained, dark grey/grey in colour, medium dense and dry, encountered to investigation limits of 1.2 m bgl in TB001 and TB003.
> RESIDUAL: Silty CLAY of medium to high plasticity, pale grey mottled orange brown, firm to stiff consistency and moisture content above plastic limit, encountered from 0.37-0.75 m bgl in TB002.
> EXTREMELY WEATHERED MATERIAL (EWM): Silty Sandy CLAY of medium plasticity, pale grey mottled orange and moisture content equal to plastic limit, encountered in TB002 from 0.75-1.1 m bgl.

Depths of subsurface units are provided in Table 4-1 below.

Table 4-1 Summary of Subsurface Conditions.

Test Bore ID	DEPTH OF PROFILE (m BGL)					
	SEAL	PAVEMENT	FILL	ALLUVIAL	RESIDUAL / EWM	TERMINATION
TB001	0.02	0.25	0.32	1.2	-	1.2
TB002	0.03	0.2	0.37	-	1.1	1.1
TB003	0.03	0.2	0.45	1.2	-	1.2

Notes to table:
- "-": Not encountered.

Groundwater was not encountered during the pavement investigation however groundwater conditions are likely to fluctuate with variations in climatic and site conditions. For detailed description of subsurface conditions, engineering logs should be referenced attached in Appendix B, together with explanatory notes.

4.2.2 Internal Subdivision

A summary of subsurface conditions has been provided below, with depths of encountered material provided in Table 4-2 Table 4-1below. The subsurface conditions encountered across the site generally comprised:

> TOPSOIL: Silty/Sandy CLAY / Silty SAND generally of low plasticity / fine to coarse grained, grey and dark brown, with varying fractions of sand and gravel. Typically, the topsoil was of colluvium origin, with the top 0.1 m organically impacted.
> COLLUVIUM:
  - Silty/Sandy CLAY generally of low to medium plasticity, varying from dark brown, black and grey, with varying fractions of sand, gravel and cobbles, and generally of stiff consistency.
  - Sandy GRAVEL generally fine to coarse and angular, grey mottled yellow, varying fractions of fine to coarse grained sand and cobbles, generally loose to medium dense.
> AEOLIAN: SAND generally ranging from fine to coarse grained, pale grey, grey and brown. Aeolian sand was generally loose to medium dense.
> ALLUVIUM:
  - Silty/Gravelly CLAY, generally medium to high plasticity, grey/pale grey mottled yellow, with varying fractions of fine to coarse rounded gravels. Generally cohesive alluvium material ranged from firm to very stiff.
  - Clayey SAND, generally fine to coarse grained, brown and black, generally loose to medium dense.
> RESIDUAL: CLAY / Silty/Sandy/Gravelly CLAY ranging from low to high plasticity, of varying colours comprising yellow, orange, red and grey, with varying fractions of fine to coarse grained sand, and fine to coarse angular to sub-angular gravel. Residual clays ranged from firm to hard consistency.

- EXTREMELY WEATHERED MATERIAL:
  - Silty/Gravelly CLAY ranging from low to medium plasticity, pale grey mottled yellow, with varying fractions of fine to coarse angular gravel and fine to coarse grained sand, generally of very stiff to hard.
  - Clayey GRAVEL generally fine to coarse and angular, grey mottled yellow, varying fractions of fine to coarse grained sand and cobbles, generally loose to medium dense.
- WEATHERED ROCK: SANDSTONE / SILTSTONE generally highly fractured, with fracturing decreasing with depth prior to refusal.

Depths of subsurface units are provided in Table 4-2 below.

Table 4-2 Summary of Subsurface Conditions.

Test Bore ID	DEPTH OF PROFILE (m BGL)							
	TOPSOIL	COLLUVIUM	AEOLIAN	ALLUVIAL	RESIDUAL	EWM	ROCK	TERMINATION
TP001	0.1	0.3	-	-	2.2	>3.0	-	3.0
TP002	0.1	0.55	-	-	0.9	-	>1.9	1.9
TP003	0.1	0.5	-	-	-	-	>1.2	1.2
TP004	0.2	0.45	-	-	-	1.3	>1.4	1.4
TP005	0.1	0.3	-	-	>3.0	-	-	3.0
TP006	0.15	-	1.1	>3.3	-	-	-	3.3
TP007	0.2	-	>2.9	-	-	-	-	2.9
TP008	0.1	0.25	-	-	0.9	-	>1.4	1.4
TP009	0.1	0.45	-	-	-	-	>1.3	1.3
TP010	0.1	0.3	-	-	1.45	1.8	>2.15	2.15
TP011	0.2	-	-	-	0.5	-	>0.95	0.95
TP012	0.1	0.5	-	-	1.5	1.8	>2.2	2.2
TP013	0.15	-	-	2.8	>3.5	-	-	3.5
TP014	0.1	0.4	-	-	1.1	1.4	>1.65	1.65
TP015	0.1	0.3	-	-	1.45	1.8	>2.2	2.2
TP016	0.2	-	-	-	2.5	>3.0	-	3.0
TP017	0.1	-	1.4	1.9	>2.2	-	-	2.2

Notes to table:
- "-": Not encountered.
- EWM: Extremely Weathered Material.

Groundwater was encountered in TP013 and TP016 at depths of 1.7 m and 1.75 m BGL respectively, notably within test pits undertaken in gullies at the base of natural overland flow paths. Groundwater conditions are likely to fluctuate with variations in climatic and site conditions. For detailed description of subsurface conditions, engineering logs should be referenced attached in Appendix B, together with explanatory notes.

4.3 Laboratory Testing

4.3.1 Shrink Swell Testing

The result of the laboratory shrink swell test undertaken on proposed founding material is summarised below in Table 4-3, with the test report sheet attached in Appendix C.

Table 4-3 Summary of Shrink Swell Test Results

Test Location	Depth (m)	Material Description	E_{SW} (%)	E_{SH} (%)	I_{SS} (%)
TP005	0.8-1.0	Silty CLAY	0.1	4.5	2.5
TP008	0.65-0.85	Silty CLAY	-0.1	3.9	2.2
TP014	0.3-0.4	Silty CLAY	1.6	5.6	3.6
TP016	1.2-1.4	Silty CLAY	-0.1	3.4	1.9

Notes to table:
E_{SW}: Swelling Strain
E_{SH}: Shrinkage Strain
I_{SS}: Shrink Swell Index

4.3.2 California Bearing Ratio Test Results

The result of the standard compaction CBR testing undertaken on the crushed sandstone fill, the proposed carpark pavement subgrade, is summarised below in Table 4-4 with the laboratory report sheet attached in Appendix C.

Table 4-4 Summary of CBR Test Results

Test Location	Depth (m)	Material Description	W (%)	SOMC (%)	SMDD (t/m^3)	Swell (%)	CBR (%)
TP002	0.6-0.8	CLAY	30.1	26.5	1.50	1.5	3.0
TP007	0.4-0.6	SAND	3.1	16.5	1.79	0.0	50
TP012	0.7-0.9	CLAY	27.5	28.5	1.46	0.5	7.0
TP015	1.0-1.2	CLAY	27.0	25.0	1.56	1.0	4.5

Notes to table:
W: Field Moisture Content
SOMC: Standard Optimum Moisture Content
SMDD: Standard Maximum Dry Density

4.3.3 Emerson Class Test Results

The result of the Emerson Class test undertaken on a representative sample of the water quality basin material is summarised below in Table 4-5 with the laboratory report sheets attached in Appendix C.

Table 4-5 Summary of Emerson Class Test Results

Hole ID	Depth (m)	Soil Type	Emerson Class	Notes
TP010	0.55-0.65	CLAY	6	No Dispersion
TP012	0.7-0.9	CLAY	6	No Dispersion

4.3.4 Atterberg Limits Test Results

The results of the laboratory Atterberg Limits tests undertaken on cohesive subsoils are summarised below in Table 4-6 with the test report sheets attached in Appendix C.

Table 4-6 Summary of Atterberg Limits Test Results

Test Pit ID	Depth (m)	Soil Type	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
TP010	0.55-0.65	CLAY	78	16	62
TP012	0.7-0.9	CLAY	72	25	47

5 Geotechnical Comments & Recommendations

5.1 Croll Street

Investigation undertaken within the Croll Street alignment comprised three (3) test bores within the southern portion of the alignment. The investigation indicated overall pavement thicknesses within the alignment ranged from 0.2-0.25 m. Pavement composition typically comprised a Clayey Sandy GRAVEL base layer of sandstone origin.

At the time of investigation, the pavement appeared to be performing adequately, with minor patchwork noted within the existing alignment. It is noted however, the pavement has most likely been subject to relatively light traffic loading.

5.2 Earthworks

At the time of reporting, detailed civil design was still in progress, with concept bulk earthworks plans available [2]. Based off the bulk earthworks plan supplied, it is expected proposed earthworks for the development would comprise the following:

> Excavations in the order of 2-10 m along the northern boundary of the Site.

> Filling ranging from 0.5-5.0 m in the southern and middle portions of the Site.

> Trenching for installation of proposed in ground services (e.g. sewer and stormwater).

5.2.1 Excavations

5.2.1.1 Excavatability

Based on the anticipated depths of cut and encountered subsurface conditions, excavations are expected to be undertaken predominately within the residual soils and weathered rock profile. Minor excavations within the colluvium, aeolian, and alluvial soil are expected, associated with removal of unsuitable founding material or filling preparation. Excavations are expected to be readily undertaken utilising conventional earthmoving equipment, such as backhoes and excavators. Where excavations are expected to extended into the weathered rock, most likely along the northern portion of the Site, additional rock ripping attachments will be required.

The investigation identified weathered rock in the majority of test pit locations along the northern boundary of the Site, at depths ranging from 0.45 to 1.80m bgl. Machine refusal occurred at depths ranging from 0.95 to 2.15 m bgl, using a 14-tonne excavator fitted with an 800mm toothed bucket. Weathered rock encountered within test pits was generally blocky with small joint spacing within the top 0.3-0.5 m, with joint spacing increasing with depth. Excavations into the highly fractured rock were relatively easy, with excavatability decreasing significantly with depth as defect spacing increased.

Considering the depths of excavation proposed and the shallow rock depth encountered across site, rock will be encountered during construction. As such, it would be considered prudent to make allowance for hydraulic rock hammer excavation or use of large capacity excavators/dozers with ripper attachments. This is particularly necessary where excavations to a potentially significant depth below rock level are proposed, such as those expected along the northern boundary of the Site, and in the deeper sections of utility (e.g. sewer, stormwater) installation or deeper cut areas to the proposed allotments and pavement alignments.

5.2.1.2 Stability of Excavations

Excavations or trenches in the residual stiff or better soils and the weathered rock profile could be expected to stand close to vertical in the short-term. It is expected colluvial, Aeolian and alluvial soils would be prone to collapse and therefore should be benched or battered accordingly. Unsupported excavations into the natural site soils will likely be subject to local slumping if elevated groundwater conditions exist and seepage occurs (e.g. after sustained periods of wet weather). Instability was noted in test pits undertaken within the Aeolian and saturated alluvial soils, associated with cohesionless material and groundwater. Should areas of instability or significant groundwater flows be encountered during excavation, a suitably qualified geotechnical engineer should inspect the excavations with respect to stability.

Where personnel are to enter excavations, options for short-term excavations include benching or battering back of the excavations at 1H:1V or the support of excavations within the residual soil and extremely weathered rock profile. Short-term excavations within the more competent rock may be battered at steeper than 1H:1V and may not require support, however this would be subject to specific geotechnical assessment, and highly fractured rock would require remediation in the form of scabbling, erosion protection or retention.

It is recommended that long-term excavations should be either battered at 2H:1V or flatter and protected against erosion or be supported by engineer designed and suitably constructed retaining walls. Excavations may be battered steeper than 2H:1V in rock materials, subject to specific geotechnical assessment, however highly fractured rock will require some form of stabilisation.

5.2.2 Filling & Batter Slopes

5.2.2.1 Methodology

Based on the current landform, it is expected filling will be required to achieve final design levels, however the extent of fill had not been finalised at the time of the current investigation. Regardless, fill should be placed and compacted in accordance with AS 3798-2007 *Guidelines on Earthworks for Commercial and Residential Developments* [5].

It is expected that fill operations during bulk earthworks would comprise the following:

- Removal of any existing uncontrolled fill, stockpiles, topsoil, slopewash, colluvium, alluvium or deleterious materials from the areas where fill is to be placed. Any unsuitable material including foreign matter must be removed from the fill areas.
- Fill materials must be free of vegetation including tree stumps, roots, root fibres or other organic matter. Silts or material with high silt portions such as the topsoil material must be blended with other site soils to be used as fill.
- Fill should not comprise material with particle sizes of greater than 200mm or 2/3 of the compacted layer thickness. On-site ripped rock may need to be treated to allow the reuse in road alignments and for general filling during bulk earthworks.
- Benching of the slopes where fill is to be placed with slopes steeper than 8H:1V will be required.
- Placement of fill in uniform horizontal layers with compaction of each layer to a minimum dry density ratio of 95% Standard Compaction (AS 1289-5.5.1) at moisture contents in the order of 85-115% of SOMC or ±2% but generally as close to SOMC as practical. Over compaction should be avoided.
- Where filling is proposed for support of commercial structures, fill materials should be of suitable quality, with compacted layers to a minimum dry density ratio of 98% Standard Compaction (AS 1289-5.5.1). It is also recommended fill operations be conducted under Level 1 supervision, in accordance with AS3798-2007 [5].
- Within the road alignment, subgrade formation should be in accordance with Section 6.4.2 and the moisture specification will need to be maintain at -2 to 0% of OMC.

Where high reactivity material is used as fill, it should be placed a suitable distance from the surface to avoid the material impacting negatively on-site classifications. It is suggested that this material only be used in lots requiring filling of >1.0m, where the top 1.0m of filling consists of lower reactivity material.

5.2.2.2 Batter Slopes

All controlled fill should be battered at a slope of 2H:1V or preferably flatter and temporary erosion control should be provided. To prevent erosion in the long term, provision of protection by vegetation and with the provision of adequate drainage is also required. Where a batter of 2H:1V is not possible, the fill should be supported by an engineer designed and suitably constructed retaining walls.

5.2.2.3 Material Suitability

Fill materials utilised within the proposed development are expected to comprise predominantly site won materials composed of colluvium, aeolian and alluvial materials, residual clays, and ripped weathered rock.

Generally, all soils excavated on site with the exception of topsoil and high silt content soils are considered suitable for reuse as engineering fill. All vegetation including tree stumps, roots and root fibres, or other organic material should be removed from the site won materials prior to reuse. Given the presence of mature trees within the site area, issues relating to removal of organics are likely, as such, additional work may be necessary, including braking up of excavated clays and hand removal of tree roots.

All site-won ripped rock would be suitable for reuse as engineering fill, following reconditioning and grading for particle size requirements. It is recommended to use the weathered rock materials at levels close to the road design subgrade level.

5.2.3 Groundwater

Groundwater was encountered in TP013 and TP016 at depths of 1.7 m and 1.75 m BGL respectively, notably within test pits undertaken in gullies at the base of natural overland flow paths. It is expected that following periods of inclement weather, groundwater levels could rise significantly in areas underlain by Alluvial/Aeolian sands, and portions of the Site downstream of overland drainage paths.

Where excavations are proposed in areas underlain by Alluvial/Aeolian sands and portions of the Site downstream of overland drainage paths allowances for groundwater management through the use of sump and pump techniques (or similar) should be made.

5.3 Existing Stormwater Drainage Remediation

Existing stormwater drainage lines and rural dams will require remediation where earthworks are proposed.

5.3.1 Dam Decommissioning

Three existing dams were noted on the Site during the investigation. It is understood that existing dams are to be decommissioned and filled as part of the bulk earthworks. Decommissioning is likely to comprise:

> Breaching and draining of any ponded water within the existing dams as soon as practical to allow any sediment to dry as much as possible prior to removal and bulk earthworks commencing;

> Removal of any existing fill (dam wall), stockpiles, topsoil, slope-wash / colluvium, over-wet, organic or deleterious materials from the areas where fill is to be placed;

> Stripping within the existing dam footprints. It should be noted that the removal of all sediment as well as dam walls from the development area is required.

> Inspection of all stripped surfaces should be undertaken by an experienced geotechnical consultant to confirm removal of all deleterious material and suitable foundation materials prior to placement of fill. Filling is to be undertaken as detailed above.

5.3.2 Overland Flow Path

Where earthworks within existing overland flow paths/gullies are proposed, the following methodology should be followed:

> Breaching/pumping of any ponded water within existing drainage lines as soon as practical to allow any sediment to dry as much as possible prior to removal and bulk earthworks commencing.

> Stripping/removal of any existing fill, topsoil, slope-wash / colluvium, over wet, organic or deleterious materials from areas proposed to be filled or founded on.

> Inspection of all stripped surfaces should be undertaken by an experienced geotechnical consultant to confirm removal of all deleterious material and suitable foundation materials prior to placement of fill or founding.

Special consideration should be made to excavations within the drainage lines as soils are likely to be saturated, resulting in potential slumping. Allowances should also be made for groundwater management techniques following periods of inclement weather.

5.4 Basin Construction

Based on the current concept design plans, it is expected two (2) stormwater basins (Y2-Y3) are proposed within the eastern and southern portions of the Site.

5.4.1 Proposed Construction

Based on the proposed location of the basins, it is expected basin construction will comprise filling for embankments and central impoundment area. Internal and external batters are to comprise slopes of a maximum 5H:1V. Earthworks for the proposed basins will vary based on location as detailed below.

5.4.1.1 Basin Y2

Basin Y2 is proposed to be constructed within the eastern portion of the Site. Test pitting conducted within the proposed basin footprint indicates the existing conditions within the proposed footprint comprise a combination of stiff colluvial CLAY, residual CLAY and gravelly CLAY EWM overlying siltstone. The colluvial material will be unsuitable for founding, with founding to be undertaken within the residual soil. Where foundations for the impoundment area extend into the EWM gravelly CLAY and weathered rock, a 300 mm clay liner may be required. Foundations for the proposed basin will be subject to inspection by a suitably qualified geotechnical consultant.

5.4.1.2 Basin Y3

Basin Y3 is proposed to be constructed within the south-west portion of the Site, partially constructed within the existing gully line. As such, it is expected existing conditions within the footprint of the proposed basin will likely comprise a combination of alluvial Silty CLAY within the gully line, and residual Silty CLAY / fractured weathered rock outside it. It is expected construction of the proposed basin will require removal of unsuitable alluvial Clay from within the gully alignment such that the proposed embankments are founding in the underlying residual clay or weathered rock. This will be subject to inspection by a suitably qualified geotechnical consultant. Where foundations for the impoundment area extend into the EWM gravelly CLAY and weathered rock, a 300 mm clay liner may be required.

5.4.2 Embankment Requirements

Table 5-1 below provides general material requirements and compaction specifications for the construction of a zoned embankment for temporary and permanent basins.

Table 5-1 Embankment Material Specification

Specifications	Zone 1 – Clay Core Material	Zone 2 – Embankment Fill
Material Property		
Material Description	CLAY, sandy/silty CLAYs with minor gravel content	
Plasticity Index	10-50%	
Permeability	< 10^{-9} m/s	N/A
Emerson Class	Minimum Class 4	Minimum Class 2
Maximum particle Size	50mm	200mm or 2/3 of the compacted layer
Percentage Fine Content (Material Passing 0.075mm)	> 25%	> 20%
Compaction Requirements		
Compaction (Standard Relative Density AS1289 5.7.1)	Minimum 98%	Minimum 95%
Moisture Content	-1 to +2 of SOMC	-1 to +2 of SOMC

Notes to table:
SOMC: Standard Optimum Moisture Content
N/A: Not applicable

Based on the results of the Atterberg Limits testing and Emerson Class testing, site clays are generally suitable for use in both zone 1 and 2, however where highly plastic clays are encountered, blending with lower plastic materials may be required.

Excavations to form the foundation of the impoundment area would be expected to comprise the stiff colluvial and firm residual clay profile. In the event rock or EWM gravelly CLAY is encountered during earthworks, inspection of the exposed rock impoundment area would be required to assess any defects of the rock profile. Where excessive fracturing or large joints are observed, seepage would be expected and piping could occur. A 300 mm impermeable clay liner will be required to be placed in the basin impoundment area to reduce potential seepage into the underlying strata. All batter slopes within the impoundment area should be 1V:5H or flatter.

5.4.3 Basin Material

Where suitable site-won residual clay is available for construction of the clay core associated with the proposed stormwater basins, appropriate care should be taken during excavations to ensure sufficient suitable material is sourced. This would include a multistage excavation process to reduce blending with colluvium and weathered rock material generally including:

(1) Stripping of surficial topsoil material;

(2) Excavation/removal of colluvium material until the residual clay layer is exposed;

(3) Excavation of the residual clay and placement into a separate stockpile. Excavations should be to design invert level or to the transition into weathered rock material (whatever is encountered first). Weathered rock material should not be excavated and mixed with the clay material.

Excavating directly to design invert level following stripping of topsoil results in mixing potentially suitable clays with both overlying colluvium gravels/sands and underlying weathered rock resulting in an unsuitable material for clay core construction.

Where insufficient suitable material is able to be sourced, importing suitable material or utilisation of a clay borrow area may be necessary subject to guidance by an experienced geotechnical consultant. The material to be utilised should also be inspected by an experienced geotechnical consultant.

5.4.4 Embankment Foundation Treatment

Based on the subsurface conditions encountered during the investigation, existing subsurface conditions within the footprints of the proposed basin comprises alluvial, colluvial, residual and extremely weathered rock materials. All alluvial and colluvial materials are to be removed from within the embankment foundation alignment, with founding to be undertaken within residual & EWM materials for the basin walls and impoundment area.

The following general foundation preparation requirements must be adopted:

- Removal of all uncontrolled filling associated with previous dams or topsoil material.
- Static proof-rolling of the exposed foundation area under the embankment with a heavy (minimum 10 tonne) roller or similar as directed by the geotechnical consultant. Soft or weak areas detected during the proof rolling shall be excavated and replaced with compacted fill comprising low permeability clay meeting the requirements of Zone 1 material.
- Protection of the prepared foundation to prevent excessive wetting or drying prior to placement of embankment fill material. Trafficking of the exposed foundation should be limited (or avoided where possible) to prevent permanent deformation.
- Embankment clay core to have a minimum 500 mm key below the invert of the basin.
- Inspection of clay or controlled filling foundation and key by an experienced geotechnical consultant to assess potential defects and potential seepage.

Where basins are proposed within existing overland flow paths, allowance for groundwater management techniques such as sump and pump should be made.

5.4.5 Keyway Construction

The basin will consist of a keyway location subject to founding conditions during construction. The basin walls should be founded in residual clay/extremely weathered rock. The location of the keyway subject to inspection by a suitably qualified geotechnical consultant. Keyway construction is to comply with material specifications as per Table 5-1 and general filling methodology outlined in Section 5.1.2.

5.4.6 Stormwater Outlets and Seepage Collars

A seepage collar will be required to be constructed along the stormwater pipes traversing the dam embankment to increase the length of the percolation path and reduce the risk of piping developing around the stormwater pipes.

Seepage collars are generally made of concrete with a required width depending on pipe diameter but are typically three times the pipe diameter.

5.4.7 Surface Erosion Control

Topsoil shall be spread over the exposed surfaces of the embankment to a depth of at least 150mm and sown with pasture grass to establish a good cover as soon as practical.

Large vegetation shall not be allowed to become established on or near the embankment. Tree roots (especially eucalyptus tree roots) can cause the core to crack and encourage piping development, resulting in the failure of the dam wall.

All trees and shrubs shall be restricted to a minimum distance of 1.5 times the height of the tree away from the embankment of the dam.

Rock rip rap scour protection shall be included for erosion control at all inlet and outlet points including emergency spillways.

5.4.8 Embankment Construction and Upstream Batters

Following the preparation of the embankment foundations, formation of the embankment must be undertaken from foundation to the crown using the compaction requirements specified in Table 5-1. Compaction of the embankment material must be undertaken using pad foot rollers.

Upstream batters of the basin should be graded at 5H:1V or flatter, with diversion drains/bunds to divert any surface flows towards the specified inlet discharge points to limit erosion of the batter faces. Emergency spillways are to be included in the construction of the basins as per the provided drawings.

5.5 Preliminary Site Classification

Australian Standard AS 2870-2011 [3] established performance requirements and specific designs for common foundation conditions as well as providing guidance on the design of footing systems using engineering principles. Site classes are defined on Table 2.1 and 2.3 of AS 2870-2011 [3] and are presented in Table 5-2 below.

Table 5-2 General Definition of Site Classes

Site Class	Foundation	Characteristic Surface Movement
A	Most sand and rock sites with little or no ground movement from moisture changes	
S	Slightly reactive clay sites, which may experience only slight ground movement from moisture changes	0 - 20mm
M	Moderately reactive clay or silt sites, which may experience moderate ground movement from moisture changes	20 - 40mm
H1	Highly reactive clay sites, which may experience high ground movement from moisture changes	40 - 60mm
H2	Highly reactive clay sites, which may experience very high ground movement from moisture changes	60 - 75mm
E	Extremely reactive sites, which may experience extreme ground movement from moisture changes	> 75mm
A to P	Filled sites (refer to clause 2.5.3 of AS 2870)	
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.	

Reactive sites are sites consisting of clayey soils that swell on wetting and shrink on drying, resulting in ground movements that can damage lightly loaded structures. The amount of ground movement is related to the physical properties of the clay and environmental factors such as climate, vegetation and watering. A higher probability of damage can occur on reactive sites where abnormal moisture conditions occur, as defined in AS 2870. Details on appropriate site and foundation maintenance practices are presented in Appendix B of AS 2870-2011 and in CSIRO Information Sheet BTF 18, Foundation Maintenance and Footing Performance: A Homeowner's Guide [6], which is attached as Appendix D of this report.

Current laboratory shrink-swell test results, summarised in Table 4.3.1, indicated that the tested clay material within and surrounding the site area was predominantly moderately to highly reactive, with a reported I_{ss} values ranging from 1.9% to 3.6%.

The classification of sites with controlled fill of depths greater than 0.8m in sand and 0.4m in material other than sand (i.e. deep fill) would be classified as Class P. An alternative classification may be given to sites with controlled fill where consideration is made to the potential movement of the fill and underlying soil based on the moisture conditions at the time of construction and the long-term equilibrium moisture conditions. With reference to the current landform, many of the lots may potentially have controlled fill depths greater than 0.4m. However, using AS2870 to assess the surface movement would allow for reclassification of these lots.

Based on the encountered subsurface profile, and in accordance with the AS2870-2011 [3] and in the absence of abnormal moisture conditions, it is expected site classifications at the Site would range from Class S – Slightly Reactive in areas comprising predominately sands, to Class H1 – Highly Reactive in areas predominately comprising highly plastic clays.

Based on the provided plans, significant regrade is proposed to achieve final lot designs. Dependent on the extent of regrade proposed and utilised fill materials assumed to be site won, anticipated surface movement of up to 60mm could occur. As such, lot classifications following regrade are anticipated to range from *Class M to Class H1*.

Following the proposed earthworks activities for the development, reduction of the subsurface cracked zone depth within the lots subject to cutting and filling will result in potentially higher classification depending on the reactivity of the soils to be used as lot filling. The range of classifications assumes that all footings are founded below any topsoil or unsuitable materials, in the natural clay and rock profiles.

Care will be required to manage material to avoid Class H2 to E classifications following regrading activities. This will require placing the more reactive clay fill materials in the lower areas of deeper fill and utilising less reactive clays in the upper layers of the fill profile. Strict moisture control is essential with material being placed as close to SOMC as practical while avoiding placing clays that are wet of optimum, with care taken not to over compact materials. Where high reactivity material is used as fill, the site classifications may increase. Reactive clay material should be placed a suitable distance from the surface to avoid the material impacting negatively on the site classifications. Imported fill should be generally *Iss* ≤1.0% to achieve classifications H1 – Highly reactive and below.

5.6 Footings

All footings should be founded below any topsoil, uncontrolled fill or deleterious materials. All footings for the same structure should be founded on strata of similar stiffness and reactivity to minimise the risk of differential movements.

All footings excavations should be inspected prior to installation of structural steel by a suitably experienced engineer or geotechnical consultant to confirm that the founding conditions are as described in this report. All loose material should be cleared from the footing excavations before concrete is poured.

5.6.1 High Level Footings

High-level footing alternatives could be expected to comprise slabs-on-ground with edge beams or pad footings for the support of concentrated loads. Such footings designed in accordance with engineering principles and founded in stiff or better soils (below topsoil, uncontrolled fill or other deleterious material) may be proportioned on an allowable bearing capacity of 100kPa or 600kPa if founded on rock. The founding conditions should be assessed by a geotechnical consultant or experienced engineer to confirm suitable conditions.

5.6.2 Piered Footings

Piered footings are considered as an alternative to deep edge beams or high-level footings. It is suggested that piered footings, founded in the weathered rock could be proportioned on an end bearing pressure of 600kPa. Piered footings, founded in the stiff or better residual clay could be proportioned on an end bearing pressure of 100kPa.

5.7 Retaining Structures

In the absence of detailed civil design, it is anticipated that retaining walls will be utilised across the proposed development to reduce existing site gradients. All retaining structures in greater than 1.0m in height are to be designed by a suitably qualified engineer. Design of retaining structures should consider the following;

> Surcharge loading from slopes and structures above the wall;

> Account for loading from any proposed compaction or fill behind the wall;

> Provide adequate surface and subsurface drainage behind all retaining walls including a free draining granular backfill to prevent the build-up of hydrostatic pore pressures behind the wall;

> Utilise materials that are not susceptible to deterioration; and

> Ensure all walls are founded in materials appropriate for the loading conditions.

Footings for the proposed retaining walls should be founded below any topsoil, uncontrolled filling, or deleterious materials within the natural residual soils or underlying weathered rock profile.

5.7.1 Retaining Wall Design Parameters

It is anticipated based on encountered subsurface conditions, the proposed retaining walls are expected to predominantly retain granular colluvial materials, natural site clays, and filling materials as part of the site regrade.

It is recommended to calculate the lateral earth coefficient values based on the wall geometry, type and backfill slopes using the values provided in Table 5-3 below. The earth coefficients presented in the following table have been derived assuming level backfill and vertical wall arrangements and may require refinement following detailed civil design.

It should be noted that the retaining wall parameters provided in Table 5-3 below are typical, and could be refined on a wall by wall basis.

Table 5-3 Retaining Wall Design Parameters

Parameter	Stiff (or better) Site CLAYs and Controlled CLAY FILLING
Bulk Unit Weight (kN/m^3)	18
Effective Friction Angle, ϕ'	27°
Effective Cohesion, c'	2 kPa
Undrained Shear Strength, S_U	75kPa
Active Earth Pressure Coefficient, K_A	0.33
Passive Earth Pressure Coefficient, K_P	2.5

Where retaining walls are proposed to be founded within the alluvial profile, foundation treatment may be required comprising removal and replacement of unsuitable material. This would be subject to inspection by a suitably qualified geotechnical consultant.

5.7.2 Rock Excavation Retention

Based on the existing landform, it is expected excavations along the northern boundary will be in the order of 10 m. It is expected a large portion of the excavations are such that the rock will be encountered. Excavations in rock will need to be undertaken under supervision of a geotechnical engineer to provide recommendations of suitable batter angles and remedial options to ensure long term stability of constructed batters.

Results from the investigation indicate the weathered rock is highly fractured with block fracturing evident in test pits. Where excavations into the rock are proposed to stand near vertical, the application of stabilisation treatments such as shotcreting, active/passive mesh, rock anchors or scabbling will be required to prevent erosion and provide long term stability to the face. Allowance should be made for engineering design and construction supervision for stabilisation treatments.

6 Pavement Thickness Design

Pavement thickness design has been undertaken based on the findings of the geotechnical investigation and Mid Coast Council (MCC) requirements. The following guidelines have been adopted for the design of the internal roads:

> Austroads Guide to Pavement Technology, Part 2: Pavement Structural Design (AGPT02-17) [7].

> Mid Coast Council (MCC) AUS-SPEC Infrastructure Specifications – 0042 Pavement Design (November 2020) [8].

6.1 Design Parameters

6.1.1 Design Traffic Loading

Design traffic loading for the internal roads has been adopted from MCC AUS-SPEC 0041 – Geometric Sealed Road Design [9] based on a number lots serviced for each road. Table 6-1 provides a summary of the proposed internal road traffic loading.

Table 6-1 Design Traffic Loading

Road	Designation	Design Traffic (ESA)
Road 1 and 2	Access Street	6.0×10^4
Road 3 and 4	Local Street	3.0×10^5

Notes to table:
ESA: Equivalent Standard Axles

The location and extent of the section of the internal roads are shown in Figure 1, attached in Appendix A. Where traffic data varies from the information provided in this report, review of pavement design and additional consultation with Stantec may be required.

6.1.2 Design Subgrade

Review of the supplied plans in conjunction with the anticipated subsurface conditions encountered at test locations during the investigation, subgrade conditions along the proposed road alignments are expected to comprise a mixture of filling (incl. areas of over-excavated topsoil and colluvial materials), residual clays and weathered rock.

Based on the results of the laboratory testing undertaken as part of the investigation, and encountered subsurface conditions along the proposed road alignments the following design CBR values have been adopted:

> CBR = 3.0%, Residual/Alluvial CLAY and General FILL; and

> CBR = 8.0%, Select FILL overlying 3% CLAY, Aeolian SAND, and SANDSTONE / SILTSTONE.

Dependent on the extent of regrade to the proposed road alignments, colluvial materials may be encountered at design subgrade level. Colluvial materials at design subgrade level may require removal, nominally 300mm, and replacement with site won material, subject to inspection.

Swell testing conducted during CBR testing indicates the subgrade materials have a moderate swell potential as defined in Table 5.2 of Austroads [7]. As a result, the clay subgrade material would have moderate potential for volume change due to moisture variations and strategies to minimise volume change as outlined in clause 5.3.5 of Austroads [7] should be considered. Inspection by a geotechnical consultant to identify the presence of reactive subgrade materials during construction should also be undertaken to determine the need for any implementation of strategies.

Where weathered rock is encountered at design subgrade level for a sufficient length during construction, relative design subgrade CBR values of 8% may be adopted for the proposed subgrade, however would be subject to inspection by an experience geotechnical consultant.

Based on a review of the encountered subsurface conditions in proximity to the proposed road alignments, weathered rock subgrades and associated design CBR, would be anticipated where proposed cut depths are expected to exceed approximately 0.5 to 1.0m below existing natural ground levels.

6.2 Flexible Pavement Design

Pavement design for the proposed internal roads has been undertaken in general accordance with Section 4 of Mid Coast Council's AUS-SPEC Infrastructure Specifications – 0042 Pavement Design [8] and Austroads Part 2 (AGPT02-17) [7].

Design pavement thickness calculated for the internal pavements are summarised in Table 6-2 and Table 6-3 below. It must be noted that the design thickness presented below are minimum thicknesses regardless of construction tolerances.

It should be noted where cul-de-sac/turning heads are proposed, asphalt wearing course is to be increased to 50 mm in accordance with MCC requirements [8], as per note 3 in Table 6-2 and Table 6-3 below.

Table 6-2 Flexible Pavement Thickness Design: Road 1 and 2 - Local Access

Road Name	Road 1 and 2			Recommended Material Type(1)
Wearing Course (2) (3)	40mm (7 mm Primer Seal)	40mm (7 mm Primer Seal)	40mm (7 mm Primer Seal)	AC10 (C320 binder or similar)
Base Course(4)	150mm	150mm	150mm	DGB20(5)
Subbase	180mm	110mm	110mm	DGS20/DGS40(5)
Total Thickness	370mm	300mm	300mm	
Select Thickness(6)	-	300mm	-	CBR ≥ 15%
Subgrade Material	Residual/Alluvial CLAY and General FILLING	Select FILL overlying CLAY	SAND, SANDSTONE/SILTSTONE	
Design Subgrade CBR	3%	3%	8%	
Design Traffic	6.0×10^4 DESA			
Design Life	30 years			

Notes to above tables:
(1) Refer to Section 6.4.2 for material specifications.
(2) Asphalt thickness as per council requirements [8].
(3) Asphalt thickness for turning head / cul-de-sac to be increased to 50 mm.
(4) 150mm basecourse thickness adopted for tie in with kerb and gutter construction.
(5) Additional base material permitted as part of blended material that conforms to TfNSW / RMS material specifications as per MCC specification 1141 [10].
(6) Select fill not included in total pavement thickness.

Table 6-3 Flexible Pavement Thickness Design: Road 3 and 4 - Local Street

Road Name	Road 1 and 2			Recommended Material Type(1)
Wearing Course (2) (3)	40mm (7 mm Primer Seal)	40mm (7 mm Primer Seal)	40mm (7 mm Primer Seal)	AC10 (C320 binder or similar)
Base Course(4)	150mm	150mm	150mm	DGB20(5)
Subbase	260mm	110mm	110mm	DGS20/DGS40(5)
Total Thickness	450mm	300mm	300mm	
Select Thickness(6)	-	300mm	-	CBR ≥ 15%
Subgrade Material	Residual/Alluvial CLAY and General FILLING	Select FILL overlying CLAY	SAND, SANDSTONE/SILTSTONE	
Design Subgrade CBR	3%	3%	8%	
Design Traffic	3.0×10^5 DESA			
Design Life	30 years			

Notes to above tables:
(1) Refer to Section 6.4.2 for material specifications.
(2) Asphalt thickness as per council requirements [8].
(3) Asphalt thickness for turning head / cul-de-sac to be increased to 50 mm.
(4) 150mm basecourse thickness adopted for tie in with kerb and gutter construction.
(5) Additional base material permitted as part of blended material that conforms to TfNSW / RMS material specifications as per MCC specification 1141 [10].
(6) Select fill not included in total pavement thickness.

6.3 Rigid Pavement Design

Review of the supplied documentation indicates the Site is to be accessed through a roundabout intersecting the Site with Croll Street. Standard design practice indicates rigid pavements are most suitable for roundabout pavement design.

The option of roundabout pavement construction utilising rigid pavement materials is detailed below. It should be noted that the layer thicknesses are minimum thicknesses regardless of construction tolerances. Reference should also be made to the material requirement and compaction specification in this report.

Table 6-4 New Pavement Construction: Rigid Pavement – Roundabout

Layer	Thickness	Recommended Material Type (1)
Base	185 mm	SFCP
Subbase	100 mm	DGB20
Subgrade	Residual CLAY / General FILLING / SAND / SILTSTONE / SANDSTONE	Min. 3% CBR
Effective CBR	3%	
Design traffic	4.29×10^5 N_{DT} (2)	

Notes to table:
SFCP: Steel Fibre Reinforced Concrete Pavement.
(1) Refer to Section 6.4.2 for full material specification and compaction requirements.
(2) Design traffic for rigid pavement utilising a 40 year design life.

6.4 Construction Notes

6.4.1 Subgrade Preparation

Subgrade preparation for pavement formation for new pavements could generally be expected to comprise the following.

> Excavation, including removal of all topsoil, unsuitable colluvium (subject to inspection) and uncontrolled filling, to subgrade formation level, with the spoiling of any deleterious or over wet material. Based on the encountered subsurface conditions, subgrade replacement of the colluvial soils may be required with anticipated depths in the order of 0.25 to 0.5m bgl, subject to inspection following the initial removal of topsoil.

> Subgrades in rock are to be thoroughly ripped to a minimum of 300mm below the design subgrade level and to extend to the sides of the formation to provide drainage away from the pavement. Ripped material is to conform to the particle size characteristics described for fill material (200mm or 2/3 compacted layer thickness) and is to be compacted to form the subgrade construction layer unless the ripped material is deemed unsuitable for subgrade purposes.

> Where filling for subgrade is proposed in areas mapped as alluvial deposits, bridging through the use of site won sandstone/siltstone may be required.

> Excavation to design subgrade level, with the stockpiling of the excavated material for reuse as select (if acceptable) following the reconditioning and removal of oversized material.

> Excavation of loose and oversize filling and elimination of abrupt changes between subgrade conditions, such from rock to soil, and from granular fill to fine grained natural soils. Particular care should be taken at the interface of the Aeolian sand beds and the residual clays.

> Identification of the need for removal and replacement of any potential higher reactive clays would be undertaken by visual inspection.

> Fill material to be used as subgrade shall conform to the appropriate specifications as detailed in this report and MCC Specifications.

> Where sections of pavement proposed to comprise a combination of fill and cut as part of the proposed regrade and geometric design, over-excavation and replacement with a suitable fill material may be necessary subject to inspection by an experienced geotechnical consultant.

> Where deep colluvium profiles are present and removal is not viable, moisture reconditioning and blending with a cohesive material may be required under instruction from an experienced geotechnical consultant.

> Proof rolling of the exposed subgrade with a heavy (minimum 10 tonne static) roller. Results of the proof roll could be used to determine the extent of remedial treatment required, as directed by the on-site geotechnical consultant.

> Compaction of the subgrade filling or select should be to at least 100% of SMDD in layers of not greater than 300 mm compacted thickness at a moisture ratio of generally between 60-90% but less than 100% of SOMC.

> Protection of the subgrade to prevent any excessive wetting or drying.

> Formation of the pavement in accordance with the above recommendations and specifications.

It is recommended that trafficking of the subgrade be minimised or avoided (where possible) during construction to prevent the permanent deformation of the subgrade. The boxed road alignment should not be used as a haul road during construction.

Particular care should be taken in the choice of compaction equipment and methods where pavement construction is to be undertaken in the vicinity of existing structures. Observation and monitoring of residences within adjacent residential developments for signs of distress should be undertaken in conjunction with proof rolling and compaction of the subgrade and pavement materials.

6.4.2 Material Specification and Compaction Requirements

6.4.2.1 Flexible Pavement

Flexible pavement materials and compaction requirements for the new pavement construction should conform to Mid Coast Council specifications [10] and the following requirements.

Table 6-5 Pavement Materials and Compaction Requirements

Pavement Course	Material Specification	Compaction Requirements
Wearing Course Asphalt or sprayed seal	Material complying with MCC specifications [11] and [12].	
Basecourse High quality crushed rock	Material complying with MCC requirements [10].	Min 98% Modified Compaction (AS1289 5.2.1) or Min 102% Standard Compaction (AS1289 5.1.1)
Subbase Subbase quality crushed rock	Material complying with MCC requirements [10].	Min 95% Modified Compaction (AS1289 5.2.1) or 100% Standard Compaction (AS1289 5.1.1)
Select Crushed rock or gravel	CBR ≥ 15%	Min 100% Standard Compaction (AS1289 5.1.1)
Subgrade Or replacement	Min CBR 3% Residual/Alluvial Clays and General Fill Min CBR 8% Select Fill, Sandstone/Siltstone, SAND	Min 100% Standard Compaction (AS1289 5.1.1)

Minimum testing on all pavement materials should include a four-day soaked CBR, Atterberg Limits, Particle Size Distribution analysis and Wet/Dry strength determination. Pre-treatment of materials prior to testing would be advisable for material subject to breakdown.

The selection of appropriate construction materials that are durable and insensitive to moisture change is essential in areas subject to periodic inundation and/or wet ground conditions.

6.4.2.2 Rigid Pavement

Rigid pavement materials and compaction requirements for the new pavement construction should conform to MCC requirements and the following requirements.

Table 6-6 Rigid Pavement - Material Specification and Compaction Requirements

Pavement Course	Material Specification	Requirements
Base Concrete Pavement	SFCP concrete, with integrally-cast shoulders	28day compressive strength = 50MPa (1) 28day flexural strength =5.5MPa
Basecourse High quality crushed rock	Material complying with MCC requirements [10].	Min 98% Modified Compaction (AS1289 5.2.1) or Min 102% Standard Compaction (AS1289 5.1.1)
Subgrade or replacement	Minimum CBR 8%	Min 100% Standard (AS 1289 5.1.1)

Notes to table:
(1) Concrete with 50 MPa compressive strength likely required to achieve specified concrete flexural strength.

6.4.3 Wearing Course

Wearing courses should be in accordance with MCC specifications [12] and [11] with consideration to RMS QA Specifications R116 [13] and Austroads AGPT04B-07 Guide to Pavement Technology, Part 4B: Asphalt [14].

The design and construction of wearing courses should be in in consultation with the preferred supplier taking into account traffic volume and type. All pavement surfaces should be primed or primer sealed prior to the application of bituminous spayed seal.

6.4.4 Pavement Compaction

Difficulty obtaining specified compaction requirements can be expected in areas of low strength subgrade. which are evident in areas where the road is to be constructed in fill and firm clays near surface are expected and subgrade replacement is not undertaken. Vibratory compaction can lead to potential problems with the development of excess pore pressures and permanent deformation of the subgrade. Large capacity oscillating rollers are better suited to deep lift compaction. Static or low amplitude rolling may be appropriate in conjunction with thinner layers in poor subgrade areas likely associated with alluvial soils encountered within gully lines.

It is essential to ensure that compaction is achieved though the full thickness of any pavement layers. A rough interface and bond is required between all pavement layers, generally achieved through scarification of the first layer prior to placement and compaction of the second and subsequent pavement layers.

6.4.5 Select / bridging layers

It is anticipated a select / bridging layer may be required in areas comprising alluvial clay subgrade if elevated moisture conditions are present. The suitability of the subgrade and need for a select layer will largely be dependent on the climatic conditions prevailing prior to and at the time of construction and will require assessment by a suitably qualified consultant during construction.

6.4.6 Pavement Drainage

The moisture regime associated with a pavement has a significant influence on the performance of the pavement since the stiffness/strength of the pavement materials and subgrade is dependent on the moisture content of the materials. Accordingly, to protect the pavement materials and subgrade from wetting up and softening, particular care would be required to provide a waterproof seal for the pavement materials and adequate surface and sub-surface drainage of the pavement and adjacent area.

6.4.7 Subsoil Drainage

It is recommended that subsoil drainage be installed at subgrade level along both sides of constructed pavements where the road is in cut, to intercept any subsurface flows. Detailing of subsoil drainage should be in accordance with Austroads 2017 [7].

The subgrade should be constructed with sufficient cross fall (normally 3%) to assist with any moisture entering the pavement not becoming trapped. The drains should be located below or behind the kerb to intercept any moisture ingress from outside and within the road alignment. Where there is no kerb or gutter the subsoil drain should be placed at the edge of the pavement formation. Subsoil drains will require flush-out points and regular maintenance to ensure their correct operation.

Attention to detail in drainage design and construction is essential for optimum performance. Expensive drainage systems can be blocked or otherwise prevented from operating by inappropriate construction procedures or drainage design. Poor performance of a drainage system can, in turn result in major deficiencies in pavement performance. It is acknowledged that provision of adequate surface and subsoil drainage in low-lying areas can be difficult; however, the provision of adequate pavement drainage is essential to performance. In these circumstances, the selection, construction and maintenance of appropriate drainage mechanisms is essential.

The suitability of subsoil drainage systems is dependent on the ability to adequately drain the pavement. Where there is insufficient fall to allow drainage, other pavement drainage measures such as drainage blankets and high permeability non-moisture sensitive pavement materials should be considered. The pavement design provided assumes drained pavement conditions.

The selection of appropriate construction materials that are insensitive to moisture change is essential in areas subject to periodic inundation and/or wet ground conditions.

6.4.8 Pavement Interface and Tie-in

It is recommended that where new pavement sections abut existing sections, the pavement should have a vertical construction joint to match the existing section. It should be noted that when variable pavements are abutted then the potential for localised failure is greater. Care should be exercised in the placement and compaction of the subgrade and pavements in this area to maximise the performance of the pavement.

Consideration should also be given to sealing any cracks that may develop between existing and new pavements, benching to tie in pavements and the use of a strain relieving membranes at the interface may be appropriate. The need for an intra-pavement drain can be assessed at the time of construction.

6.4.9 Inspections

The subgrade will require inspection by an experienced geotechnical consultant after boxing out or before and after filling to design subgrade level. The purpose of inspections is to confirm design parameters, assess the suitability of the subgrade to support the pavement and delineate areas which may require subgrade replacement / select and areas requiring remedial treatment prior to rehabilitation.

6.4.10 References

All works and materials used in construction should be designed and constructed in accordance with Mid Coast Council Specifications or as specified in this report. Where discrepancies may occur, clarification should be sought from Council.

Earthworks and testing should generally be undertaken in accordance with AS 3798-2007 Guidelines on Earthworks for Commercial and Residential Developments [5] where not otherwise specified.

7 Limitations

Stantec has performed investigation and consulting services for this project in general accordance with current professional and industry standards. The extent of testing was limited to discrete test locations and variations in ground conditions can occur between test locations that cannot be inferred or predicted.

A geotechnical consultant or qualified engineer shall provide inspections during construction to confirm assumed conditions in this assessment. If subsurface conditions encountered during construction differ from those given in this report, further advice shall be sought without delay.

Stantec, or any other reputable consultant, cannot provide unqualified warranties nor does it assume any liability for the site conditions not observed or accessible during the investigations. Site conditions may also change subsequent to the investigations and assessment due to ongoing use.

This report and associated documentation was undertaken for the specific purpose described in the report and shall not be relied on for other purposes. This report was prepared solely for the use by Addenbrooke Pty Ltd and any reliance assumed by other parties on this report shall be at such parties own risk.

8 References

[1] Stantec Australia Pty Ltd, “Blueys Beach Development - Overall General Arrangment Plan (50522033-C-1004),” May 2022.

[2] Stantec Australia Pty Ltd, “Blueys Beach Development – Isopach (50522033-C-1008),” May 2022.

[3] Australian Standard AS2870-2011, “Residential Slabs and Footings,” Standards Australia, 2011.

[4] NSW Department of Planning, Industry & Environment, “MinView,” 2019. [Online]. Available: https://minview.geoscience.nsw.gov.au/. [Accessed August 2020].

[5] Australian Standard AS3798-2007, “Guidelines on Earthworks for Commercial and Residential Structures,” Standards Australia, 2007.

[6] Building Technology File 18 (BTF 18), “Foundation Maintenance and Footing Performance: A Homeowner’s Guide,” CSIRO Publishing, 2003.

[7] Austroads AGPT02-17, “Guide to Pavement Technology Part 2: Pavement Structural Design,” Austroads Ltd, 2017.

[8] Mid Coast Council, “AUS-SPEC Infrastructure Specifications – 0042 Pavement Design,” November 2020.

[9] Mid Coast Council, “AUS-SPEC 0041 – Geometric Sealed Road Design,” November 2020.

[10] Mid Coast Council, “AUS-SPEC Infrastructure Specifications - 1141 Flexible Pavement Base and Subbase,” December 2020.

[11] Mid Coast Council , “AUS-SPEC Infrastructure Specifications - 1144 Asphalt (Roadways),” December 2020.

[12] Mid Coast Council, “AUS-SPEC Infrastructure Specifications - 1143 Sprayed Bituminous Surfacing,” December 2020.

[13] RMS QA Specification R116 (Ed 8 Rev 2), “Heavy Duty Dense Graded Asphalt,” Roads and Maritime Services, January 2012.

[14] Austroads AGPT04B-07, Guide to Pavement Technology Part 4B: Asphalt, Austroads Ltd, May 2007.

APPENDIX

A

SITE PLAN

Cardno

now

Stantec

NOTES:

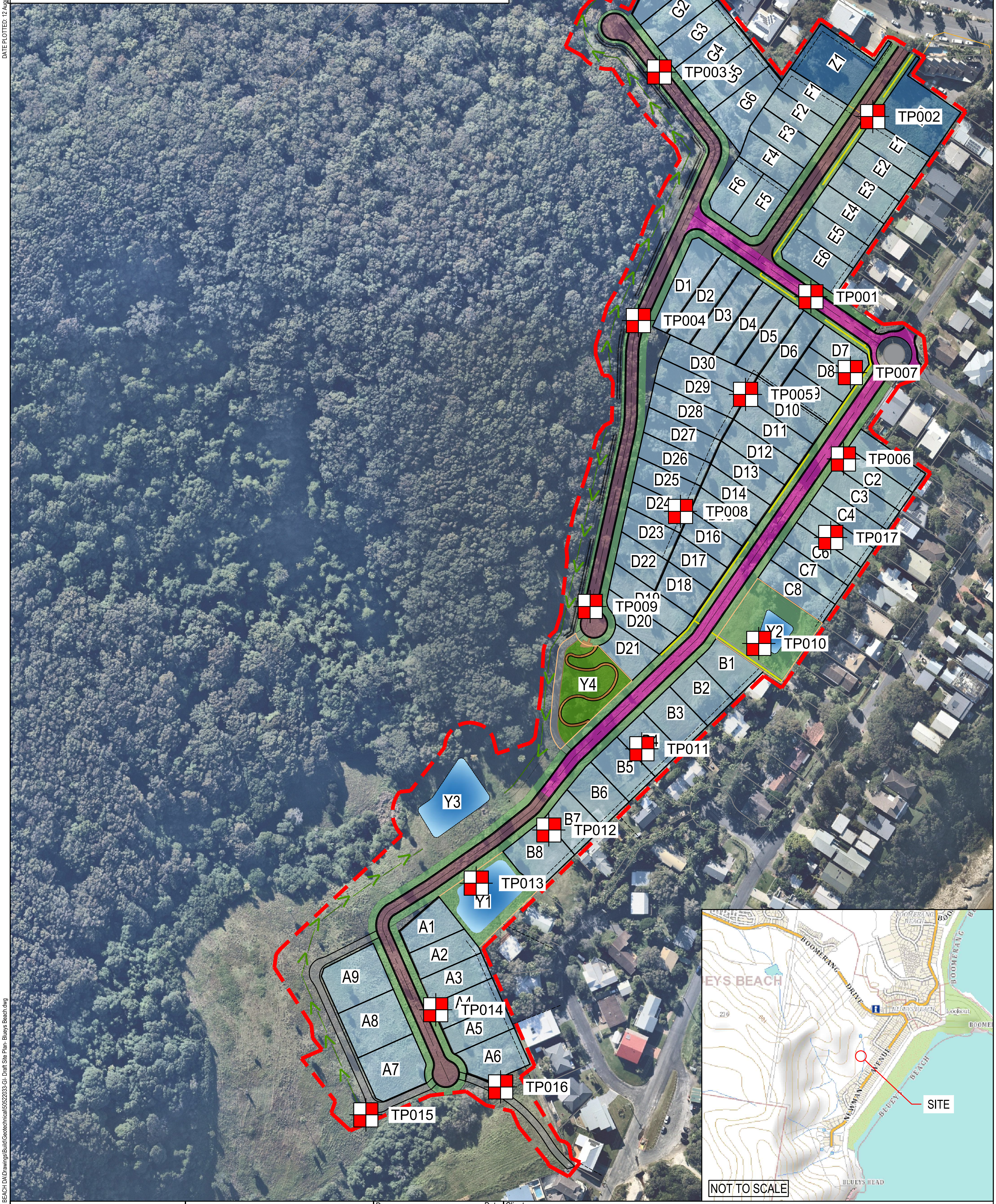
Image underlay adapted from Metromaps aerial imagery.

LEGEND:

TP001 Approximate test pit locations and numbers.

0 50m

SCALE 1:2000 @A3



Cardno
Shaping the Future
Cardno (NSW/ACT) Pty Ltd | ABN 95 001 145 035
Unit 1, 10 Denney Street
Broadmeadow, NSW 2292
Tel: 02 4965 4555 Fax: 02 4965 4666
Web: www.cardno.com.au

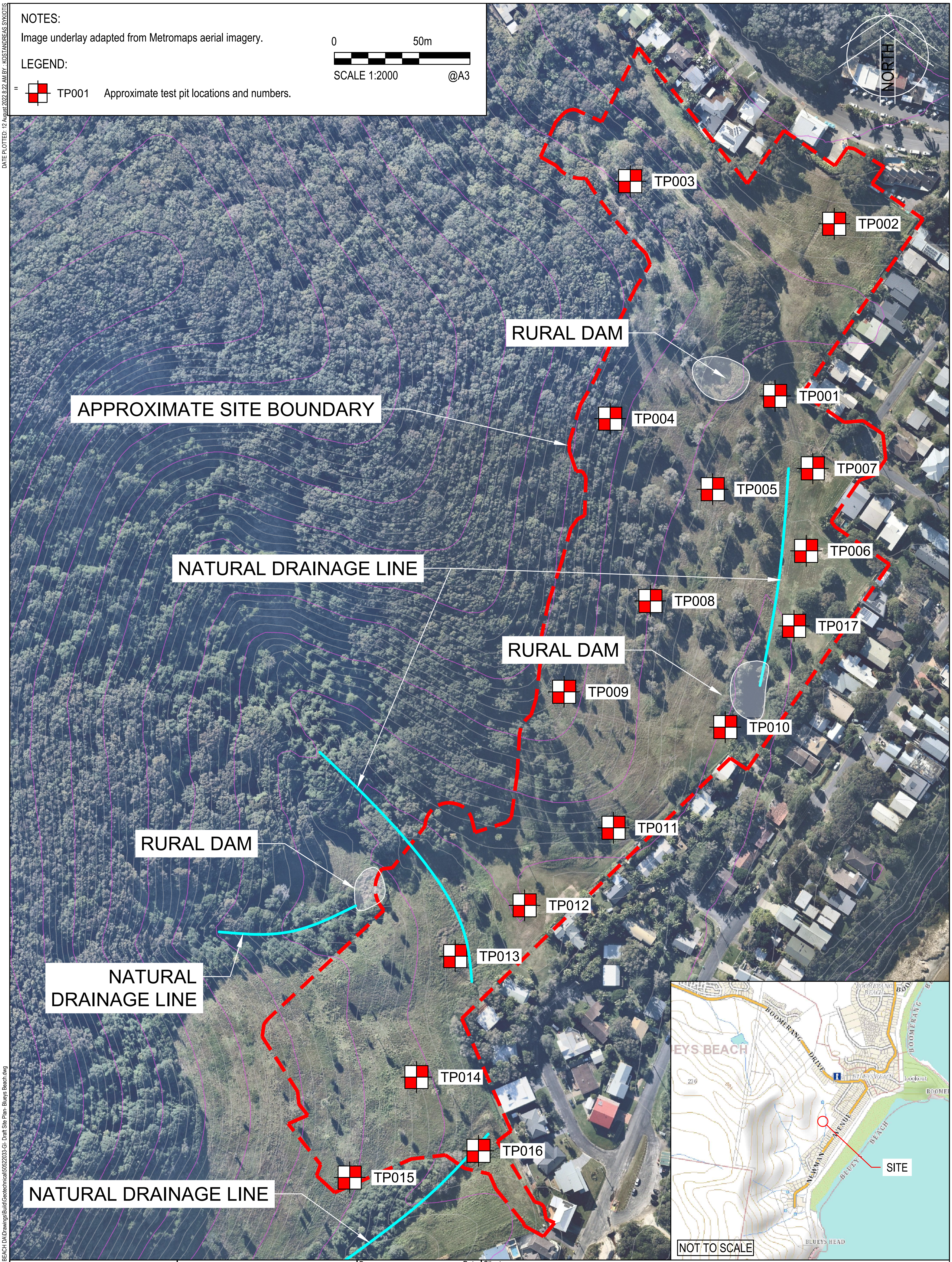
Drawn KS	Date 7/6/2022	Client	Addenbrooke Pty Ltd
Checked IGP	Date 7/6/2022	Project	Blueys Beach Residential Development Blueys Beach, NSW
Designed	Date		
Verified	Date	Title	Geotechnical Investigation Figure 1 Lot Layout Plan
Approved			

Status PRELIMINARY NOT TO BE USED FOR CONSTRUCTION PURPOSES		
Project Number 50522033	Scale 1:2000	Size A3
Drawing Number Figure 1		Revision 001

DATE PLOTTED: 12 August 2022 8:55 AM BY : KOSTANDREAS SYKIOTIS

XREF's: X-Lot Areas_Option C; X-Final Lot Areas_Option E

CAD File: A:\Projects\505\FY22\033_BLUEYS BEACH DA\Drawings\Build\Geotechnical\50522033-GI- Draft Site Plan- Blueys Beach.dwg



Cardno
Shaping the Future
Cardno (NSW/ACT) Pty Ltd | ABN 95 001 145 035
Unit 1, 10 Denney Street
Broadmeadow, NSW 2292
Tel: 02 4965 4555 Fax: 02 4965 4666
Web: www.cardno.com.au

Drawn KS	Date 7/6/2022	Client: Addenbrooke Pty Ltd
Checked IGP	Date 7/6/2022	Project: Blueys Beach Residential Development Blueys Beach, NSW
Designed	Date	Status: PRELIMINARY NOT TO BE USED FOR CONSTRUCTION PURPOSES
Verified	Date	Project Number 50522033 / Scale 1:2000 / Size A3
Approved		Title: Geotechnical Investigation Figure 2 Contour Plan
		Drawing Number Figure 2 / Revision 001

DATE PLOTTED: 12 August 2022 8:22 AM BY : KOSTANDREAS SYKIOTIS
XREF's: X-Lot Areas_Option C; X-Final Lot Areas_Option E
CAD File: A:\Projects\505\FY22\033_BLUEYS BEACH DA\Drawings\Build\Geotechnical\50522033-GI- Draft Site Plan- Blueys Beach.dwg

DATE PLOTTED: 12 August 2022 9:30 AM BY : KOSTANDREAS SYKIOTIS

NOTES:

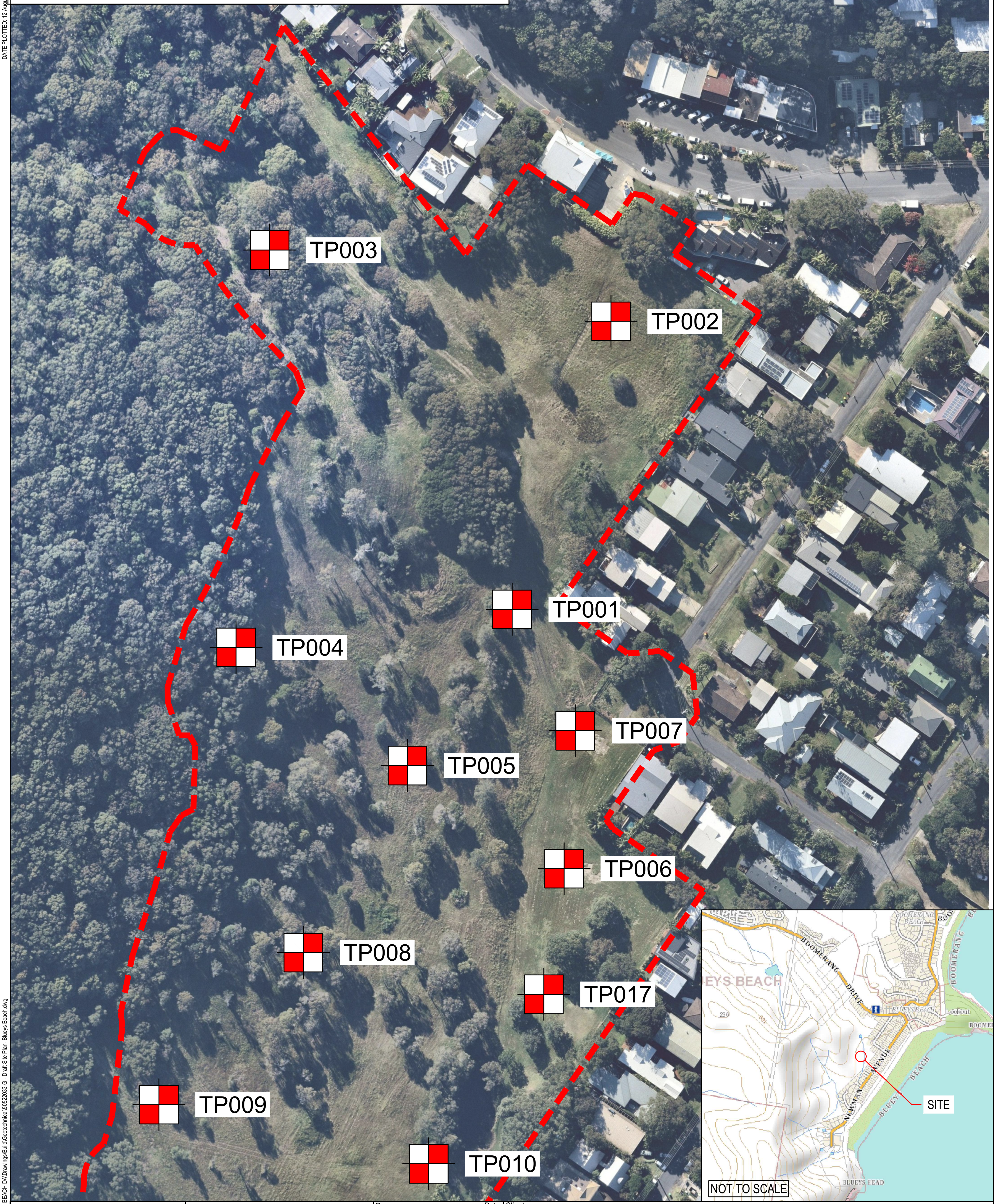
Image underlay adapted from Metromaps aerial imagery.

LEGEND:

= TP001 Approximate test pit locations and numbers.

0 25 50m

SCALE 1:1250 @A3



XREF's: X-Lot Areas_Option C; X-Final Lot Areas_Option E

CAD File: A:\Projects\505\FY22\033_BLUEYS BEACH DA\Drawings\Build\Geotechnical\50522033-GI- Draft Site Plan- Blueys Beach.dwg

Cardno
Shaping the Future
Cardno (NSW/ACT) Pty Ltd | ABN 95 001 145 035
Unit 1, 10 Denney Street
Broadmeadow, NSW 2292
Tel: 02 4965 4555 Fax: 02 4965 4666
Web: www.cardno.com.au

Drawn KS	Date 7/6/2022	Client	Addenbrooke Pty Ltd
Checked IGP	Date 7/6/2022	Project	Blueys Beach Residential Development Blueys Beach, NSW
Designed	Date		
Verified	Date	Title	Geotechnical Investigaiton Figure 3 Test Pit Location Plan
Approved			

Status			
PRELIMINARY NOT TO BE USED FOR CONSTRUCTION PURPOSES			
Project Number 50522033	Scale 1:1250	Size A3	
Drawing Number Figure 3		Revision 001	

NOTES:

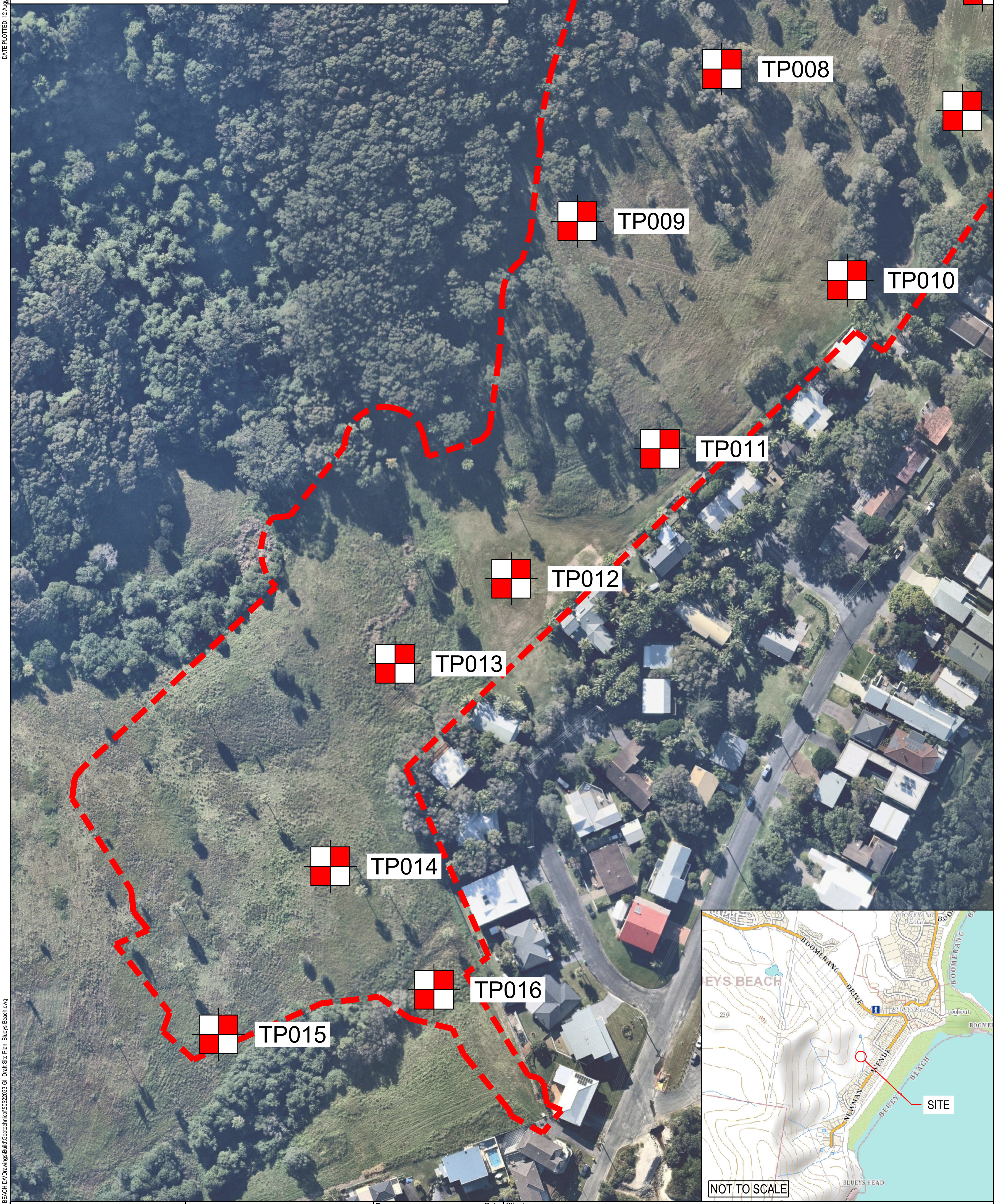
Image underlay adapted from Metromaps aerial imagery.

LEGEND:

TP001 Approximate test pit locations and numbers.

0 25 50m

SCALE 1:1250 @A3



Cardno
Shaping the Future
Cardno (NSW/ACT) Pty Ltd | ABN 95 001 145 035
Unit 1, 10 Denney Street
Broadmeadow, NSW 2292
Tel: 02 4965 4555 Fax: 02 4965 4666
Web: www.cardno.com.au

Drawn KS	Date 7/6/2022	
Checked IGP	Date 7/6/2022	
Designed	Date	
Verified	Date	
Approved		

Client: Addenbrooke Pty Ltd

Project: Blueys Beach Residential Development Blueys Beach, NSW

Title: Geotechnical Investigaiton Figure 4 Test Pit Location Plan

Status: PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION PURPOSES

Project Number	Scale	Size
50522033	1:1250	A3

Drawing Number	Revision
Figure 4	001

DATE PLOTTED: 12 August 2022 9:28 AM BY: KOSTANDREAS SYKIOTIS

XREF's: X-Lot Areas_Option C; X-Final Lot Areas_Option E
CAD File: A:\Projects\505\FY22\033_BLUEYS BEACH DA\Drawings\Build\Geotechnical\50522033-GI- Draft Site Plan- Blueys Beach.dwg

NOTES:

Image underlay adapted from Metromaps aerial imagery.

LEGEND:

TB00X Approximate test bore locations and numbers.

0 5 10m

SCALE 1:300 @A3

Cardno
Shaping the Future
Cardno (NSW/ACT) Pty Ltd | ABN 95 001 145 035
Unit 1, 10 Denney Street
Broadmeadow, NSW 2292
Tel: 02 4965 4555 Fax: 02 4965 4666
Web: www.cardno.com.au

Drawn KS	Date 7/6/2022	Client	Croll Street
Checked IGP	Date 7/6/2022	Project	Blueys Beach Residential Development Blueys Beach, NSW
Designed	Date	Title	Geotechnical Investigaiton Figure 5 Croll Street
Verified	Date		
Approved			

Status: PRELIMINARY NOT TO BE USED FOR CONSTRUCTION PURPOSES		
Project Number 50522033	Scale 1:300	Size A3
Drawing Number Figure 5		Revision 001

DATE PLOTTED: 12 August 2022 9:27 AM BY : KOSTANDREAS SYKIOTIS

XREFs: X-Lot Areas_Option C; X-Final Lot Areas_Option E

CAD File: A:\Projects\505\FY22\033_BLUEYS BEACH DA\Drawings\Build\Geotechnical\50522033-GI- Draft Site Plan- Blueys Beach.dwg

APPENDIX

B

ENGINEERING LOGS

TEST PIT LOG SHEET

Client: Addenbrooke Pty Ltd
Project: Blueys Beach Subdivision
Location: Blueys Beach

Hole No: TP001

Job No: 50522033
Sheet: 1 of 1

Position: Refer to site plan	**Angle from Horizontal:** 90°	**Surface Elevation:**
Machine Type: 13.5 tonne Excavator	**Excavation Method:** 800mm Tooth Bucket	
Excavation Dimensions:		**Contractor:** Cardno
Date Excavated: 24/1/22	**Logged By:** KS	**Checked By:** GA

Method	Resistance	Stability	Water	Sample or Field Test	DCP (blows per 150 mm)	Depth (m)	Classification	SOIL TYPE, plasticity or particle characteristic, colour, secondary and minor components ROCK TYPE, grain size and type, colour, fabric & texture, strength, weathering, defects and structure	Moisture Condition	Consistency Relative Density	STRUCTURE & Other Observations
EX	E	Stable	Groundwater Not Encountered			0.00–0.10m	CL	Silty CLAY: low plasticity, dark brown, with fine to coarse grained sand, trace fine to medium sub-angular gravel	M (<PL)	St	TOPSOIL 0.00 m: Organically impacted to 0.1 m from surface.
				ES 0.10 - 0.20 m ES1		0.10–0.30m	CL	Silty CLAY: low plasticity, dark brown, with fine to coarse grained sand, trace fine to medium sub-angular gravel			COLLUVIUM
						0.30–0.85m	CH	CLAY: high plasticity, grey mottled yellow and red, with silt	M (≈PL)	St	RESIDUAL SOIL
						0.85–2.20m	CH	Silty CLAY: high plasticity, grey mottled red, trace fine to coarse grained sand	M (≈PL)	St to VSt	
	F					2.20–3.00m	CI	Silty CLAY: medium plasticity, pale grey mottled orange and red, with fine sub-angular ironstone gravel, trace fine to coarse grained sand	M (≈PL)	H	EXTREMELY WEATHERED
						3.00m		TERMINATED AT 3.00 m Target depth			

DCP scale: 1 3 6 12

METHOD
EX Excavator bucket
R Ripper
HA Hand auger
PT Push tube
SON Sonic drilling
AH Air hammer
PS Percussion sampler
AS Short spiral auger
AD/V Solid flight auger: V-Bit
AD/T Solid flight auger: TC-Bit
HFA Hollow flight auger
WB Washbore drilling
RR Rock roller

PENETRATION
VE Very Easy (No Resistance)
E Easy
F Firm
H Hard
VH Very Hard (Refusal)

WATER
Water Level on Date shown
water inflow
water outflow

FIELD TESTS
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer
DCP - Dynamic Cone Penetrometer
PSP - Perth Sand Penetrometer
MC - Moisture Content
PBT - Plate Bearing Test
IMP - Borehole Impression Test
PID - Photoionisation Detector
VS - Vane Shear; P=Peak, R=Resdual (uncorrected kPa)

SAMPLES
B - Bulk disturbed sample
D - Disturbed sample
ES - Environmental sample
U - Thin wall tube 'undisturbed'

MOISTURE
D - Dry
M - Moist
W - Wet
PL - Plastic limit
LL - Liquid limit
w - Moisture content

SOIL CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

Refer to explanatory notes for details of abbreviations and basis of descriptions

CARDNO (NSW/ACT) PTY LTD

Cardno

TEST PIT LOG SHEET

Client: Addenbrooke Pty Ltd
Project: Blueys Beach Subdivision
Location: Blueys Beach

Hole No: TP002

Job No: 50522033
Sheet: 1 of 1

Position: Refer to site plan	**Angle from Horizontal:** 90°	**Surface Elevation:**
Machine Type: 13.5 tonne Excavator	**Excavation Method:** 800mm Tooth Bucket	
Excavation Dimensions:		**Contractor:** Cardno
Date Excavated: 24/1/22	**Logged By:** KS	**Checked By:** GA

Method	Resistance	Stability	Water	Sample or Field Test	DCP (blows per 150 mm) 1 3 6 12	Depth (m)	Graphic Log	Classification	SOIL TYPE, plasticity or particle characteristic, colour, secondary and minor components ROCK TYPE, grain size and type, colour, fabric & texture, strength, weathering, defects and structure	Moisture Condition	Consistency Relative Density	STRUCTURE & Other Observations
EX	E	Stable	Groundwater Not Encountered	ES 0.00 - 0.10 m ES3				CL	0.10m Sandy CLAY: low plasticity, dark brown-black, fine to coarse grained sand, with fine to coarse, sub-angular to angular gravel, trace cobbles			TOPSOIL 0.00 m: Organically impacted to 0.1 m from surface.
						0.5		CL	0.55m Sandy CLAY: low plasticity, dark brown-black, fine to coarse grained sand, with fine to coarse, sub-angular to angular gravel, trace cobbles	M (<PL)	St	COLLUVIUM
				B 0.60 - 0.80 m	REF			CH	0.90m CLAY: high plasticity, grey mottled yellow, with fine to coarse, angular gravel, with silt	M (≈PL)	St	RESIDUAL SOIL
	F					1.0			SILTSTONE, grey mottled yellow, highly weathered			WEATHERED ROCK
	H					1.5						
	VH								1.90m As above; decrease in fracturing/defects			
						2.0			TERMINATED AT 1.90 m Refusal / Slow Progress on Weathered Rock			
						2.5						
						3.0						

METHOD
- EX Excavator bucket
- R Ripper
- HA Hand auger
- PT Push tube
- SON Sonic drilling
- AH Air hammer
- PS Percussion sampler
- AS Short spiral auger
- AD/V Solid flight auger: V-Bit
- AD/T Solid flight auger: TC-Bit
- HFA Hollow flight auger
- WB Washbore drilling
- RR Rock roller

PENETRATION
- VE Very Easy (No Resistance)
- E Easy
- F Firm
- H Hard
- VH Very Hard (Refusal)

WATER
- Water Level on Date shown
- water inflow
- water outflow

FIELD TESTS
- SPT - Standard Penetration Test
- HP - Hand/Pocket Penetrometer
- DCP - Dynamic Cone Penetrometer
- PSP - Perth Sand Penetrometer
- MC - Moisture Content
- PBT - Plate Bearing Test
- IMP - Borehole Impression Test
- PID - Photoionisation Detector
- VS - Vane Shear; P=Peak, R=Resdual (uncorrected kPa)

SAMPLES
- B - Bulk disturbed sample
- D - Disturbed sample
- ES - Environmental sample
- U - Thin wall tube 'undisturbed'

MOISTURE
- D - Dry
- M - Moist
- W - Wet
- PL - Plastic limit
- LL - Liquid limit
- *w* - Moisture content

SOIL CONSISTENCY
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard

RELATIVE DENSITY
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

Refer to explanatory notes for details of abbreviations and basis of descriptions

CARDNO (NSW/ACT) PTY LTD

TEST PIT LOG SHEET

Client: Addenbrooke Pty Ltd
Project: Blueys Beach Subdivision
Location: Blueys Beach

Hole No: TP003

Job No: 50522033
Sheet: 1 of 1

Position: Refer to site plan	**Angle from Horizontal:** 90°	**Surface Elevation:**
Machine Type: 13.5 tonne Excavator	**Excavation Method:** 800mm Tooth Bucket	
Excavation Dimensions:		**Contractor:** Cardno
Date Excavated: 24/1/22	**Logged By:** KS	**Checked By:** GA

Method	Resistance	Stability	Water	Sample or Field Test	DCP (blows per 150 mm)	Depth (m)	Classification	SOIL TYPE, plasticity or particle characteristic, colour, secondary and minor components ROCK TYPE, grain size and type, colour, fabric & texture, strength, weathering, defects and structure	Moisture Condition	Consistency Relative Density	STRUCTURE & Other Observations
EX	E-F	Stable	Groundwater Not Encountered			0.00–0.10m	SM	Silty SAND: fine to coarse grained, grey, with fine angular gravel	D	St	TOPSOIL 0.00 m: Organically impacted to 0.1 m from surface.
EX	E-F	Stable				0.10–0.50m	GP	Sandy GRAVEL: fine to coarse, sub-angular to angular, grey, fine to coarse grained sand	D	MD	COLLUVIUM
EX	H	Stable			REF	0.50–1.00m		SANDSTONE, fine to medium grained, grey mottled yellow, highly weathered			WEATHERED ROCK
EX	VH	Stable				1.00–1.20m		As above; decrease in fracturing/defects			
						1.20m		TERMINATED AT 1.20 m Refusal / Slow Progress on Weathered Rock			

Depth scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0; DCP scale: 1 3 6 12

METHOD
EX - Excavator bucket
R - Ripper
HA - Hand auger
PT - Push tube
SON - Sonic drilling
AH - Air hammer
PS - Percussion sampler
AS - Short spiral auger
AD/V - Solid flight auger: V-Bit
AD/T - Solid flight auger: TC-Bit
HFA - Hollow flight auger
WB - Washbore drilling
RR - Rock roller

PENETRATION
VE - Very Easy (No Resistance)
E - Easy
F - Firm
H - Hard
VH - Very Hard (Refusal)

WATER
Water Level on Date shown
water inflow
water outflow

FIELD TESTS
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer
DCP - Dynamic Cone Penetrometer
PSP - Perth Sand Penetrometer
MC - Moisture Content
PBT - Plate Bearing Test
IMP - Borehole Impression Test
PID - Photoionisation Detector
VS - Vane Shear; P=Peak, R=Resdual (uncorrected kPa)

SAMPLES
B - Bulk disturbed sample
D - Disturbed sample
ES - Environmental sample
U - Thin wall tube 'undisturbed'

MOISTURE
D - Dry
M - Moist
W - Wet
PL - Plastic limit
LL - Liquid limit
w - Moisture content

SOIL CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

Refer to explanatory notes for details of abbreviations and basis of descriptions

CARDNO (NSW/ACT) PTY LTD

CARDNO 2.01.6 LIB.GLB Log CARDNO NON-CORED 50522033 BLUEYS BEACH SUBDIVISION.GPJ <<DrawingFile>> 12/08/2022 10:59 10.02.00.04 Datgel AGS RTA, Photo, Monitoring Tools

TEST PIT LOG SHEET

Client: Addenbrooke Pty Ltd
Project: Blueys Beach Subdivision
Location: Blueys Beach

Hole No: TP004

Job No: 50522033 **Sheet:** 1 of 1

Position: Refer to site plan	**Angle from Horizontal:** 90°	**Surface Elevation:**
Machine Type: 13.5 tonne Excavator	**Excavation Method:** 800mm Tooth Bucket	
Excavation Dimensions:		**Contractor:** Cardno
Date Excavated: 24/1/22	**Logged By:** KS	**Checked By:** GA

Method	Resistance	Stability	Water	Sample or Field Test	DCP (blows per 150 mm) 1 3 6 12	Depth (m)	Classification	SOIL TYPE, plasticity or particle characteristic, colour, secondary and minor components ROCK TYPE, grain size and type, colour, fabric & texture, strength, weathering, defects and structure	Moisture Condition	Consistency Relative Density	STRUCTURE & Other Observations
EX	E-F	Stable	Groundwater Not Encountered			0.20m	SM	Silty SAND: fine to coarse grained, grey, with fine angular gravel	D	St	TOPSOIL 0.00 m: Organically impacted to 0.1 m from surface.
						0.45m	CI	Gravelly CLAY: medium plasticity, yellow mottled grey, fine to coarse, sub-angular to angular gravel, with fine to coarse grained sand	M (<PL)	St	COLLUVIUM
						1.30m	GC	Clayey GRAVEL: fine to coarse, angular, grey mottled yellow, with cobbles, trace fine to coarse grained sand	M (<PL)	L	EXTREMELY WEATHERED
	H				REF	1.40m		SANDSTONE, fine to medium grained, blue grey mottled yellow			WEATHERED ROCK
								TERMINATED AT 1.40 m Refusal / Slow Progress on Weathered Rock			

Depth scale (m): 0.5, 1.0, 1.5, 2.0, 2.5, 3.0

METHOD
- EX Excavator bucket
- R Ripper
- HA Hand auger
- PT Push tube
- SON Sonic drilling
- AH Air hammer
- PS Percussion sampler
- AS Short spiral auger
- AD/V Solid flight auger: V-Bit
- AD/T Solid flight auger: TC-Bit
- HFA Hollow flight auger
- WB Washbore drilling
- RR Rock roller

PENETRATION
- VE Very Easy (No Resistance)
- E Easy
- F Firm
- H Hard
- VH Very Hard (Refusal)

WATER
- Water Level on Date shown
- water inflow
- water outflow

FIELD TESTS
- SPT - Standard Penetration Test
- HP - Hand/Pocket Penetrometer
- DCP - Dynamic Cone Penetrometer
- PSP - Perth Sand Penetrometer
- MC - Moisture Content
- PBT - Plate Bearing Test
- IMP - Borehole Impression Test
- PID - Photoionisation Detector
- VS - Vane Shear; P=Peak, R=Resdual (uncorrected kPa)

SAMPLES
- B - Bulk disturbed sample
- D - Disturbed sample
- ES - Environmental sample
- U - Thin wall tube 'undisturbed'

MOISTURE
- D - Dry
- M - Moist
- W - Wet
- PL - Plastic limit
- LL - Liquid limit
- *w* - Moisture content

SOIL CONSISTENCY
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard

RELATIVE DENSITY
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

Refer to explanatory notes for details of abbreviations and basis of descriptions

CARDNO (NSW/ACT) PTY LTD

Cardno

TEST PIT LOG SHEET

Client: Addenbrooke Pty Ltd
Project: Blueys Beach Subdivision
Location: Blueys Beach

Hole No: TP005

Job No: 50522033
Sheet: 1 of 1

Position: Refer to site plan
Angle from Horizontal: 90°
Surface Elevation:

Machine Type: 13.5 tonne Excavator
Excavation Method: 800mm Tooth Bucket

Excavation Dimensions:
Contractor: Cardno

Date Excavated: 24/1/22
Logged By: KS
Checked By: GA

Method	Resistance	Stability	Water	Sample or Field Test	Depth (m)	Classification	Material Description	Moisture Condition	Consistency Relative Density	STRUCTURE & Other Observations
EX	E-F	Stable	Groundwater Not Encountered		0.00–0.10	CL	Sandy Silty CLAY: low plasticity, dark brown-black, fine to coarse grained sand	M (<PL)	St	TOPSOIL 0.00 m: Organically impacted to 0.1 m from surface.
					0.10–0.30	CL	Sandy Silty CLAY: low plasticity, dark brown-black, fine to coarse grained sand			COLLUVIUM
				B 0.80 - 1.00 m 2 x B	0.30–1.80	CI-CH	Silty CLAY: medium to high plasticity, grey mottled white and orange, with fine to medium, angular gravel, trace fine to coarse grained sand	M (>PL)	St / VSt	RESIDUAL SOIL
	F				1.80–3.00	CI	Silty CLAY: medium plasticity, pale grey mottled orange and red, with fine to coarse, angular gravel, trace fine to coarse grained sand	M (>PL)	H	
					3.00		TERMINATED AT 3.00 m Target depth			

DCP (blows per 150 mm) scale: 1 3 6 12

METHOD
EX - Excavator bucket
R - Ripper
HA - Hand auger
PT - Push tube
SON - Sonic drilling
AH - Air hammer
PS - Percussion sampler
AS - Short spiral auger
AD/V - Solid flight auger: V-Bit
AD/T - Solid flight auger: TC-Bit
HFA - Hollow flight auger
WB - Washbore drilling
RR - Rock roller

PENETRATION
VE - Very Easy (No Resistance)
E - Easy
F - Firm
H - Hard
VH - Very Hard (Refusal)

WATER
Water Level on Date shown
water inflow
water outflow

FIELD TESTS
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer
DCP - Dynamic Cone Penetrometer
PSP - Perth Sand Penetrometer
MC - Moisture Content
PBT - Plate Bearing Test
IMP - Borehole Impression Test
PID - Photoionisation Detector
VS - Vane Shear; P=Peak, R=Resdual (uncorrected kPa)

SAMPLES
B - Bulk disturbed sample
D - Disturbed sample
ES - Environmental sample
U - Thin wall tube 'undisturbed'

MOISTURE
D - Dry
M - Moist
W - Wet
PL - Plastic limit
LL - Liquid limit
w - Moisture content

SOIL CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

Refer to explanatory notes for details of abbreviations and basis of descriptions

TEST PIT LOG SHEET

Client: Addenbrooke Pty Ltd
Project: Blueys Beach Subdivision
Location: Blueys Beach

Hole No: TP006

Job No: 50522033 | **Sheet:** 1 of 1

Position: Refer to site plan | **Angle from Horizontal:** 90° | **Surface Elevation:**

Machine Type: 13.5 tonne Excavator | **Excavation Method:** 800mm Tooth Bucket

Excavation Dimensions: | **Contractor:** Cardno

Date Excavated: 24/1/22 | **Logged By:** KS | **Checked By:** GA

Method	Resistance	Stability	Water	Sample or Field Test	Depth (m)	Classification	SOIL TYPE, plasticity or particle characteristic, colour, secondary and minor components ROCK TYPE, grain size and type, colour, fabric & texture, strength, weathering, defects and structure	Moisture Condition	Consistency Relative Density	STRUCTURE & Other Observations
EX	E	Stable	Groundwater Not Encountered		0.15m		Silty SAND: fine to coarse grained, dark grey	D	MD	TOPSOIL 0.00 m: Organically impacted to 0.1 m from surface.
					1.10m		SAND: fine to medium grained, pale grey	D	L to MD	AEOLIAN
				ASS 1.20 - 1.30 m ASS1	2.20m		SAND: fine to medium grained, brown, with silt	M	L to MD	ALLUVIUM
				ASS 2.30 - 2.40 m ASS2	2.90m		SAND: fine to coarse grained, mottled brown and black, with clay	M	L to MD	
				ASS 2.90 - 3.00 m ASS3	3.30m		Clayey SAND: fine to coarse grained, brown	M	L to MD	
							TERMINATED AT 3.30 m Target depth			

DCP (blows per 150 mm): 1 3 6 12

METHOD
EX Excavator bucket
R Ripper
HA Hand auger
PT Push tube
SON Sonic drilling
AH Air hammer
PS Percussion sampler
AS Short spiral auger
AD/V Solid flight auger: V-Bit
AD/T Solid flight auger: TC-Bit
HFA Hollow flight auger
WB Washbore drilling
RR Rock roller

PENETRATION
VE Very Easy (No Resistance)
E Easy
F Firm
H Hard
VH Very Hard (Refusal)

WATER
Water Level on Date shown
water inflow
water outflow

FIELD TESTS
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer
DCP - Dynamic Cone Penetrometer
PSP - Perth Sand Penetrometer
MC - Moisture Content
PBT - Plate Bearing Test
IMP - Borehole Impression Test
PID - Photoionisation Detector
VS - Vane Shear; P=Peak, R=Resdual (uncorrected kPa)

SAMPLES
B - Bulk disturbed sample
D - Disturbed sample
ES - Environmental sample
U - Thin wall tube 'undisturbed'

MOISTURE
D - Dry
M - Moist
W - Wet
PL - Plastic limit
LL - Liquid limit
w - Moisture content

SOIL CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

Refer to explanatory notes for details of abbreviations and basis of descriptions

CARDNO (NSW/ACT) PTY LTD

TEST PIT LOG SHEET

Client: Addenbrooke Pty Ltd
Project: Blueys Beach Subdivision
Location: Blueys Beach
Job No: 50522033
Hole No: TP007
Sheet: 1 of 1

Position: Refer to site plan
Angle from Horizontal: 90°
Surface Elevation:
Machine Type: 13.5 tonne Excavator
Excavation Method: 800mm Tooth Bucket
Excavation Dimensions:
Contractor: Cardno
Date Excavated: 24/1/22
Logged By: KS
Checked By: GA

Method	Resistance	Stability	Water	Sample or Field Test	DCP (blows per 150 mm)	Depth (m)	Graphic Log	Classification	SOIL TYPE, plasticity or particle characteristic, colour, secondary and minor components ROCK TYPE, grain size and type, colour, fabric & texture, strength, weathering, defects and structure	Moisture Condition	Consistency Relative Density	STRUCTURE & Other Observations
EX	E	Unstable	Groundwater Not Encountered	ES 0.05 - 0.15 m ES4		0.20m			Silty SAND: fine to coarse grained, dark grey	D	MD	TOPSOIL 0.00 m: Organically impacted to 0.1 m from surface.
				B 0.40 - 0.60 m		2.90m			SAND: fine to medium grained, pale grey	M	L	AEOLIAN
									TERMINATED AT 2.90 m Collapse			

METHOD
EX Excavator bucket
R Ripper
HA Hand auger
PT Push tube
SON Sonic drilling
AH Air hammer
PS Percussion sampler
AS Short spiral auger
AD/V Solid flight auger: V-Bit
AD/T Solid flight auger: TC-Bit
HFA Hollow flight auger
WB Washbore drilling
RR Rock roller

PENETRATION
VE Very Easy (No Resistance)
E Easy
F Firm
H Hard
VH Very Hard (Refusal)

WATER
Water Level on Date shown
water inflow
water outflow

FIELD TESTS
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer
DCP - Dynamic Cone Penetrometer
PSP - Perth Sand Penetrometer
MC - Moisture Content
PBT - Plate Bearing Test
IMP - Borehole Impression Test
PID - Photoionisation Detector
VS - Vane Shear; P=Peak, R=Resdual (uncorrected kPa)

SAMPLES
B - Bulk disturbed sample
D - Disturbed sample
ES - Environmental sample
U - Thin wall tube 'undisturbed'

MOISTURE
D - Dry
M - Moist
W - Wet
PL - Plastic limit
LL - Liquid limit
w - Moisture content

SOIL CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

Refer to explanatory notes for details of abbreviations and basis of descriptions

CARDNO (NSW/ACT) PTY LTD

TEST PIT LOG SHEET

Hole No: TP008

Client: Addenbrooke Pty Ltd			
Project: Blueys Beach Subdivision			
Location: Blueys Beach	**Job No:** 50522033		**Sheet:** 1 of 1
Position: Refer to site plan	**Angle from Horizontal:** 90°	**Surface Elevation:**	
Machine Type: 13.5 tonne Excavator	**Excavation Method:** 800mm Tooth Bucket		
Excavation Dimensions:		**Contractor:** Cardno	
Date Excavated: 24/1/22	**Logged By:** KS	**Checked By:** GA	

Method	Resistance	Stability	Water	Sample or Field Test	DCP (blows per 150 mm)	Depth (m)	Classification	SOIL TYPE, plasticity or particle characteristic, colour, secondary and minor components ROCK TYPE, grain size and type, colour, fabric & texture, strength, weathering, defects and structure	Moisture Condition	Consistency Relative Density	STRUCTURE & Other Observations
EX	E-F	Stable	Groundwater Not Encountered			0.10m	CI	Silty CLAY: medium plasticity, dark brown-black, trace fine to coarse gained sand, trace fine to coarse, angular gravel	M (<PL)	St	TOPSOIL 0.00 m: Organically impacted to 0.1 m from surface.
						0.25m	CI	Silty CLAY: medium plasticity, dark brown-black, trace fine to coarse gained sand, trace fine to coarse, angular gravel			COLLUVIUM
					REF	0.55m	CI	Sandy CLAY: medium plasticity, yellow brown mottled orange, fine to coarse grained sand, trace fine, angular gravel	M (<PL)	St	RESIDUAL SOIL
				B 0.65 - 0.85 m		0.90m	CI	Gravelly CLAY: medium plasticity, pale grey mottled yellow, fine to coarse, angular gravel	M (>PL)	H	
	F / VH					1.40m		SILTSTONE, fine grained, blue-grey mottled yellow As above; decrease in fracturing/defects			WEATHERED ROCK
								TERMINATED AT 1.40 m Refusal / Slow Progress on Weathered Rock			

DCP scale: 1 3 6 12. Depth scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0

METHOD
EX Excavator bucket
R Ripper
HA Hand auger
PT Push tube
SON Sonic drilling
AH Air hammer
PS Percussion sampler
AS Short spiral auger
AD/V Solid flight auger: V-Bit
AD/T Solid flight auger: TC-Bit
HFA Hollow flight auger
WB Washbore drilling
RR Rock roller

PENETRATION
VE Very Easy (No Resistance)
E Easy
F Firm
H Hard
VH Very Hard (Refusal)

WATER
Water Level on Date shown
water inflow
water outflow

FIELD TESTS
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer
DCP - Dynamic Cone Penetrometer
PSP - Perth Sand Penetrometer
MC - Moisture Content
PBT - Plate Bearing Test
IMP - Borehole Impression Test
PID - Photoionisation Detector
VS - Vane Shear; P=Peak, R=Resdual (uncorrected kPa)

SAMPLES
B - Bulk disturbed sample
D - Disturbed sample
ES - Environmental sample
U - Thin wall tube 'undisturbed'

MOISTURE
D - Dry
M - Moist
W - Wet
PL - Plastic limit
LL - Liquid limit
w - Moisture content

SOIL CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

Refer to explanatory notes for details of abbreviations and basis of descriptions

CARDNO (NSW/ACT) PTY LTD

Cardno

TEST PIT LOG SHEET

Client: Addenbrooke Pty Ltd
Project: Blueys Beach Subdivision
Location: Blueys Beach
Job No: 50522033

Hole No: TP009

Sheet: 1 of 1

Position: Refer to site plan | **Angle from Horizontal:** 90° | **Surface Elevation:**

Machine Type: 13.5 tonne Excavator | **Excavation Method:** 800mm Tooth Bucket

Excavation Dimensions: | **Contractor:** Cardno

Date Excavated: 24/1/22 | **Logged By:** KS | **Checked By:** GA

Method	Resistance	Stability	Water	Sample or Field Test	DCP (blows per 150 mm)	Depth (m)	Classification	Depth	SOIL TYPE, plasticity or particle characteristic, colour, secondary and minor components / ROCK TYPE, grain size and type, colour, fabric & texture, strength, weathering, defects and structure	Moisture Condition	Consistency Relative Density	STRUCTURE & Other Observations
EX	E	Stable	Groundwater Not Encountered				SM	0.10m	Silty SAND: fine to coarse grained, dark grey-brown	D	St	TOPSOIL 0.00 m: Organically impacted to 0.1 m from surface.
				ES 0.10 - 0.20 m ES7	REF		GP	0.45m	Sandy GRAVEL: fine to coarse, angular, grey, fine to coarse grained sand, with clay	D	MD	COLLUVIUM
	F					0.5, 1.0			SANDSTONE, fine grained, with clay seams, highly weathered			WEATHERED ROCK
	VH							1.30m	As above; decrease in fracturing/defect spacing.			
						1.5, 2.0, 2.5, 3.0			TERMINATED AT 1.30 m Refusal / Slow Progress on Weathered Rock			

METHOD
EX Excavator bucket
R Ripper
HA Hand auger
PT Push tube
SON Sonic drilling
AH Air hammer
PS Percussion sampler
AS Short spiral auger
AD/V Solid flight auger: V-Bit
AD/T Solid flight auger: TC-Bit
HFA Hollow flight auger
WB Washbore drilling
RR Rock roller

PENETRATION
VE Very Easy (No Resistance)
E Easy
F Firm
H Hard
VH Very Hard (Refusal)

WATER
Water Level on Date shown
water inflow
water outflow

FIELD TESTS
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer
DCP - Dynamic Cone Penetrometer
PSP - Perth Sand Penetrometer
MC - Moisture Content
PBT - Plate Bearing Test
IMP - Borehole Impression Test
PID - Photoionisation Detector
VS - Vane Shear; P=Peak, R=Resdual (uncorrected kPa)

SAMPLES
B - Bulk disturbed sample
D - Disturbed sample
ES - Environmental sample
U - Thin wall tube 'undisturbed'

MOISTURE
D - Dry
M - Moist
W - Wet
PL - Plastic limit
LL - Liquid limit
w - Moisture content

SOIL CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

Refer to explanatory notes for details of abbreviations and basis of descriptions

CARDNO (NSW/ACT) PTY LTD

CARDNO 2.01.6 LIB.GLB Log CARDNO NON-CORED 50522033 BLUEYS BEACH SUBDIVISION.GPJ <<DrawingFile>> 12/08/2022 10:59 10.02.00.04 Datgel AGS RTA, Photo, Monitoring Tools

TEST PIT LOG SHEET

Hole No: TP010

Client: Addenbrooke Pty Ltd
Project: Blueys Beach Subdivision
Location: Blueys Beach
Job No: 50522033
Sheet: 1 of 1

Position: Refer to site plan | **Angle from Horizontal:** 90° | **Surface Elevation:**
Machine Type: 13.5 tonne Excavator | **Excavation Method:** 800mm Tooth Bucket
Excavation Dimensions: | **Contractor:** Cardno
Date Excavated: 24/1/22 | **Logged By:** KS | **Checked By:** GA

Method	Resistance	Stability	Water	Sample or Field Test	Depth (m)	Classification	SOIL TYPE, plasticity or particle characteristic, colour, secondary and minor components; ROCK TYPE, grain size and type, colour, fabric & texture, strength, weathering, defects and structure	Moisture Condition	Consistency Relative Density	STRUCTURE & Other Observations
EX	E	Stable	Groundwater Not Encountered		0.00–0.10m	CL	Silty Sandy CLAY: low plasticity, dark brown-black, trace fine to coarse grained sand, trace fine angular gravel	M (<PL)	St	TOPSOIL 0.00 m: Organically impacted to 0.1 m from surface.
					0.10–0.30m	CL	Silty Sandy CLAY: low plasticity, dark brown-black, trace fine to coarse grained sand, trace fine angular gravel			COLLUVIUM
				B 0.55 - 0.65 m	0.30–1.45m	CH	CLAY: high plasticity, pale grey mottled yellow, orange and red, trace silt	M (>PL)	F	RESIDUAL SOIL
	F				1.45–1.80m	CI	Gravelly CLAY: medium plasticity, pale grey mottled yellow, fine to coarse angular gravel	M (>PL)	VSt	EXTREMELY WEATHERED
	H				1.80–2.15m		SILTSTONE, pale grey mottled dark brown As above; decrease in fracturing/defects			WEATHERED ROCK
					2.15m		TERMINATED AT 2.15 m Refusal / Slow Progress on Weathered Rock			

DCP (blows per 150 mm): scale 1 3 6 12

METHOD
EX Excavator bucket
R Ripper
HA Hand auger
PT Push tube
SON Sonic drilling
AH Air hammer
PS Percussion sampler
AS Short spiral auger
AD/V Solid flight auger: V-Bit
AD/T Solid flight auger: TC-Bit
HFA Hollow flight auger
WB Washbore drilling
RR Rock roller

PENETRATION
VE Very Easy (No Resistance)
E Easy
F Firm
H Hard
VH Very Hard (Refusal)

WATER
Water Level on Date shown
water inflow
water outflow

FIELD TESTS
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer
DCP - Dynamic Cone Penetrometer
PSP - Perth Sand Penetrometer
MC - Moisture Content
PBT - Plate Bearing Test
IMP - Borehole Impression Test
PID - Photoionisation Detector
VS - Vane Shear; P=Peak, R=Resdual (uncorrected kPa)

SAMPLES
B - Bulk disturbed sample
D - Disturbed sample
ES - Environmental sample
U - Thin wall tube 'undisturbed'

MOISTURE
D - Dry
M - Moist
W - Wet
PL - Plastic limit
LL - Liquid limit
w - Moisture content

SOIL CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

Refer to explanatory notes for details of abbreviations and basis of descriptions

TEST PIT LOG SHEET

Client: Addenbrooke Pty Ltd
Project: Blueys Beach Subdivision
Location: Blueys Beach
Job No: 50522033

Hole No: TP011

Sheet: 1 of 1

Position: Refer to site plan	**Angle from Horizontal:** 90°	**Surface Elevation:**
Machine Type: 13.5 tonne Excavator	**Excavation Method:** 800mm Tooth Bucket	
Excavation Dimensions:		**Contractor:** Cardno
Date Excavated: 24/1/22	**Logged By:** KS	**Checked By:** GA

Method	Resistance	Stability	Water	Sample or Field Test	DCP (blows per 150 mm)	Depth (m)	Classification	SOIL TYPE, plasticity or particle characteristic, colour, secondary and minor components; ROCK TYPE, grain size and type, colour, fabric & texture, strength, weathering, defects and structure	Moisture Condition	Consistency Relative Density	STRUCTURE & Other Observations
EX	E	Stable	Groundwater Not Encountered			0.00–0.20	CL	Silty Sandy CLAY: low plasticity, dark brown, fine to coarse grained sand, trace fine, angular gravel	D	St	TOPSOIL 0.00 m: Organically impacted to 0.1 m from surface.
						0.20–0.50	CL	Gravelly CLAY: low plasticity, orange mottled pale grey, fine to coarse, angular gravel	M (>PL)	VSt	RESIDUAL SOIL
	F / H				REF	0.50–0.95		Clayey GRAVEL: fine to coarse, angular, pale grey mottled orange clay As above; decrease in fracturing/defects			WEATHERED ROCK
						0.95		TERMINATED AT 0.95 m Refusal / Slow Progress on Weathered Rock			

DCP scale: 1 3 6 12

METHOD
EX Excavator bucket
R Ripper
HA Hand auger
PT Push tube
SON Sonic drilling
AH Air hammer
PS Percussion sampler
AS Short spiral auger
AD/V Solid flight auger: V-Bit
AD/T Solid flight auger: TC-Bit
HFA Hollow flight auger
WB Washbore drilling
RR Rock roller

PENETRATION
VE Very Easy (No Resistance)
E Easy
F Firm
H Hard
VH Very Hard (Refusal)

WATER
Water Level on Date shown
water inflow
water outflow

FIELD TESTS
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer
DCP - Dynamic Cone Penetrometer
PSP - Perth Sand Penetrometer
MC - Moisture Content
PBT - Plate Bearing Test
IMP - Borehole Impression Test
PID - Photoionisation Detector
VS - Vane Shear; P=Peak, R=Resdual (uncorrected kPa)

SAMPLES
B - Bulk disturbed sample
D - Disturbed sample
ES - Environmental sample
U - Thin wall tube 'undisturbed'

MOISTURE
D - Dry
M - Moist
W - Wet
PL - Plastic limit
LL - Liquid limit
w - Moisture content

SOIL CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

Refer to explanatory notes for details of abbreviations and basis of descriptions

CARDNO (NSW/ACT) PTY LTD

TEST PIT LOG SHEET

Client: Addenbrooke Pty Ltd
Project: Blueys Beach Subdivision
Location: Blueys Beach

Hole No: TP012

Job No: 50522033 | **Sheet:** 1 of 1

Position: Refer to site plan | **Angle from Horizontal:** 90° | **Surface Elevation:**

Machine Type: 13.5 tonne Excavator | **Excavation Method:** 800mm Tooth Bucket

Excavation Dimensions: | **Contractor:** Cardno

Date Excavated: 24/1/22 | **Logged By:** KS | **Checked By:** GA

Depth (m)	Method	Resistance	Stability	Water	Sample or Field Test	Classification	Soil Type / Material Description	Moisture Condition	Consistency / Relative Density	Structure & Other Observations
0.00–0.10	EX		Stable	Groundwater Not Encountered		CL	Sandy CLAY: low plasticity, grey, fine to coarse grained sand, trace fine to coarse, angular gravel			TOPSOIL 0.00 m: Organically impacted to 0.1 m from surface.
0.10–0.50	EX		Stable			CL	Sandy CLAY: low plasticity, grey, fine to coarse grained sand, trace fine to coarse, angular gravel	D	St	COLLUVIUM
0.50–1.50	EX		Stable		B 0.70 - 0.90 m	CI-CH	CLAY: medium to high plasticity, pale grey mottled orange and red, trace silt	M (<PL)	VSt	RESIDUAL SOIL
1.50–1.80	EX		Stable			CI	Silty CLAY: medium plasticity, grey mottled yellow, trace fine to coarse grained sand, trace fine to coarse, angular gravel	M (≈PL)	VSt	EXTREMELY WEATHERED
1.80–2.20	EX		Stable				SILTSTONE, fractured As above; decrease in fracturing/defects			WEATHERED ROCK
2.20							TERMINATED AT 2.20 m Refusal / Slow Progress on Weathered Rock			

DCP (blows per 150 mm): scale 1 3 6 12

METHOD
- EX Excavator bucket
- R Ripper
- HA Hand auger
- PT Push tube
- SON Sonic drilling
- AH Air hammer
- PS Percussion sampler
- AS Short spiral auger
- AD/V Solid flight auger: V-Bit
- AD/T Solid flight auger: TC-Bit
- HFA Hollow flight auger
- WB Washbore drilling
- RR Rock roller

PENETRATION
- VE Very Easy (No Resistance)
- E Easy
- F Firm
- H Hard
- VH Very Hard (Refusal)

WATER
- Water Level on Date shown
- water inflow
- water outflow

FIELD TESTS
- SPT - Standard Penetration Test
- HP - Hand/Pocket Penetrometer
- DCP - Dynamic Cone Penetrometer
- PSP - Perth Sand Penetrometer
- MC - Moisture Content
- PBT - Plate Bearing Test
- IMP - Borehole Impression Test
- PID - Photoionisation Detector
- VS - Vane Shear; P=Peak, R=Resdual (uncorrected kPa)

SAMPLES
- B - Bulk disturbed sample
- D - Disturbed sample
- ES - Environmental sample
- U - Thin wall tube 'undisturbed'

MOISTURE
- D - Dry
- M - Moist
- W - Wet
- PL - Plastic limit
- LL - Liquid limit
- *w* - Moisture content

SOIL CONSISTENCY
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard

RELATIVE DENSITY
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

Refer to explanatory notes for details of abbreviations and basis of descriptions

CARDNO (NSW/ACT) PTY LTD

Cardno®

TEST PIT LOG SHEET

Client: Addenbrooke Pty Ltd
Project: Blueys Beach Subdivision
Location: Blueys Beach

Hole No: TP013

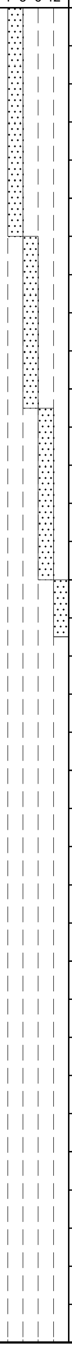
Job No: 50522033
Sheet: 1 of 1

Position: Refer to site plan	**Angle from Horizontal:** 90°	**Surface Elevation:**
Machine Type: 13.5 tonne Excavator	**Excavation Method:** 800mm Tooth Bucket	
Excavation Dimensions:		**Contractor:** Cardno
Date Excavated: 24/1/22	**Logged By:** KS	**Checked By:** GA

Excavation: Method EX (0.00–3.50 m); Resistance E (0.00–2.80 m), E-F (2.80–3.50 m); Stability: Stable; Water: 24/01/22 (water level shown at approx. 1.70 m)

Sampling & Testing (Sample or Field Test):
- ASS 1.60 - 1.70 m ASS4
- ASS 2.00 - 2.10 m ASS5
- ASS 2.90 - 3.00 m ASS6

DCP (blows per 150 mm): 1 3 6 12



Depth (m): 0.5, 1.0, 1.5, 2.0, 2.5, 3.0

Depth	Classification	SOIL TYPE, plasticity or particle characteristic, colour, secondary and minor components ROCK TYPE, grain size and type, colour, fabric & texture, strength, weathering, defects and structure	Moisture Condition	Consistency Relative Density	STRUCTURE & Other Observations
0.15m	CL	Sandy CLAY: low plasticity, grey, fine to coarse grained sand	M (<PL)	St	TOPSOIL 0.00 m: Organically impacted to 0.15 m from surface.
0.80m	CI	Silty CLAY: medium plasticity, grey mottled yellow	M (>PL)	F to St	ALLUVIUM
1.95m	CI-CH	Silty CLAY: medium to high plasticity, pale grey mottled yellow	M (>PL)	VSt	
2.80m	CI	Gravelly CLAY: medium plasticity, grey, fine to coarse, rounded gravel	M (>PL)	VSt	
3.50m	CH	Silty CLAY: high plasticity, dark grey, trace fine to medium, angular gravel As above: with fine to medium, angular gravel	M (>PL)	VSt	RESIDUAL SOIL

TERMINATED AT 3.50 m
Target depth

METHOD
- EX Excavator bucket
- R Ripper
- HA Hand auger
- PT Push tube
- SON Sonic drilling
- AH Air hammer
- PS Percussion sampler
- AS Short spiral auger
- AD/V Solid flight auger: V-Bit
- AD/T Solid flight auger: TC-Bit
- HFA Hollow flight auger
- WB Washbore drilling
- RR Rock roller

PENETRATION
- VE Very Easy (No Resistance)
- E Easy
- F Firm
- H Hard
- VH Very Hard (Refusal)

WATER
- Water Level on Date shown
- water inflow
- water outflow

FIELD TESTS
- SPT - Standard Penetration Test
- HP - Hand/Pocket Penetrometer
- DCP - Dynamic Cone Penetrometer
- PSP - Perth Sand Penetrometer
- MC - Moisture Content
- PBT - Plate Bearing Test
- IMP - Borehole Impression Test
- PID - Photoionisation Detector
- VS - Vane Shear; P=Peak, R=Resdual (uncorrected kPa)

SAMPLES
- B - Bulk disturbed sample
- D - Disturbed sample
- ES - Environmental sample
- U - Thin wall tube 'undisturbed'

MOISTURE
- D - Dry
- M - Moist
- W - Wet
- PL - Plastic limit
- LL - Liquid limit
- *w* - Moisture content

SOIL CONSISTENCY
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard

RELATIVE DENSITY
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

Refer to explanatory notes for details of abbreviations and basis of descriptions

CARDNO (NSW/ACT) PTY LTD

Cardno

TEST PIT LOG SHEET

Client: Addenbrooke Pty Ltd
Project: Blueys Beach Subdivision
Location: Blueys Beach

Job No: 50522033

Hole No: TP014

Sheet: 1 of 1

Position: Refer to site plan | **Angle from Horizontal:** 90° | **Surface Elevation:**
Machine Type: 13.5 tonne Excavator | **Excavation Method:** 800mm Tooth Bucket
Excavation Dimensions: | **Contractor:** Cardno
Date Excavated: 24/1/22 | **Logged By:** KS | **Checked By:** GA

Method	Resistance	Stability	Water	Sample or Field Test	Depth (m)	Classification	Depth to base	SOIL TYPE, plasticity or particle characteristic, colour, secondary and minor components ROCK TYPE, grain size and type, colour, fabric & texture, strength, weathering, defects and structure	Moisture Condition	Consistency Relative Density	STRUCTURE & Other Observations
EX	E	Stable	Groundwater Not Encountered		0.0–0.10	CL-CI	0.10m	Sandy CLAY: low to medium plasticity, dark brown, fine to coarse grained sand, trace fine to coarse, rounded gravel	D	St	TOPSOIL 0.00 m: Organically impacted to 0.1 m from surface.
EX	E	Stable	Groundwater Not Encountered	B 0.30 - 0.40 m	0.10–0.40	CL-CI	0.40m	Sandy CLAY: low to medium plasticity, dark brown, fine to coarse grained sand, trace fine to coarse, rounded gravel	D	St	COLLUVIUM
EX	E	Stable	Groundwater Not Encountered		0.40–0.90	CI-CH	0.90m	CLAY: medium to high plasticity, pale grey mottled orange, trace fine, angular gravel, trace silt	M (<PL)	VSt	RESIDUAL SOIL
EX	E	Stable	Groundwater Not Encountered		0.90–1.10	CL-CI	1.10m	Gravelly CLAY: low to medium plasticity, grey mottled orange, fine to coarse angular to sub-angular gravel	M (<PL)	VSt	
EX	F	Stable	Groundwater Not Encountered		1.10–1.40	GC	1.40m	Clayey GRAVEL: fine to coarse, angular, grey mottled orange	M (<PL)	MD	EXTREMELY WEATHERED
EX	H	Stable	Groundwater Not Encountered		1.40–1.65		1.65m	SILTSTONE, fine grained, grey mottled orange, fractured As above; decrease in fracturing/defects			WEATHERED ROCK
								TERMINATED AT 1.65 m Refusal / Slow Progress on Weathered Rock			

DCP (blows per 150 mm): scale 1 3 6 12; REF at approx. 0.90 m

Depth scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0

METHOD
EX Excavator bucket
R Ripper
HA Hand auger
PT Push tube
SON Sonic drilling
AH Air hammer
PS Percussion sampler
AS Short spiral auger
AD/V Solid flight auger: V-Bit
AD/T Solid flight auger: TC-Bit
HFA Hollow flight auger
WB Washbore drilling
RR Rock roller

PENETRATION
VE Very Easy (No Resistance)
E Easy
F Firm
H Hard
VH Very Hard (Refusal)

WATER
Water Level on Date shown
water inflow
water outflow

FIELD TESTS
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer
DCP - Dynamic Cone Penetrometer
PSP - Perth Sand Penetrometer
MC - Moisture Content
PBT - Plate Bearing Test
IMP - Borehole Impression Test
PID - Photoionisation Detector
VS - Vane Shear; P=Peak, R=Resdual (uncorrected kPa)

SAMPLES
B - Bulk disturbed sample
D - Disturbed sample
ES - Environmental sample
U - Thin wall tube 'undisturbed'

MOISTURE
D - Dry
M - Moist
W - Wet
PL - Plastic limit
LL - Liquid limit
w - Moisture content

SOIL CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

Refer to explanatory notes for details of abbreviations and basis of descriptions

CARDNO (NSW/ACT) PTY LTD

TEST PIT LOG SHEET

Client: Addenbrooke Pty Ltd
Project: Blueys Beach Subdivision
Location: Blueys Beach

Hole No: TP015
Job No: 50522033 — **Sheet:** 1 of 1

Position: Refer to site plan — **Angle from Horizontal:** 90° — **Surface Elevation:**
Machine Type: 13.5 tonne Excavator — **Excavation Method:** 800mm Tooth Bucket
Excavation Dimensions: — **Contractor:** Cardno
Date Excavated: 24/1/22 — **Logged By:** KS — **Checked By:** GA

Excavation: Method EX (0.00–2.20 m); Resistance E-F (0.00–1.80 m), H (1.80–2.20 m); Stability: Stable; Water: Groundwater Not Encountered

Sampling & Testing: B 1.00 - 1.20 m

Depth (m)	Classification	Material Description	Moisture Condition	Consistency / Relative Density	Structure & Other Observations
0.00–0.10m	CL-CI	Sandy CLAY: low to medium plasticity, dark brown, fine to coarse grained sand, trace fine to coarse gravel	D	St	TOPSOIL 0.00 m: Organically impacted to 0.1 m from surface.
0.10–0.30m	CL-CI	Sandy CLAY: low to medium plasticity, dark brown, fine to coarse grained sand, trace fine to coarse gravel	D	St	COLLUVIUM
0.30–1.00m	CI-CH	Silty CLAY: medium to high plasticity, pale grey mottled brown, trace fine angular gravel, trace fine to coarse grained sand	M (<PL)	St	RESIDUAL SOIL
1.00–1.45m	CL-CI	Gravelly CLAY: low to medium plasticity, grey mottled orange, fine to coarse angular to sub-angular gravel	M (<PL)	St	
1.45–1.80m	GC	Clayey GRAVEL: fine to coarse, angular, grey mottled orange	M (<PL)	MD	EXTREMELY WEATHERED
1.80–2.20m		SILTSTONE, grey mottled orange As above; decrease in fracturing/defects			WEATHERED ROCK

TERMINATED AT 2.20 m
Refusal / Slow Progress on Weathered Rock

DCP (blows per 150 mm): 1 3 6 12

METHOD
EX Excavator bucket
R Ripper
HA Hand auger
PT Push tube
SON Sonic drilling
AH Air hammer
PS Percussion sampler
AS Short spiral auger
AD/V Solid flight auger: V-Bit
AD/T Solid flight auger: TC-Bit
HFA Hollow flight auger
WB Washbore drilling
RR Rock roller

PENETRATION
VE Very Easy (No Resistance)
E Easy
F Firm
H Hard
VH Very Hard (Refusal)

WATER
Water Level on Date shown
water inflow
water outflow

FIELD TESTS
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer
DCP - Dynamic Cone Penetrometer
PSP - Perth Sand Penetrometer
MC - Moisture Content
PBT - Plate Bearing Test
IMP - Borehole Impression Test
PID - Photoionisation Detector
VS - Vane Shear; P=Peak, R=Resdual (uncorrected kPa)

SAMPLES
B - Bulk disturbed sample
D - Disturbed sample
ES - Environmental sample
U - Thin wall tube 'undisturbed'

MOISTURE
D - Dry
M - Moist
W - Wet
PL - Plastic limit
LL - Liquid limit
w - Moisture content

SOIL CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

Refer to explanatory notes for details of abbreviations and basis of descriptions

TEST PIT LOG SHEET

Hole No: TP016

Client: Addenbrooke Pty Ltd
Project: Blueys Beach Subdivision
Location: Blueys Beach
Job No: 50522033
Sheet: 1 of 1

Position: Refer to site plan | **Angle from Horizontal:** 90° | **Surface Elevation:**
Machine Type: 13.5 tonne Excavator | **Excavation Method:** 800mm Tooth Bucket
Excavation Dimensions: | **Contractor:** Cardno
Date Excavated: 24/1/22 | **Logged By:** KS | **Checked By:** GA

Depth (m)	Method	Resistance	Stability	Water	Sample or Field Test	Classification	Material Description (SOIL TYPE, plasticity or particle characteristic, colour, secondary and minor components; ROCK TYPE, grain size and type, colour, fabric & texture, strength, weathering, defects and structure)	Moisture Condition	Consistency / Relative Density	STRUCTURE & Other Observations
0.00–0.20m	EX	E-F	Stable			SC	Silty Clayey SAND: fine to coarse grained, brown	M (<PL)	St	TOPSOIL 0.00 m: Organically impacted to 0.1 m from surface.
0.20–0.60m	EX	E-F	Stable			CI-CH	CLAY: medium to high plasticity, orange mottled grey	M (<PL)	St	RESIDUAL SOIL
0.60–1.80m	EX	E-F	Stable	24/01/22	SB 1.20 - 1.40 m	CI-CH	Silty CLAY: medium to high plasticity, grey mottled orange As above; trace fine to coarse grained sand, trace fine angular gravel	M (>PL)	VSt	
1.80–2.50m	EX	F	Stable			CI-CH	Silty CLAY: medium to high plasticity, pale grey mottled orange, with fine to coarse, angular gravel	M (≈PL)	H	
2.50–3.00m	EX	F	Stable			CL	Silty Gravelly CLAY: low plasticity, pale grey, fine to coarse, angular gravel	M (<PL)	H	EXTREMELY WEATHERED
3.00m							TERMINATED AT 3.00 m Target depth			

DCP (blows per 150 mm): 1 3 6 12

Depth scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0

METHOD
EX Excavator bucket
R Ripper
HA Hand auger
PT Push tube
SON Sonic drilling
AH Air hammer
PS Percussion sampler
AS Short spiral auger
AD/V Solid flight auger: V-Bit
AD/T Solid flight auger: TC-Bit
HFA Hollow flight auger
WB Washbore drilling
RR Rock roller

PENETRATION
VE Very Easy (No Resistance)
E Easy
F Firm
H Hard
VH Very Hard (Refusal)

WATER
Water Level on Date shown
water inflow
water outflow

FIELD TESTS
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer
DCP - Dynamic Cone Penetrometer
PSP - Perth Sand Penetrometer
MC - Moisture Content
PBT - Plate Bearing Test
IMP - Borehole Impression Test
PID - Photoionisation Detector
VS - Vane Shear; P=Peak, R=Resdual (uncorrected kPa)

SAMPLES
B - Bulk disturbed sample
D - Disturbed sample
ES - Environmental sample
U - Thin wall tube 'undisturbed'

MOISTURE
D - Dry
M - Moist
W - Wet
PL - Plastic limit
LL - Liquid limit
w - Moisture content

SOIL CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

Refer to explanatory notes for details of abbreviations and basis of descriptions

CARDNO (NSW/ACT) PTY LTD

TEST PIT LOG SHEET

Client: Addenbrooke Pty Ltd
Project: Blueys Beach Subdivision
Location: Blueys Beach
Job No: 50522033

Hole No: TP017

Sheet: 1 of 1

Position: Refer to site plan
Angle from Horizontal: 90°
Surface Elevation:
Machine Type: 13.5 tonne Excavator
Excavation Method: 800mm Tooth Bucket
Excavation Dimensions:
Contractor: Cardno
Date Excavated: 24/1/22
Logged By: KS
Checked By: GA

Method	Resistance	Stability	Water	Sample or Field Test	Depth (m)	Classification	Material Description (soil type, plasticity or particle characteristic, colour, secondary and minor components)	Moisture Condition	Consistency / Relative Density	Structure & Other Observations
EX	E	Stable	Groundwater Not Encountered		0.00–0.10	SM	Silty SAND: fine to coarse grained, dark brown	D	St	TOPSOIL 0.00 m: Organically impacted to 0.1 m from surface.
					0.10–1.40	SP	SAND: fine to coarse grained, grey, with silt	D	F to St	AEOLIAN
					1.40–1.90	SC	Clayey SAND: fine to coarse grained, brown	M	St to VSt	ALLUVIUM
					1.90–2.20	CI	Sandy CLAY: medium plasticity, brown, fine to coarse grained sand			RESIDUAL SOIL
					2.20		TERMINATED AT 2.20 m Target depth			

DCP (blows per 150 mm): 1 3 6 12

METHOD
EX Excavator bucket
R Ripper
HA Hand auger
PT Push tube
SON Sonic drilling
AH Air hammer
PS Percussion sampler
AS Short spiral auger
AD/V Solid flight auger: V-Bit
AD/T Solid flight auger: TC-Bit
HFA Hollow flight auger
WB Washbore drilling
RR Rock roller

PENETRATION
VE Very Easy (No Resistance)
E Easy
F Firm
H Hard
VH Very Hard (Refusal)

WATER
Water Level on Date shown
water inflow
water outflow

FIELD TESTS
SPT - Standard Penetration Test
HP - Hand/Pocket Penetrometer
DCP - Dynamic Cone Penetrometer
PSP - Perth Sand Penetrometer
MC - Moisture Content
PBT - Plate Bearing Test
IMP - Borehole Impression Test
PID - Photoionisation Detector
VS - Vane Shear; P=Peak, R=Resdual (uncorrected kPa)

SAMPLES
B - Bulk disturbed sample
D - Disturbed sample
ES - Environmental sample
U - Thin wall tube 'undisturbed'

MOISTURE
D - Dry
M - Moist
W - Wet
PL - Plastic limit
LL - Liquid limit
w - Moisture content

SOIL CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

RELATIVE DENSITY
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

Refer to explanatory notes for details of abbreviations and basis of descriptions

CARDNO (NSW/ACT) PTY LTD

APPENDIX

C

LABORATORY TEST REPORTS

Cardno

now

Stantec

Material Test Report

Intrax Consulting Engineers Pty Ltd
Morisset Laboratory
Unit 2, 50 Alliance Avenue Morisset NSW 2264
Phone: 0411 379 761
Email: steve.waugh@intrax.com.au

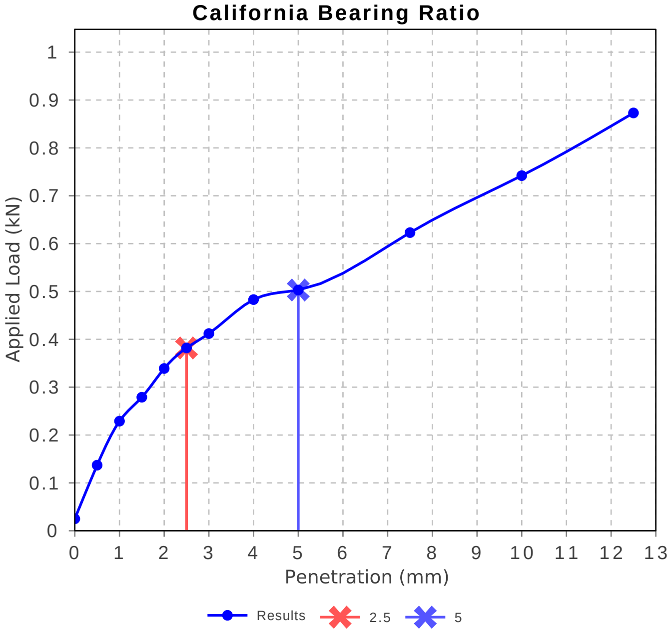
Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Steve Waugh
Laboratory Manager

NATA Accredited Laboratory Number: 19862

Report Number: **PRJ702862-1**
Issue Number: 1
Date Issued: 28/02/2022
Client: Cardno NSW
Unit 1, 10 Denny Street, Broadmeadow NSW 2292
Contact: Ian Piper
Project Number: PRJ702862
Project Name: Blueys beach investigation
Project Location: S#182756 Blueys Beach Subdivision, Blueys Beach, Nsw, 2428
Client Reference: 50522033
Work Request: 3478
Sample Number: M22-3478A
Date Sampled: 24/01/2022
Dates Tested: 04/02/2022 - 25/02/2022
Sampling Method: Sampled by Client - Tested as Received
The results apply to the sample as received
Sample Location: **TP002, Depth: 0.6 - 0.8m**

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	2.5 mm		
CBR %	**3.0**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Method used to Determine Plasticity	visual		
Maximum Dry Density (t/m^3)	1.50		
Optimum Moisture Content (%)	26.5		
Laboratory Density Ratio (%)	100.0		
Laboratory Moisture Ratio (%)	99.5		
Dry Density after Soaking (t/m^3)	1.48		
Field Moisture Content (%)	30.1		
Moisture Content at Placement (%)	26.5		
Moisture Content Top 30mm (%)	34.1		
Moisture Content Rest of Sample (%)	29.1		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Curing Hours	96.0		
Swell (%)	1.5		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0		



Material Test Report

Report Number:	**PRJ702862-1**
Issue Number:	1
Date Issued:	28/02/2022
Client:	Cardno NSW
	Unit 1, 10 Denny Street, Broadmeadow NSW 2292
Contact:	Ian Piper
Project Number:	PRJ702862
Project Name:	Blueys beach investigation
Project Location:	S#182756 Blueys Beach Subdivision, Blueys Beach, Nsw, 2428
Client Reference:	50522033
Work Request:	3478
Sample Number:	M22-3478C
Date Sampled:	24/01/2022
Dates Tested:	04/02/2022 - 21/02/2022
Sampling Method:	Sampled by Client - Tested as Received
	The results apply to the sample as received
Sample Location:	**TP007, Depth: 0.4 - 0.6m**

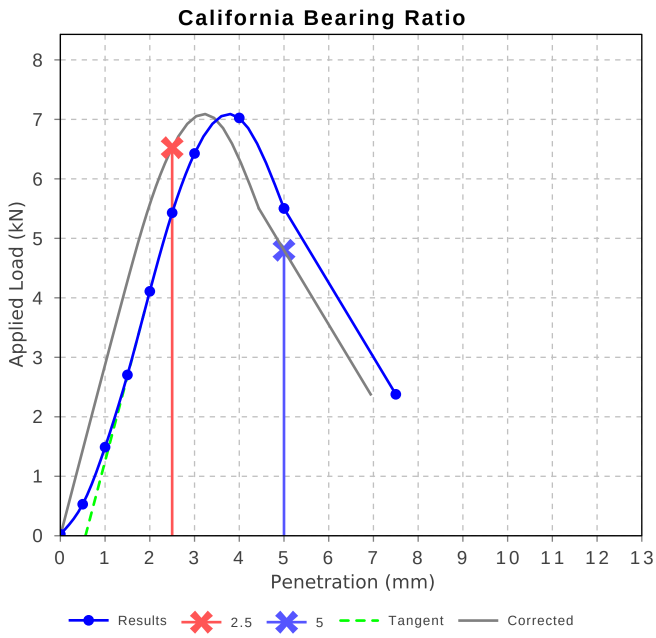
Intrax Consulting Engineers Pty Ltd
Morisset Laboratory
Unit 2, 50 Alliance Avenue Morisset NSW 2264
Phone: 0411 379 761
Email: steve.waugh@intrax.com.au

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Steve Waugh
Laboratory Manager

NATA Accredited Laboratory Number: 19862

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	2.5 mm		
CBR %	**50**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Method used to Determine Plasticity	visual		
Maximum Dry Density (t/m^3)	1.79		
Optimum Moisture Content (%)	16.5		
Laboratory Density Ratio (%)	100.0		
Laboratory Moisture Ratio (%)	100.0		
Dry Density after Soaking (t/m^3)	1.78		
Field Moisture Content (%)	3.1		
Moisture Content at Placement (%)	16.5		
Moisture Content Top 30mm (%)	17.4		
Moisture Content Rest of Sample (%)	17.2		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Curing Hours	2.5		
Swell (%)	0.0		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0.0		
sheared SAND			



Material Test Report

Report Number:	**PRJ702862-1**
Issue Number:	1
Date Issued:	28/02/2022
Client:	Cardno NSW
	Unit 1, 10 Denny Street, Broadmeadow NSW 2292
Contact:	Ian Piper
Project Number:	PRJ702862
Project Name:	Blueys beach investigation
Project Location:	S#182756 Blueys Beach Subdivision, Blueys Beach, Nsw, 2428
Client Reference:	50522033
Work Request:	3478
Sample Number:	M22-3478E
Date Sampled:	24/01/2022
Dates Tested:	04/02/2022 - 25/02/2022
Sampling Method:	Sampled by Client - Tested as Received
	The results apply to the sample as received
Sample Location:	**TP010, Depth: 0.55 - 0.65m**

Intrax
LAND
Intrax Consulting Engineers Pty Ltd
Morisset Laboratory
Unit 2, 50 Alliance Avenue Morisset NSW 2264
Phone: 0411 379 761
Email: steve.waugh@intrax.com.au

NATA
WORLD RECOGNISED ACCREDITATION

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Steve Waugh
Laboratory Manager
NATA Accredited Laboratory Number: 19862

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	78		
Plastic Limit (%)	16		
Plasticity Index (%)	**62**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Moisture Condition Determined By	AS 1289.3.1.2		
Linear Shrinkage (%)	19.5		
Cracking Crumbling Curling	Curling		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**6**		
Soil Description	Refer to Client logs		
Nature of Water	Distilled		
Temperature of Water (^{o}C)	23		

Material Test Report

Intrax LAND
Intrax Consulting Engineers Pty Ltd
Morisset Laboratory
Unit 2, 50 Alliance Avenue Morisset NSW 2264
Phone: 0411 379 761
Email: steve.waugh@intrax.com.au

Accredited for compliance with ISO/IEC 17025 - Testing

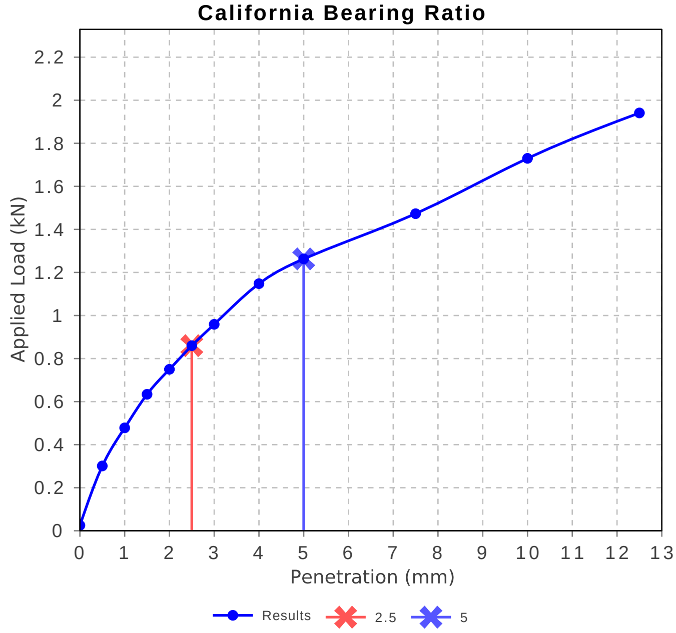
NATA
WORLD RECOGNISED ACCREDITATION

Approved Signatory: Steve Waugh
Laboratory Manager

NATA Accredited Laboratory Number: 19862

Report Number:	**PRJ702862-1**
Issue Number:	1
Date Issued:	28/02/2022
Client:	Cardno NSW
	Unit 1, 10 Denny Street, Broadmeadow NSW 2292
Contact:	Ian Piper
Project Number:	PRJ702862
Project Name:	Blueys beach investigation
Project Location:	S#182756 Blueys Beach Subdivision, Blueys Beach, Nsw, 2428
Client Reference:	50522033
Work Request:	3478
Sample Number:	M22-3478F
Date Sampled:	24/01/2022
Dates Tested:	04/02/2022 - 25/02/2022
Sampling Method:	Sampled by Client - Tested as Received
	The results apply to the sample as received
Sample Location:	**TP012, Depth: 0.7 - 0.9m**

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	2.5 mm		
CBR %	**7**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Method used to Determine Plasticity	visual		
Maximum Dry Density (t/m^3)	1.46		
Optimum Moisture Content (%)	28.5		
Laboratory Density Ratio (%)	100.0		
Laboratory Moisture Ratio (%)	99.5		
Dry Density after Soaking (t/m^3)	1.45		
Field Moisture Content (%)	27.5		
Moisture Content at Placement (%)	28.3		
Moisture Content Top 30mm (%)	31.2		
Moisture Content Rest of Sample (%)	29.5		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Curing Hours	96.0		
Swell (%)	0.5		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0		



Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	72		
Plastic Limit (%)	25		
Plasticity Index (%)	**47**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Moisture Condition Determined By	AS 1289.3.1.2		
Linear Shrinkage (%)	17.0		
Cracking Crumbling Curling	Curling		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**6**		
Soil Description	Refer to Client logs		
Nature of Water	Distilled		
Temperature of Water (^{o}C)	22		

Material Test Report

Intrax Consulting Engineers Pty Ltd
Morisset Laboratory
Unit 2, 50 Alliance Avenue Morisset NSW 2264
Phone: 0411 379 761
Email: steve.waugh@intrax.com.au

Accredited for compliance with ISO/IEC 17025 - Testing

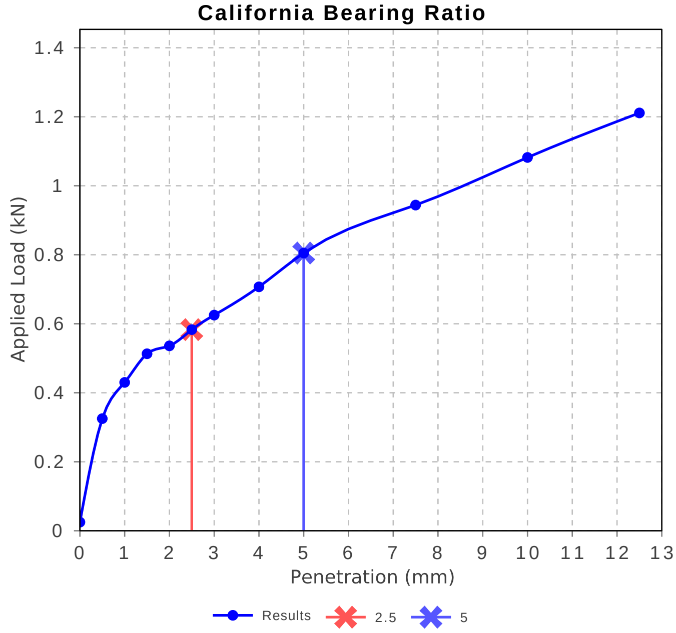
WORLD RECOGNISED ACCREDITATION

Approved Signatory: Steve Waugh
Laboratory Manager

NATA Accredited Laboratory Number: 19862

Report Number:	**PRJ702862-1**
Issue Number:	1
Date Issued:	28/02/2022
Client:	Cardno NSW
	Unit 1, 10 Denny Street, Broadmeadow NSW 2292
Contact:	Ian Piper
Project Number:	PRJ702862
Project Name:	Blueys beach investigation
Project Location:	S#182756 Blueys Beach Subdivision, Blueys Beach, Nsw, 2428
Client Reference:	50522033
Work Request:	3478
Sample Number:	M22-3478H
Date Sampled:	24/01/2022
Dates Tested:	04/02/2022 - 21/02/2022
Sampling Method:	Sampled by Client - Tested as Received
	The results apply to the sample as received
Sample Location:	**TP015, Depth: 1.0 - 1.2m**

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	2.5 mm		
CBR %	**4.5**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Method used to Determine Plasticity	visual		
Maximum Dry Density (t/m^3)	1.56		
Optimum Moisture Content (%)	25.0		
Laboratory Density Ratio (%)	100.5		
Laboratory Moisture Ratio (%)	98.0		
Dry Density after Soaking (t/m^3)	1.56		
Field Moisture Content (%)	27.0		
Moisture Content at Placement (%)	24.7		
Moisture Content Top 30mm (%)	26.7		
Moisture Content Rest of Sample (%)	25.3		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Curing Hours	96.0		
Swell (%)	1.0		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0		



Material Test Report

Report Number:	**PRJ702862-1**
Issue Number:	1
Date Issued:	28/02/2022
Client:	Cardno NSW
	Unit 1, 10 Denny Street, Broadmeadow NSW 2292
Contact:	Ian Piper
Project Number:	PRJ702862
Project Name:	Blueys beach investigation
Project Location:	S#182756 Blueys Beach Subdivision, Blueys Beach, Nsw, 2428
Client Reference:	50522033
Work Request:	3478
Sample Number:	M22-3478J
Date Sampled:	24/01/2022
Dates Tested:	04/02/2022 - 21/02/2022
Sampling Method:	Sampled by Client - Tested as Received
	The results apply to the sample as received
Sample Location:	**TB002, Depth: 0.4 - 0.65m**

Intrax LAND

Intrax Consulting Engineers Pty Ltd
Morisset Laboratory
Unit 2, 50 Alliance Avenue Morisset NSW 2264
Phone: 0411 379 761
Email: steve.waugh@intrax.com.au

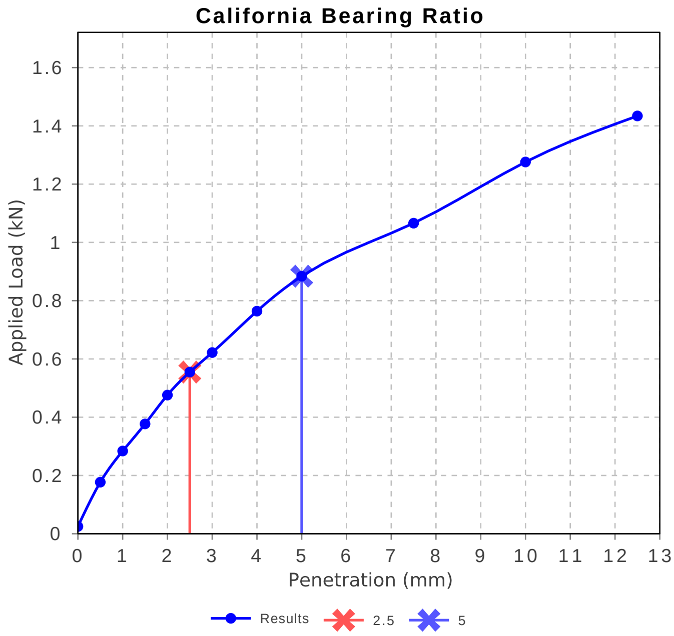
Accredited for compliance with ISO/IEC 17025 - Testing

NATA WORLD RECOGNISED ACCREDITATION

Approved Signatory: Steve Waugh
Laboratory Manager

NATA Accredited Laboratory Number: 19862

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	5 mm		
CBR %	**4.5**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Method used to Determine Plasticity	visual		
Maximum Dry Density (t/m^3)	1.49		
Optimum Moisture Content (%)	26.5		
Laboratory Density Ratio (%)	100.5		
Laboratory Moisture Ratio (%)	98.5		
Dry Density after Soaking (t/m^3)	1.47		
Field Moisture Content (%)	27.3		
Moisture Content at Placement (%)	26.4		
Moisture Content Top 30mm (%)	29.9		
Moisture Content Rest of Sample (%)	27.5		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Curing Hours	96.0		
Swell (%)	2.0		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0		



Material Test Report

Report Number:	**PRJ702862-1**
Issue Number:	1
Date Issued:	28/02/2022
Client:	Cardno NSW
	Unit 1, 10 Denny Street, Broadmeadow NSW 2292
Contact:	Ian Piper
Project Number:	PRJ702862
Project Name:	Blueys beach investigation
Project Location:	S#182756 Blueys Beach Subdivision, Blueys Beach, Nsw, 2428
Client Reference:	50522033
Work Request:	3478
Date Sampled:	21/01/2022
Dates Tested:	04/02/2022 - 22/02/2022
Sampling Method:	Sampled by Client - Tested as Received
	The results apply to the sample as received
Location:	S#182756 Blueys Beach Subdivision, Blueys Beach, Nsw, 2428

Intrax Consulting Engineers Pty Ltd
Morisset Laboratory
Unit 2, 50 Alliance Avenue Morisset NSW 2264
Phone: 0411 379 761
Email: steve.waugh@intrax.com.au

Accredited for compliance with ISO/IEC 17025 - Testing

WORLD RECOGNISED ACCREDITATION

Approved Signatory: Steve Waugh
Laboratory Manager
NATA Accredited Laboratory Number: 19862

Shrink Swell Index AS 1289 7.1.1 & 2.1.1					
Sample Number	M22-3478B	M22-3478D	M22-3478G	M22-3478I	
Date Sampled	24/01/2022	24/01/2022	24/01/2022	24/01/2022	
Date Tested	22/02/2022	22/02/2022	22/02/2022	22/02/2022	
Material Source	insitu	insitu	insitu	insitu	
Sample Location	TP005 (0.8 - 1.0m)	TP008 (0.65 - 0.85m)	TP014 (0.3 - 0.4m)	TP016 (1.2 - 1.4m)	
Inert Material Estimate (%)	0	0	0	0	
Pocket Penetrometer before (kPa)	**	**	**	**	
Pocket Penetrometer after (kPa)	**	**	**	**	
Shrinkage Moisture Content (%)	26.2	22.8	26.5	23.7	
Shrinkage (%)	**4.5**	**3.9**	**5.6**	**3.4**	
Swell Moisture Content Before (%)	25.6	20.1	26.6	23.3	
Swell Moisture Content After (%)	27.3	22.2	29.0	24.2	
Swell (%)	**0.1**	**-0.1**	**1.6**	**-0.1**	
Shrink Swell Index Iss (%)	**2.5**	**2.2**	**3.6**	**1.9**	
Visual Description	Refer to Client logs	Refer to Client logs	Refer to Client logs	Refer to Client logs	
Cracking	MC	SC	SC	SC	
Crumbling	**	**	**	**	
Remarks	remoulded with 100% Std effort at F.Mois	remoulded with 100% Std effort at F.Mois	remoulded with 100% Std effort at F.Mois	remoulded with 100% Std effort at F.Mois	

Shrink Swell Index (Iss) reported as the percentage vertical strain per pF change in suction.
Cracking Terminology: UC Uncracked, SC Slightly Cracked, MC Moderately Cracked, HC Highly Cracked, FR Fragmented.
NATA Accreditation does not cover the performance of pocket penetrometer readings.

APPENDIX

D

CSIRO BTF-18

Cardno

now

Stantec

Foundation Maintenance and Footing Performance: A Homeowner's Guide

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.

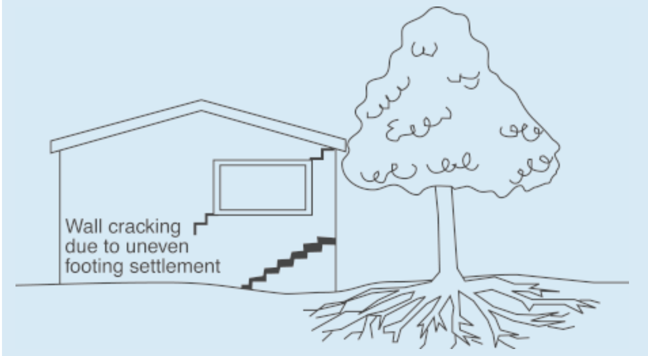
Seasonal swelling/shrinkage in clay

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.

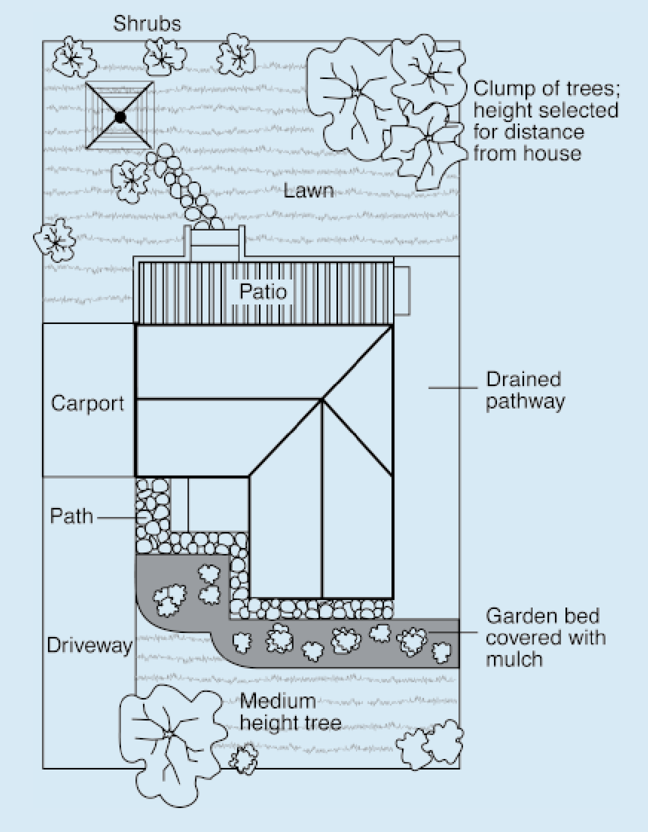
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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.

Distributed by

CSIRO PUBLISHING PO Box 1139, Collingwood 3066, Australia

Freecall 1800 645 051 Tel (03) 9662 7666 Fax (03) 9662 7555 www.publish.csiro.au

Email: publishing.sales@csiro.au