Geotechnical Assessment: Former Broken Head Quarry

Lot 1 in DP123302 and Lot 2 in DP700806, Broken Head Road, Suffolk Park, NSW 2481

Final Report

P2410392JR01V02
July 2024

environmental science & engineering

Project Details

Report Title	Geotechnical Assessment: Former Broken Head Quarry: Lot 1 in DP123302 and Lot 2 in DP700806, Broken Head Road, Suffolk Park, NSW 2481
Client	Winton Property Group acting on behalf of Darley Pty atf GWR Trust & Crisjoy Pty Ltd atf The Lighthouse Unit Trust
Document	P2410392JR01V02
Director	Andrew Norris
Manager	Andrew Norris
Principal Author	Wailen Su

Document History

Issue	Issue Date	Status	Description / Comment	Author	Reviewer	Approved
1.	19/07/2024	Draft	For Client review	WS	WB / RE	AN
2.	23/07/2024	Final	Updated from Client comments	WS	WB / RE	AN

© Copyright Martens & Associates Pty Ltd
Suite 201, 20 George St, Hornsby, NSW 2077, Australia
ACN 070 240 890 ABN 85 070 240 890
P +61-2-9476-9999 | mail@martens.com.au | www.martens.com.au

Contents

Tables

1 Introduction

1.1 Overview

This report presents the findings of a geotechnical assessment carried out by Martens and Associates (**MA**) on behalf of Winten Property Group acting on behalf of Darley Pty Ltd atf GWR Trust & Crisjoy Pty Ltd atf The Lighthouse Unit Trust at a former sand quarry, known as Broken Head Quarry, located off Broken Head Road in Suffolk Park, NSW (the **Quarry**). The purpose of this assessment is to inform a Planning Proposal (**PP**) for proposed land rezoning and future residential subdivision of the western portion of the Quarry (the **Site**). The Site location is shown in Map 01, Appendix A.

This geotechnical assessment was undertaken in general accordance with the agreed scope of work outlined in MA's proposal P2410392BC01V01, dated 28 June 2024. The geotechnical assessment and conclusions will be limited to the areas covered by the proposed development as shown in the concept layout plans (ADW, 2022), provided in Appendix B.

1.2 Location and General Site Description Details

General location and general Site description details are summarised in Table 1 below.

Table 1: Summary of Site details.

Item	Description / Comment
Site Address	Corner of Natural Lane and Broken Head Road, Suffolk Park, NSW
Legal Identifier	Lot 1 in DP123302 and Lot 2 in DP700806
LGA	Byron Shire Council (**Council**)
Site Area	32.728 ha
Investigation Area	The Investigation Area (**IA**) for this assessment comprises the footprint of the proposed residential subdivision, located in the central portion of the Site. The proposed subdivision layout (ADW, 2022) is shown on Map 02, Appendix A.
Current Zoning	The central portion of the Site, subject to proposed subdivision, is designated as Zone RU1 – Primary Production land. The remaining portion of the Site surrounding the proposed subdivision is designated as Zone C2 – Environmental Conservation land (BSC, 2014).

1.3 Proposed Development

A concept subdivision layout plan (ADW, 2022) shows the proposed development will comprise:

- Subdivision of the Site into 92 residential lots.
- Construction of a network of site access and internal roads.

The proposed subdivision layout (ADW, 2022) is provided in Appendix B for reference. Quarry pit pre rehabilitation surface levels are provided in Appendix C.

Earthworks details for the proposed subdivision were not available at time of preparation of this report.

1.4 Objectives

Assessment objectives include:

1. Identify geotechnical constraints / hazards that may impact the ability for the site to be developed for residential purposes.
2. Assess the risk(s) to the proposed development as a result of the identified geotechnical constraints / hazards.
3. Provide general geotechnical advice and recommendations necessary to demonstrate the suitability of the site for future residential land use.

1.5 Background

The Quarry supplied sand to local and regional customers since the 1920s. Sand extraction was ceased in 2015 while processing of extracted materials ceased in 2016. The quarry pit at the Site comprised three south to southwest facing benches of approximately 10 m height. Site conditions prior to quarry pit rehabilitation works are provided in Map 03, Appendix A.

Quarry rehabilitation commenced in 2016. Rehabilitation earthworks comprised minor cutting of up to approximately 2 m and filling of up to approximately 12 m to achieve present day batter grades of generally less than 1 vertical (V) : 3 horizontal (H). Some steeper batter grades of approximately 1V:1.5H remained at isolated locations in the southwestern portion of the Site. The rock cutting overlooking the former processing plant remained unchanged. Site conditions following quarry pit rehabilitation works are provided in Map 04, Appendix A.

Client provided details of the approximately quarry floor from 2014 (Appendix C) has been used for an assessment of the likely depth of fill across the site. The levels provided are compared to the contemporary surface levels to generate an estimate of fill depth (Map 06, Appendix A).

2 Investigation and Laboratory Testing Scope

2.1 Investigation Scope of Work

Following a desktop review of Site conditions, field investigations were conducted between 1 and 5 July 2024 that included:

- A site walkover by MA's geotechnical engineer.
- Engineer supervised drilling of six boreholes (BH101 to BH106) up to a maximum depth of 9.5 mbgl, using a tracked hydraulic drill rig.
- Engineer supervised excavation of two test pits (TP101 and TP102) up to a maximum depth of 3.0 mbgl, supervised by the geotechnical engineer.
- Twenty six standard penetration tests (SPT) in BH101 to BH106.
- Collection of soil samples for laboratory testing and for future reference.

Investigation locations are shown in Map 12, Appendix A.

2.2 Laboratory Testing

A selection of collected soil samples was submitted to Resource Laboratories, a National Association of Testing Authorities (NATA) accredited laboratory, for assessment of:

- Atterberg limits - five samples.
- Particle size distribution (PSD) - five samples.

3 General Site Details and Investigation Findings

3.1 General Site Details

General Site details are summarised in Table 2.

Table 2: Summary of general Site details based on desktop review and Site walkover.

Item	Description / Comment
Topography	The Site is located within undulating terrain on the western side of a northwest-southeast aligned ridge. The Site is bounded by a network of drainage swales in the northern portion of the Site, typically extending northeast to southwest to the central stormwater pond or into the dam located in the southwestern portion of the Site. Site topography is presented on Map 05, Appendix A.
Expected geology (refer to Map 07, Appendix A)	The Site is located within the Bundamba Group outcrop zone. This geology comprises typically sandstone, siltstone, claystone and conglomerate (Brunker & Cameron, 1969).
Soil Landscape (refer to Map 08, Appendix A)	The NSW Office of Environment and Heritage's (OEH) information system (eSPADE) indicates the northeastern portion of the development area to be underlain by Disturbed Terrain while the remaining Site area is underlain by the Bagotville soil landscape. These soil landscapes are described as follows: o Disturbed terrain is typically characterised by made land varying from level plains to undulating terrain which has been disturbed by human activity to a depth of at least 100 cm. Landfill includes soil, rock, building and waste material. This soil landscape is often associated with mass movement hazard and soil impermeability leading to poor drainage. o Bagotville soil landscape is typically characterised by deep (> 100 cm), moderately well drained weakly podzolised red / yellow podzolic soils overlying conglomerate which is often littered with white quartz pebbles ("hailstone gravel"). This soil landscape is often associated with steep slopes, localised rock outcrop and mass movement. Investigation results indicate that the mapped extent of disturbed terrain is likely to have been determined prior to the completion of quarrying operations as the actual extent is considerably greater than that mapped.
Typical slopes, aspect, elevation	The Site generally has a south westerly aspect with grades ranging typically between approximately 20 % (1V:5H) and 40 % (1V:2.5H) in the northern and eastern portions of the Site. The central and western portions of the Site typically have grades less than 20 % (1V:5H). Areas in the southeast of the Site are affected by steeper slopes of between approximately 40 % (1V:2.5H) and 66 % (1V:1.5H) and near vertical sandstone cuttings. Slope grades across the Site are provided in the ground stability analysis plan, presented on Map 11, Appendix A. Contoured surface levels for 2018 were provided by the client and are based on site flown LiDar survey combined with rehabilitation works design levels and are shown on Maps 03 to 05 (Appendix A). Site elevation ranges between approximately 32 mAHD in the western portion of the Site and 66 mAHD in the eastern portion.
Neighbouring Environment	The Site is surrounded by undeveloped forested land.

Item	Description / Comment
Drainage	Via overland flow to the west / southwest / south along the drainage lines across the Site into stormwater collection ponds. Indicative locations of the drainage lines are shown on Map 09, Appendix A.
Site Features	Site features observed from desktop study and site walkover, revealed: ○ Former sedimentation ponds in the western side of the Site which has been backfilled in 2016. ○ Sandstone exposure on the southern edge of the stormwater pond and southern portion of the Site. Site features are shown on Map 09, Appendix A.

3.2 Geotechnical Zones

Based on our understanding of past site activities and filling and informed by observed variation in subsurface conditions, the Site has been divided into six generalised geotechnical zones:

- Zone A is areas with fill depth greater than 2.0 m.
- Zone B is areas with fill depth less than 2.0 m.
- Zone C is the remediated sediment ponds area.
- Zone D is areas with significantly steeper slopes.
- Zone E is areas where there is limited fill.
- Zone F is the present day stormwater pond

The zones are depicted on Map 10, Appendix A.

3.3 Subsurface Conditions

Geotechnical investigation revealed the following generalised subsurface units underlie the Site:

Unit A – Fill: A mix of sand, silt and clay with variable quantities of gravel, cobbles and possible boulders. SPT results are characteristic of poorly compacted fill conditions. Occasional higher SPT counts are attributed to a more extensive gravel / cobble content, rather than a representation of improved compaction.

Unit B - Residual soil:

Unit B1: Silty sand / silty clayey gravelly sand / gravelly silty sand, associated with the weathering of sandstone, encountered in a typically medium dense condition, grading to dense where transitioning into the weathered rock unit (Unit C).

Unit B2: Silty clay / gravelly sandy silty clay, associated with the weathering of claystone / mudstone, encountered in a typically soft to firm condition, attributed to presence of groundwater, and occasionally in a stiff to very stiff condition.

Significant erosion channels were observed at the Site, suggesting Site soils are highly erodible.

Unit C - Weathered rock:

Unit C1: Extremely to highly weathered, inferred extremely low to very low strength sandstone was encountered at the base of BH102, BH104 and TP101 and observed as cut exposures at the southern extent of the Site, and along the southern shores of the stormwater collection pond in the central portion of the Site.

Unit C2: Extremely to highly weathered, inferred extremely low to very low strength mudstone / claystone, encountered at similar relative levels of between approximately 37.5 m and 38 mAHD in BH106 and BH103, respectively.

Encountered subsurface conditions within each zone are summarised below:

Zone A:

- Inferred poorly compacted, deep fill (up to approximately 8 m thick), typically comprising silty sand with variable quantities of clay and gravel is expected to be encountered up to top of bed rock.
- Extremely to highly weathered, inferred extremely low to very low strength bedrock is expected to be encountered below fill. A thin layer of residual soil overlying weathered rock may be encountered at some locations.

Zone B:

- Inferred poorly compacted, shallow to moderately deep fill (up to approximately 2 m thick), comprising typically silty sand with variable quantities of clay and gravel overlying residual soil.
- Generally medium dense / stiff to very stiff residual soil is expected below the fill up to between approximately 4.8 mbgl and 8.0 mbgl. Soft to firm residual soil, encountered in BH103, is possibly attributed to subsequent softening of residual soil by perched groundwater.
- Extremely to highly weathered, inferred extremely low to very low strength bedrock is expected below residual soil.

Zone C (former sediment ponds):

- Poorly compacted fill, comprising soft to firm silty clay with an interbedded silty gravel layer was encountered up to investigation termination depth of 5.5 mbgl. Coarse gravel to medium sized boulders are expected within the fill profile. Soft thin bands of silt were to present within the silty clay layers.

- Natural soils and weathered rock were not encountered up to investigation termination depth of 5.5 mbgl. For the purpose of this report, we have assumed the natural soil will be encountered at a depth of 6.2 mbgl, which should be confirmed by further investigation.

Zone E:

No boreholes were drilled within Zone E. However, based on our review of soil landscape, geology and geotechnical investigation results, we infer that Zone E is underlain by residual soil up to approximately 2.0 mbgl. Residual soil is overlying likely very low strength Bundamba Group Formation. We expect soil consistencies to range from at least stiff or medium dense. This should be confirmed by additional investigations at later development stages.

Zone F:

No boreholes were drilled within Zone F, being an existing stormwater pond. Based on past (2018) site observations, it is expected that the base of the stormwater pond shall be on sandstone. During the period since construction it is likely that some sediment has accumulated in the pond.

A summary of the encountered subsurface conditions is presented in Table 8, Appendix E. Encountered conditions are described in more detail on borehole logs in Appendix D with associated explanatory notes provided in Appendix I.

3.4 Groundwater Conditions

Groundwater inflow was observed during drilling of boreholes and test pits as summarised in Table 3.

Table 3: Summary of observed groundwater inflows into boreholes and test pits.

Location	Surface Level (mAHD)	Depth of Groundwater Inflow (mbgl)	Groundwater Inflow Level (mAHD)
BH102	45.0	1.0	44.0
BH103	42.5	2.0	40.5
BH104	54.0	5.3	48.7
BH105	33.6	1.1	32.5
TP101	40.0	1.2	38.8

Groundwater inflow was not encountered in BH101, BH106 and TP102 up to investigation termination depth of 7.3 mbgl. Groundwater inflow in other boreholes / test pit except for BH105 is typically encountered in sandy permeable layers, where confined by clay or at the soil / rock interface.

Based on our observation of groundwater inflow, we conclude:

- Groundwater seepage inflow across majority of the Site (except within former sediment pond i.e. across Zone C) is attributed to the presence of ephemeral perched groundwater within the soil profile or residual soil / weathered rock interface originating from infiltration of surface water during investigation / pre-investigation intense and prolonged rainfall events.
- Permanent groundwater across the majority of the Site (i.e. except Zone C) is expected to be encountered within the weathered rock profile.
- Groundwater inflow encountered during drilling of boreholes in Zone C is likely to be the permanent groundwater, which is attributed to the presence of former sediment ponds across Zone C.

4 Geotechnical Assessment

4.1 Laboratory Test Results

4.1.1 Atterberg Limits Testing

Laboratory Atterberg limits test results are summarised in Table 4 (refer Appendix F for laboratory test certificate).

Table 4: Summary of laboratory Atterberg limits test results.

BH	Depth (mbgl)	Soil Type	Atterberg Limits (%)			Plasticity Classification	Potential Volume Change [2]
			LL [1]	PL [1]	PI [1]		
BH101	1.5 – 2.0	FILL: Clayey Silty SAND	23	12	11	4.5	Low
BH102	1.0 – 1.45	FILL: Clayey Silty SAND	27	14	13	5.5	Low
BH103	2.5 – 2.95	RESIDUAL: Silty CLAY	53	26	27	11.0	High
BH104	1.0 – 1.45	FILL: Gravelly Silty SAND	27	16	11	5.5	Low
BH106	5.0 – 5.5	FILL: Silty CLAY	39	16	23	9.0	Medium

Notes:

1. LL = Liquid limit, PL= Plastic limit, PI=Plasticity index.
2. Based on Hazelton and Murphy, 2016.

Laboratory test results indicate that the tested fill materials are generally of low and medium plasticity and the tested natural clay soils are generally of high plasticity with moderate ground movement potential due to soil moisture changes.

4.1.2 PSD Testing

PSD test results are summarised in Table 5. A laboratory test certificate is provided in Appendix F.

Table 5: Summary of laboratory PSD test results.

Sample ID	Soil Type	% Gravel [1]	% Sand	% Silt	% Clay
BH101/S/3.5 – 4.0	FILL	8	71	9	12
BH102/S/2.5 – 4.5	RESIDUAL	21	58	11	10
BH103/S/0.2 – 1.0	FILL	33	31	19	17
BH104/S/3.0 – 4.0	FILL	38	44	14	8
BH106/S/1.5 – 2.5	FILL	5	72	12	11

Notes:

1. % Gravel summary includes all material greater than 2.36 mm sieve size.

PSD testing indicate that fill typically comprise sand with clay, silt and gravels.

4.2 Preliminary Material Properties

Preliminary material properties inferred from observations during borehole drilling, such as auger penetration resistance, SPT and laboratory test results as well as engineering assumptions are summarised in Table 6.

Table 6: Preliminary material properties.

Layer [1]	$\gamma_{in\text{-}situ}$ [2] (kN/m^3)	C' [3] (kPa)	Ø' [4] (deg)
ENGINEERED FILL (granular)	17 (moist) 19 (wet)	NA [5]	32
EXISTING FILL: Silty CLAY / Gravelly Sandy Silty CLAY / SLIT / Sandy Silty CLAY (poorly compacted)	16 (moist) 18 (wet)	1	24
EXISTING FILL: Silty SAND / Silty Clayey SAND / Silty Clayey Gravelly SAND (poorly compacted)	16 (moist) 18 (wet)	0	27
RESIDUAL: Silty CLAY / Gravelly Sandy Silty CLAY (soft to firm)	17 (moist) 19 (wet)	2	25
RESIDUAL: Silty CLAY (stiff to very stiff)	19 (moist) 20 (wet)	4	26
RESIDUAL: Silty SAND / Silty Clayey Gravelly SAND / Gravelly Silty SAND (medium dense to dense)	19 (moist) 20 (wet)	0	32
WEATHERED ROCK: Extremely to highly weathered, extremely to very low strength	22	10	28

Notes:

1. Refer to borehole logs in Appendix D for material description details.
2. Average material *in-situ* unit weight estimate.
3. Average drained cohesion estimate.
4. Average effective internal friction angle estimate, assuming drained conditions; may be dependent on rock defect conditions.
5. Not Applicable.

Material properties provided in Table 6 are developed for the purposes of this planning proposal assessment of site stability and likely future settlement only. They are to be further refined and informed by further investigation as the site development planning progresses.

4.3 Geotechnical Constraints

We consider the proposed development will likely be impacted by the following key geotechnical constraints:

General (including Zone D)

- Potential slope instability. Minor slope instability of over steepened fill embankment at some locations . We understand that a historical landslide in the north of the Site, west of the access track (refer to Map 09, Appendix A for indicative location) is undergoing remediation.
- Soil erosion where vegetation is not maintained.

Zone A

- Deep poorly compacted fill up to approximately 8 - 10 mbgl will undergo long term settlement and must be considered in foundation design.
- Presence of potential ephemeral perched groundwater within the soil profile may impact construction methodologies.

Zone B

- Existing poorly compacted fill up to 2.0 mbgl and presence of some soft soils shall impact foundation design.
- Presence of potential ephemeral perched groundwater within the soil profile will impact construction methodologies.

Zone C

- Deep poorly compacted fill up to 5.5 mbgl and presence of soft residual soils, considered unsuitable as foundation material for new structures, will impact foundation design and construction.
- Presence of potential ephemeral perched groundwater within the soil profile will impact construction methodologies.

Zone E

- Generally minor constraints due to absence of significant fill.
- Potential instability risk associated with the sandstone cutting along the northern edge of Zone D (refer to Map 09, Appendix A, for indicative location).

- Presence of potential ephemeral perched groundwater within the soil profile will impact construction methodologies.

Zone F

- Existing sediment pond in the central portion of the Site may contain accumulated silt sediments which, if left in situ during earthworks, would be unsuitable.

Access Road Construction

- Variable subgrade conditions.
- Poorly compacted fill subgrade in places.
- Steep natural slopes in places.

4.4 Geotechnical Risk Assessment

In order to assess the stability of the existing fill batters across the site and the deformation (i.e. settlement) behaviour of existing soft fill material under structural loading, geotechnical modelling comprising 2D finite element (FE) analysis was undertaken. Plaxis 2D, a two-dimensional FE computer program, was used to carry out numerical analysis of five cross sections (Sections A-A to E-E). The details of the FE analysis and analysis results are presented in the subsequent sections of the report.

4.4.1 Modelling Objective

The objective of the geotechnical modelling was to carry out 2D finite element (FE) analysis to assess the stability of the quarry rehabilitation fill embankment and the total surface settlement (immediate elastic and primary consolidation) of the fill profile under structural loading.

Analysis was undertaken adopting plain strain (per metre length) conditions and the Mohr-Coulomb constitutive theory. The analysis was carried out in stages to simulate initial quarry pit and sedimentation pond filling followed by a period of ongoing deformation (elastic consolidation).

4.4.2 Development of Geotechnical Model

A representative geotechnical model of the Site and its surrounds was developed based on the findings from corresponding borehole(s) undertaken during our geotechnical investigation as well as our engineering judgement. The geotechnical model for each cross section is shown in Figures 1 to 5, Appendix G. The model divides the subsurface profile into a number of soil and bedrock units. Geotechnical parameters associated with each soil and rock unit in each cross section were selected from Table 6 (Section 4.2). The corresponding representative geotechnical model of each cross section was then used in our numerical modelling and analysis.

4.4.3 Modelling Assumptions

The following assumptions were made in developing the Plaxis 2D FE models:

- Subsurface unit thicknesses and conditions were inferred from the findings of our geotechnical investigation.
- Soil and rock strength and deformation properties are homogeneous and isotropic throughout each unit.
- Fine grained (i.e. silt and clay) soil is modelled under undrained conditions to assess deformation behaviour under short term condition.
- Groundwater levels were adopted based on groundwater assessment results presented in Section 3.4 of this report.
- Hydraulic conductivity of each soil layer was evaluated based on the grain size distribution using the Van Genuchten model.
- Weathered rock is considered impermeable in comparison to overlying soils.
- A target degree of consolidation of 99% was adopted to predict potential primary consolidation settlement of the fine grained fill layer(s) under structural loading.
- A uniformly distributed building load of 20 kPa was adopted for long term settlement assessment.
- The effects of long-term secondary consolidation (i.e. creep) settlement were not determined as part of this assessment.
- Dynamic and earthquake induced impacts were not considered.
- Maximum lot width of approximately 30 m is assumed for modelling purposes.

4.4.4 Slope Instability Risk Assessment

4.4.4.1 Method of Analyses

Considering the variable subsurface conditions, depth of fill and fill batter grades across the Site, four cross sections (A-A, B-B, C-C and D-D) were selected, considered to best represent most unfavourable ground conditions with steepest grades (refer to Map 06, Appendix A, for cross section locations) as discussed below:

- Section A-A was selected to assess the stability of the south facing fill batter, targeting the deepest fill and steepest slopes (i.e. across Zones A, B and F).
- Section B-B was selected to assess the stability of the west facing fill batter, targeting the deepest fill and steepest slopes (i.e. across Zones A, B and F).
- Section C-C was selected to assess the stability of the northwest facing steeper fill batter, targeting the deepest fill area (i.e. across Zones A, B and D).

- Section D-D was selected to assess the stability of the steepest west facing batter in the south western portion of the Site (i.e. across Zones A, B and D).

Considering the varying groundwater conditions observed in the boreholes and test pits, two different groundwater scenarios were analysed for each section to assess the impact on stability of the fill batter, including:

1. Scenario 1: Perched groundwater over top of rock, at the base of the fill / natural soil profile, representing long term groundwater conditions. This was modelled under drained soil behaviour (for both coarse and fine grained soils). Where depth of top of rock is not known, such as across the south western portion of the Site (Section D-D), the groundwater level is assumed to be located below the modelled domain, for the purpose of modelling of long term conditions.

2. Scenario 2: Ephemeral perched groundwater level, at the fill / natural soil interface, representing short term (i.e. temporary) groundwater conditions (e.g. in Section D-D). This was modelled with drained (for coarse grained soil) and undrained soil behaviours (for fine grained soil). Where the location of ephemeral perched groundwater level is not known, an elevated groundwater level located within the fill profile (to saturate approximately 50% of the fill volume) was adopted for the purpose of modelling (e.g. in Sections A-A to C-C). We note that Scenario 2 is considered a sensitivity scenario.

We note that the quarry rehabilitation fill comprises predominantly granular material (i.e. sand and gravel) with only a minor portion of fines (i.e. silt and clay). In order to differentiate between Scenario 1 and Scenario 2, the behaviour of the fill material is assumed to be governed by the fines content rather than the granular content,. The predicted global minimum factor of safety (FOS) against slope instability or total ground surface settlement (immediate elastic and primary consolidation) under structural loading was evaluated and outlined in the subsequent section of the report.

4.4.4.2 Modelling Stages

The following sequence of Site development was adopted for slope stability analysis:

1. Stage 0 (initial stage) – Development of initial stress (the initial stress state in the model was developed using the K_0 method. The K_0 method applies initial in-situ stresses to the soils and rock equivalent to the K_0 pressure) under existing subsurface conditions, i.e. following placement of existing fill.

2. Stage 1 – Deformation analysis of existing fill.

3. Stage 2 – Safety analysis at the end of Stage 1 to assess stability of existing fill embankment.

4.4.4.3 Results of Slope Stability Analysis

Based on accepted engineering practice, minimum FOSs of 1.3 under short term load conditions and 1.5 under long term fill slope conditions were considered satisfactory.

Slope stability analysis results are summarised in Table 7 and illustrated in Figures 6 to 13, Appendix G.

Table 7: Obtained FOS against fill slope instability.

Groundwater Scenario	Section	Analysed FOS	Target FOS	Remarks
Scenario -1	A-A	3.0	1.5	Satisfactory
	B-B	4.9		Satisfactory
	C-C	1.5		Satisfactory
	D-D	1.1		Not satisfactory
Scenario -2 [1]	A-A	2.0	1.3	Satisfactory
	B-B	2.8		Satisfactory
	C-C	1.3		Satisfactory
	D-D	0.9 (≈1.0) [2]		Not satisfactory

Notes:

1. Modelled as a worst-case situation, despite the fill material is likely to behave as a drained material (i.e. sand and gravel) across Sections A-A to D-D.
2. Evidence of former shallow soil slides was observed in steep slope.

Plaxis analysis has returned acceptable short and long term FOSs of > 1.3 and 1.5, respectively, against global failure for all cross sections except for Section D-D.

Short and long term FOSs of 0.9 and 1.1, respectively, were returned for Section D-D, indicating the steep slopes in the southwestern portion of the Site are marginally stable.

4.4.5 Consolidation Settlement Risk Assessment (Zone C)

4.4.5.1 Method of Analyses

Total surface settlement (immediate elastic and primary consolidation) under structural loading of the fill profile in the former sediment pond was evaluated along cross section E-E (i.e. across Zone C, refer to Map 06, Appendix A, for cross section location).

Consolidation analysis was carried out adopting a 20 kPa building load, until the degree of consolidation of 99% was reached (i.e. full consolidation of the soft soil layer). Short term elastic settlement under building load was also assessed.

4.4.5.2 Modelling Stages

The following sequence of consolidation was modelled for settlement analysis:

1. Stage 0 (initial stage) – Development of initial stress (the initial stress state in the model was developed using the K_0 method. The K_0 method applies initial in-situ stresses to the soils and rocks equivalent to the K_0 pressure) under existing subsurface conditions, i.e. following placement of existing fill.
2. Stage 1 – Addition of a 20 kPa building load, simulated by the construction of a 1 m high fill embankment at existing surface level.

3. Stage 2 – Consolidation analysis until 99% target degree of consolidation was reached.

4.4.5.3 Results of Settlement Analyses

Total surface settlement was determined by the observed maximum settlement at the end of analysis experienced by a point located at the surface (refer point A in Figure 5, Appendix G). The results of settlement analysis are illustrated in Figures 14 to 16, Appendix G.

Short term elastic and subsequent consolidation analysis returned a ground surface settlement of 26 mm (Figure 14, Appendix G) and 58 mm (Figures 15 and 16, Appendix G), respectively. Therefore, the ground is expected to experience a total surface settlement of 84 mm under 20 kPa building loads.

4.4.6 Total Elastic Settlement Risk Assessment (Zones A and B)

As mentioned earlier, the quarry rehabilitation fill, particularly across Zone A and Zone B comprises predominantly granular material. Therefore no secondary consolidation of the fill material is expected across these zones. Additional Plaxis analysis was however carried out to assess the immediate elastic settlement of the fill material across Zone A and Zone B under 20 kPa building load.

Long term elastic deformation analysis returned a total ground surface settlement of approximately 20 mm and 42 mm for a fill depth of 2 m and 8 m, respectively.

4.4.7 FE Modelling Findings and Conclusions

Based on our assessment we conclude the followings:

1. Plaxis analysis returned short and long-term FOSs of > 1.3 and 1.5, respectively, against global slope failure for Sections A-A to C-C, which have grades ≤ 1V:3H. Therefore, existing fill slopes with grades not exceeding 1V:3H are considered stable and pose a low risk of instability to the proposed development.

2. Short and long term FOSs of 0.9 and 1.1, respectively, were returned for Section D-D, indicating that the southwestern existing fill batter with grades of up to 1V:1.5H is marginally stable. Slope failure may be induced by adverse conditions such as stormwater infiltration due to heavy of persistent rainfall.

3. Under a building foundation load of 20 kPa, the western area of the Site underlain by filled sedimentation ponds will likely experience total settlement of approximately 84 mm and a differential settlement of approximately 42 mm (say 50 % of total settlement).

4. Plaxis analysis results indicate that the ground is expected to experience a total surface settlement of 20 mm and 42 mm for a fill depth of 2 m and 8 m, respectively, in Zone A and Zone B under 20 kPa building load. Some differential settlement (approximately 1/3 to 1/2 of the total settlement) is expected beneath the building footprint in Zone A and Zone B due to the nonuniform nature of the fill material.

Recommendations to achieve a low risk of slope instability and ground settlement to the proposed development are included in Section 5 below.

5 Discussions, Conclusions and Recommendations

5.1 Discussion

The key geotechnical constraints at the Site based on the findings of our assessment are:

- Poorly compacted fill, up to approximately 10 m depth, comprises predominantly granular material with occasional cohesive soil and / or boulder inclusions. This material may experience some elastic settlement under a building load.
- Soft to firm residual soils underlying the fill may impact foundation design, i.e. foundation may need to extend to rock. We note that provision of appropriate surface drainage will likely improve subsurface conditions.
- Consolidation settlement due to the soft to firm fill within Zone C is likely to impact foundation design. Pile foundation will likely be required in Zone C to support future structures.
- Fill and natural slopes across the Site are generally stable. However, steep slopes at some isolated locations may require engineered designed solutions to reduce the risk of slope instability to an acceptable level.
- Limited erosion was observed at some locations along the drainage swales. Appropriate mitigation measures (e.g. concrete lining, rip-rap) should be adopted to limit erosion.

These constraints can be managed by adopting the recommendations presented in this report, including:

- Provision of appropriate stormwater runoff management systems to limit soil erosion and stormwater infiltration of the fill profile at the Site.
- Inclusion of deepened footings within the Zone C to ensure building loads are transmitted into suitable foundation material beneath existing fill materials.
- Minor ground improvement in building pads to achieve suitable foundation conditions in accordance with AS2870 (2011) and for new access roads.
- Shallow foundation design with the provision of appropriate site classification considering a combined ground settlement due to characteristic surface movement as a result of soil moisture condition variations and long term settlement of Site fill materials in accordance with AS2870 (2011).
- Deep foundations should be founded in competent natural soil / rock in accordance with AS2159 (2009).
- Carrying out earthworks in accordance with AS3798 (2009).
- Carrying out further geotechnical assessments to refine the reported recommendations throughout the development and design process.

Risk management strategies with respect to the identified key geotechnical constraints for new access roads may include:

- Ground improvement by removal and replacement of suitable existing fill materials with engineered fill to achieve suitable subgrade conditions.
- Further geotechnical investigation and laboratory CBR testing of subgrade conditions along proposed access road alignments to develop pavement thickness designs.
- Provision of surface and subsurface drainage along road alignments.
- Maintain an appropriate buffer to the crest of steep slopes.
- Supporting cuttings with engineered designed retaining walls.

5.2 Conclusion

No significant geotechnical constraints were identified that would prevent the proposed residential development at the Site, subject to adoption of the risk management strategies and general recommendations presented in the following section and any subsequent reports to develop detailed designs and construction methodologies recommended in Section 5.3. The Site is therefore considered suitable for the proposed residential development.

5.3 Recommendations

Geotechnical recommendations to mitigate the risks associated with identified geotechnical constraints relating to each risk zone are provided in Section 5.3.1. These recommendations are provided as an example of practical measures that can be implemented to allow for the future residential development of the land as proposed in the planning proposal. They are not intended to be final, nor are they the only available solution to identified geotechnical constraints and shall be refined through the site development and design process. Additional general geotechnical recommendations to mitigate the risks associated with identified geotechnical constraints for development in general are provided in Sections 5.3.2 to 5.3.5.

Further general geotechnical recommendations are provided in Appendix H.

5.3.1 Zone Specific Recommendations

Risk mitigation strategies with regards to the geotechnical constraints for each risk zone discussed in Section 4.3, are presented below.

5.3.1.1 Zone A

New structures may be supported by shallow foundations such as pad / strip footings. However, minor ground improvement may be required to achieve suitable foundation conditions in accordance with AS2870 (2011). This may include removal and replacement of existing fill materials with engineered fill. Replacement depths will depend on conditions specific to each building footprint.

Considering expected characteristic surface movements due to soil moisture condition variations changes of < 20 mm for low plasticity site clays (slightly reactive) and the assessed long term differential settlement of existing fill soils across building footprints of < 45 mm, site classifications in accordance with AS2870 (2011) of H1 and possibly H2 are expected to apply to lots in Zone A, depending on extent of material replacement and foundation material type.

Alternatively, deepened footings may be adopted to extend through all fill materials and socket into at least stiff residual soil.

5.3.1.2 Zone B

New structures may be supported by shallow foundations such as pad / strip footings. However, minor ground improvement may be required to achieve suitable foundation conditions. Similar to Zone A, this may include removal and replacement of existing fill materials with engineered fill. Although replacement depths will depend on conditions specific to each building footprint, replacement depths are not expected to exceed 2 m considering the original quarry pit surface is located within 2 m of current fill surface levels. Although replacement depths will depend on conditions specific to each building footprint, replacement depths are not expected to exceed 2 m considering the original quarry pit surface is located within 2 m of current fill surface levels.

Considering expected characteristic surface movement due to soil moisture condition variations changes of < 20 mm for low plasticity site clays (slightly reactive) and the assessed long term differential settlement of existing fill soils across building footprints of < 20 mm. Site classifications in accordance with AS2870 (2011) for shallow footing design of M and possibly H1 are expected to apply to lots in Zone B, depending on extent of material replacement and foundation material type.

Alternatively, deepened footings may be adopted to extend through all fill materials and socket into at least stiff residual soil.

5.3.1.3 Zone C

Soft cohesive soils identified within this zone are considered unsuitable as foundation material for proposed residential development.

Structures in this zone can be supported by deepened footings that extend through the unsuitable materials and found in at least stiff residual soil or weathered rock. Further assessment is required to determine top of rock level and rock conditions within building footprints.

Alternatively, removal and replacement of existing fill materials with engineered fill may be considered.

5.3.1.4 Zone D

The risk of slope instability in steep natural and fill slopes may be mitigated by:

1. Regrading of the steep slopes to maximum permanent grades of 1V:3H.

2. Installing permanent retention.
3. Improving groundwater conditions through adoption of appropriate surface and subsurface drainage systems.

5.3.1.5 Zone E

Shallow foundations, such as pad or strip footings, or concrete slab on ground are expected to be suitable for this area, subject to founding on at least stiff / medium dense natural soil. Where localised historical cutting / filling has taken place, we expect that deepened footings such as concrete piers may be adopted to achieve suitable foundation conditions. This should be confirmed by further assessment, however, does not preclude this area from development.

5.3.1.6 Zone F

Following dewatering of the existing sediment pond, removal of sediment deposits (expected to be shallow) from the base of the stormwater pond will achieve suitable conditions for necessary engineered filling and the proposed development.

5.3.2 Earthworks

Where new fill is to be placed to either replace unsuitable foundation material or to raise site levels, earthworks including subgrade and foundation preparation works and fill placement, are to be carried out under engineering control and in accordance with AS3798 (2007) and the Council Earthworks Specifications.

5.3.2.1 Material Reuse

New fill material are to comprise well graded granular soils with low potential for ground movement due to soil moisture variations.

Site won excavated fill, natural granular soils and weathered sandstone are considered suitable for reuse as fill for Site development, subject to the removal of any unsuitable inclusions in accordance with Clause 4.3 of AS3798 (2007) and the approval by an experienced geotechnical engineer.

Fill and natural clays of medium to high plasticity, silts and claystone / mudstone are considered unsuitable for use as structural fill, i.e. beneath buildings. However, their reuse as structural fill may be possible if mixed with appropriate proportions of granular material. Alternatively, these materials are considered suitable for reuse as general fill.

5.3.3 Surface Drainage

Risks associated with soil erosion and adverse groundwater impacts on foundation conditions due to stormwater infiltration, such as reduction in material strength, can be managed through the provision of appropriate surface drainage, vegetation cover and land grades to prevent the ponding of water.

Design and installation of drainage systems should be carried out in accordance with Council engineering specifications and achieve the following:

- Appropriate longitudinal grades
- Limit water ponding by maintaining appropriate energy reduction.
- Limit soil erosion.
- Drains can be easily maintained to ensure blockages can be removed.

5.3.4 Soil Erosion Control

Soil erosion risk can be controlled by:

1. Removal of soil overburden in a manner that reduces the risk of sedimentation occurring in the Council stormwater system and on neighbouring lands.
2. Including erosion control measures to prevent transportation of sediments off site.
3. Providing appropriate soil erosion control methods in accordance with Landcom (2004).
4. Use of appropriate stormwater energy dissipators.
5. Spreading of stormwater discharge to prevent concentrated stormwater runoff.
6. Site revegetation as soon as possible following completion of earthworks.

5.3.5 Further Works

Recommendations for mitigating the risks of identified geotechnical constraints to the proposed development should be refined throughout the site development and design process. This may be achieved by:

- Further geotechnical investigations tailored to the final development proposal.
- Where deepened piled foundations are adopted, undertake additional investigations including cored boreholes and point load testing of collected rock samples to determine depth to top of rock and rock foundation conditions.
- Where necessary, carrying out additional slope stability assessments of neighbouring steep land to assess impact on the final development proposal.
- Carry out additional geotechnical assessments and laboratory testing, such as California Bearing Ratio (CBR) testing within the footprint of the local access roads.
- Input by an experienced geotechnical engineer to develop the subdivision and structural designs to confirm adequate consideration of the geotechnical risks

and adoption of the recommendations provided in this and subsequent geotechnical reports.

  - Inspections and monitoring of construction works.

6 References

ADW (2022) *Concept Layout Plan*, Drawing Ref. 240392-PSK-002(A), Revision A, dated 27 October 2022 (ADW, 2022).

Brunker & Cameron (1969) *Tweed Heads 1:250 000 Geological Series Sheet SH 56-3*, 1st Edtion, Geological Survey of New South Wales, Sydney (Brunker & Cameron, 1969).

Byron Shire Council (2014) *Local Environment Plan, Land Zoning Map – Sheet LZN_003CD* (BSC, 2014).

Land and Property Information (2014) *SIX Maps Viewer, accessed on 12.07.2024.*

NSW Department of Environment & Heritage (2024) eSPADE, NSW soil and land information, www.environment.nsw.gov.au, accessed on 12.07.2024.

SLR Consulting Pty Ltd (2023) *Planning Proposal*, document reference 631.30868.00000-R01, Version No. v1.0, dated March 2023 (SLR, 2023).

Standards Australia Limited (2004) AS 1289.6.3.1:2004, *Determination of the penetration resistance of a soil – Standard penetration test (SPT)*, SAI Global Limited.

Standards Australia Limited (2017) AS 1726:2017, *Geotechnical site investigations*, SAI Global Limited.

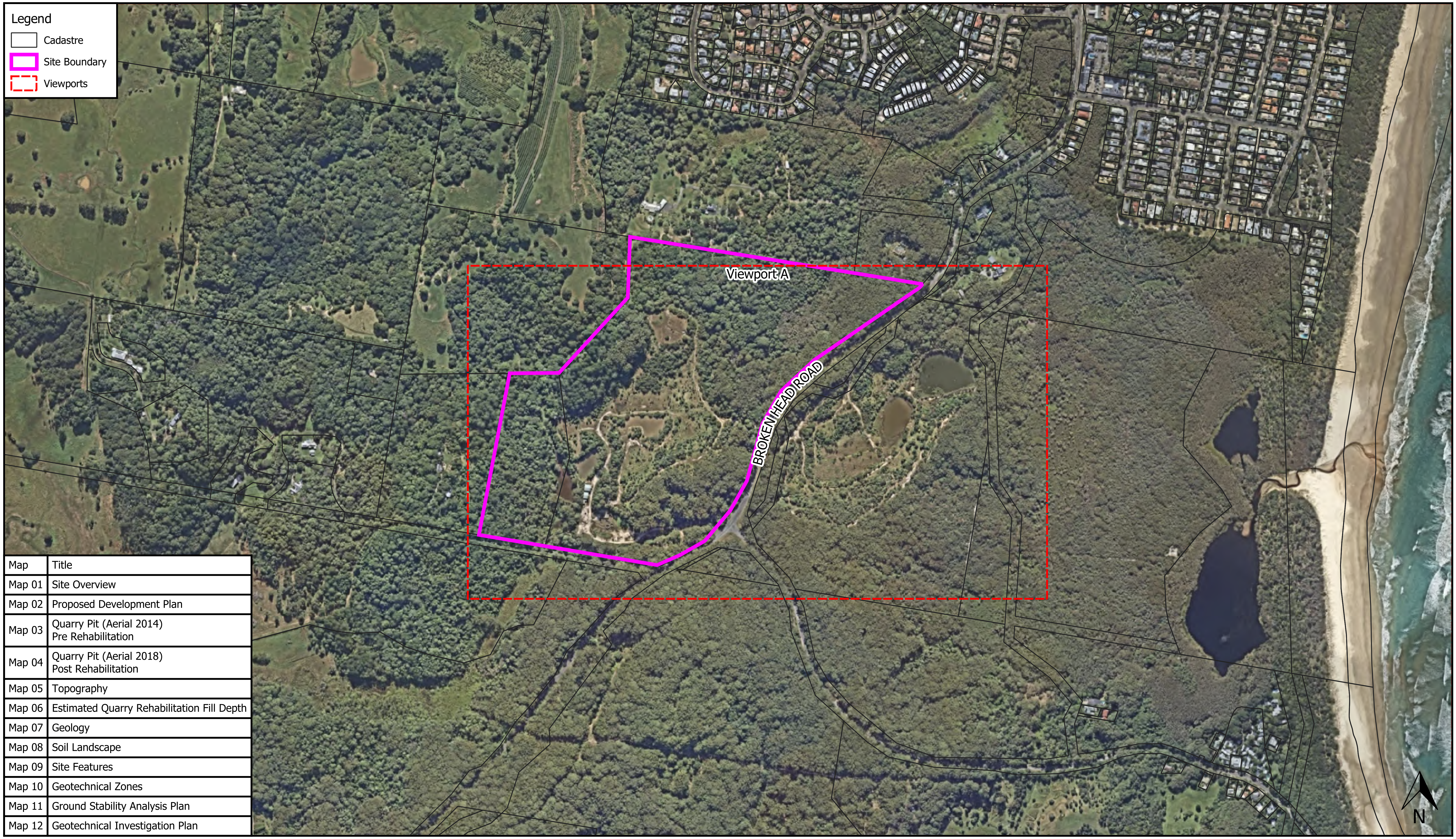
Standards Australia Limited (2009) AS 2159:2009, *Piling – Design and installation*, SAI Global Limited.

Standards Australia Limited (2011) AS 2870:2011, *Residential slabs and footings*, SAI Global Limited.

Standards Australia Limited (2018) AS 3600:2018, *Concrete Structures*, SAI Global Limited.

Standards Australia Limited (2007) AS 3798:2007, *Guidelines on earthworks for commercial and residential developments*, SAI Global Limited.

Appendix A – Maps



Map	Title
Map 01	Site Overview
Map 02	Proposed Development Plan
Map 03	Quarry Pit (Aerial 2014) Pre Rehabilitation
Map 04	Quarry Pit (Aerial 2018) Post Rehabilitation
Map 05	Topography
Map 06	Estimated Quarry Rehabilitation Fill Depth
Map 07	Geology
Map 08	Soil Landscape
Map 09	Site Features
Map 10	Geotechnical Zones
Map 11	Ground Stability Analysis Plan
Map 12	Geotechnical Investigation Plan

0 90 180 270 360 450 m

1:7500 @ A3

Viewport

Notes:
- Aerial from Nearmap (2024).
- Cadastre and Site Boundary from NSW Spatial Services Clip & Ship (2024).

Map Title / Figure:

Site Overview

Map 01	Map
Broken Head Road, Suffolk Park NSW - Lot 1 in DP123302 and Lot 2 in DP700806	Site
Geotechnical Assessment	Project
Proposed Land Rezoning and Future Residential Subdivision	Sub-Project
Winton Property Group acting on behalf of Darley Pty atf GWR Trust & Crisjoy Pty Ltd atf The Lighthouse Unit Trust	Client
23/07/2024	Date

martens
Environment | Water | Geotechnics | Civil | Projects

Project No: P2410392 Map Set: MS01-R04 EPSG: 7856

1:3000 @ A3

Viewport A

Notes:
- Aerial from Nearmap (2024).
- Cadastre and Site Boundary from NSW Spatial Services Clip & Ship (2024).
- Proposed layout from ADW Johnson (2024).

martens
Environment | Water | Geotechnics | Civil | Projects

Map Title / Figure:

Proposed Development Plan

Map 02	Map
Broken Head Road, Suffolk Park NSW - Lot 1 in DP123302 and Lot 2 in DP700806	Site
Geotechnical Assessment	Project
Proposed Land Rezoning and Future Residential Subdivision	Sub-Project
Winton Property Group acting on behalf of Darley Pty atf GWR Trust & Crisjoy Pty Ltd atf The Lighthouse Unit Trust	Client
23/07/2024	Date

1:3000 @ A3

Viewport A

Notes:
- Aerial from Nearmap (2014).
- Cadastre and Site Boundary from NSW Spatial Services Clip & Ship (2024).
- Contours for 'current surface' from Lidar and 2018 remedial works design.

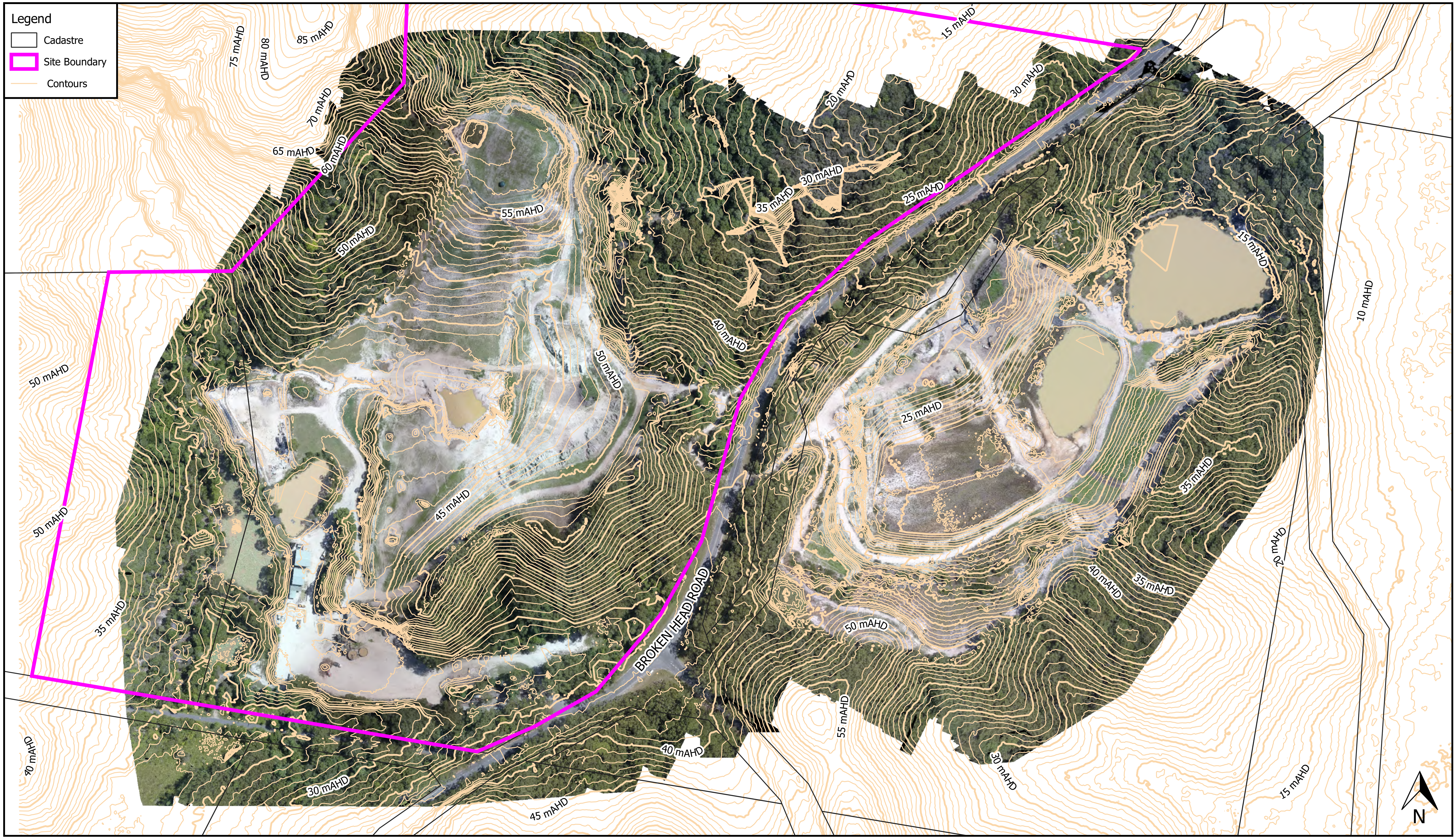
martens
Environment | Water | Geotechnics | Civil | Projects

Map Title / Figure:

Quarry Pit (Aerial 2014)
Pre Rehabilitation

Map 03	Map
Broken Head Road, Suffolk Park NSW - Lot 1 in DP123302 and Lot 2 in DP700806	Site
Geotechnical Assessment	Project
Proposed Land Rezoning and Future Residential Subdivision	Sub-Project
Winton Property Group acting on behalf of Darley Pty atf GWR Trust & Crisjoy Pty Ltd atf The Lighthouse Unit Trust	Client
23/07/2024	Date

Project No: P2410392 Map Set: MS01-R04 EPSG: 7856



0 30 60 90 120 150 m

1:3000 @ A3

Viewport

Notes:
- 2018 aerial photograph provided by client.
- Cadastre and Site Boundary from NSW Spatial Services Clip & Ship (2024).
- Contours for 'current surface' from Lidar and 2018 remedial works design.

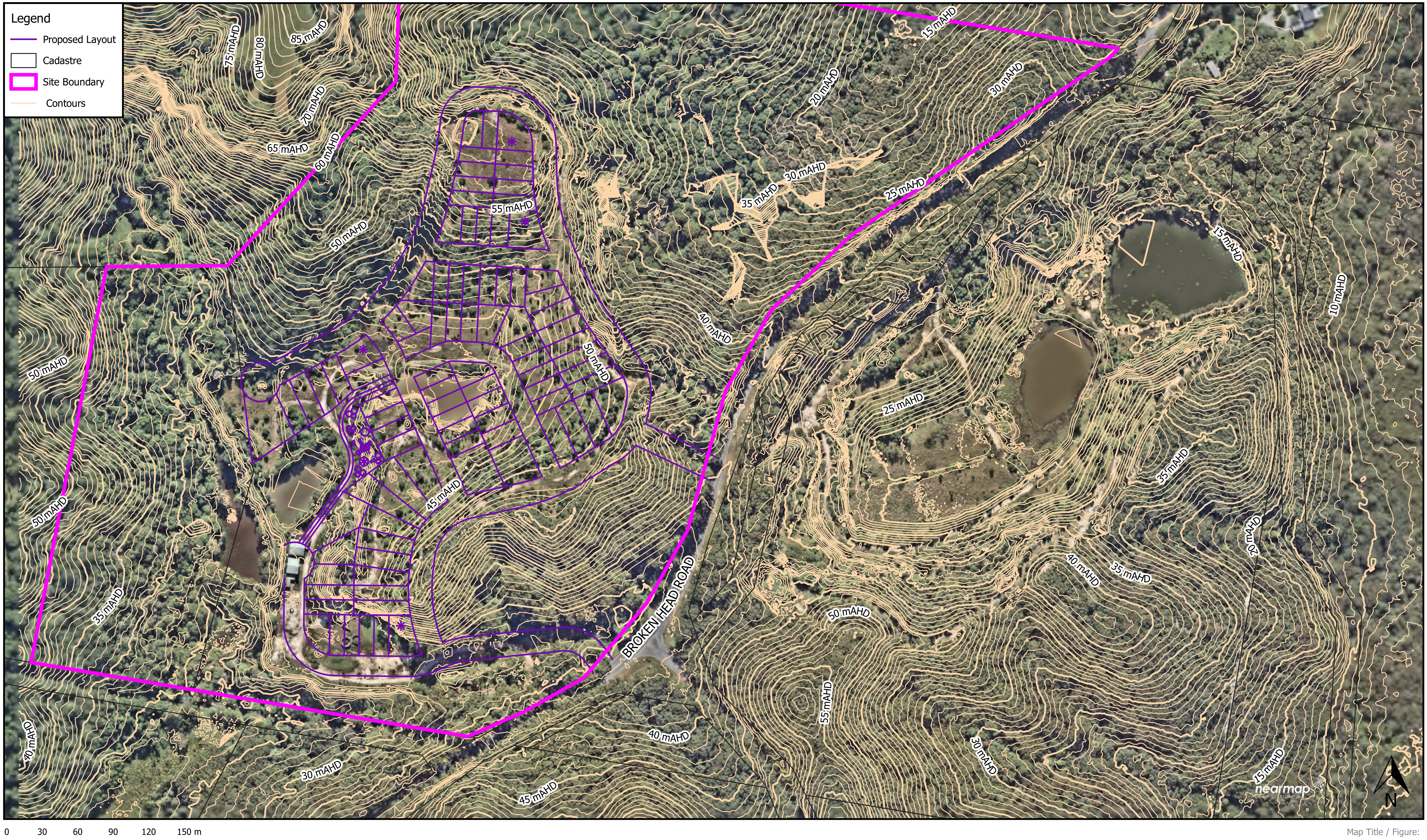
Map Title / Figure:

Quarry Pit (Aerial 2018)
Post Rehabilitation

Map 04	Map
Broken Head Road, Suffolk Park NSW - Lot 1 in DP123302 and Lot 2 in DP700806	Site
Geotechnical Assessment	Project
Proposed Land Rezoning and Future Residential Subdivision	Sub-Project
Winton Property Group acting on behalf of Darley Pty atf GWR Trust & Crisjoy Pty Ltd atf The Lighthouse Unit Trust	Client
23/07/2024	Date

martens
Environment | Water | Geotechnics | Civil | Projects

Project No: P2410392 Map Set: MS01-R04 EPSG: 7856



1:3000 @ A3

Viewport A

Notes:
- Aerial from Nearmap (2024).
- Cadastre and Site Boundary from NSW Spatial Services Clip & Ship (2024).
- Proposed layout from ADW Johnson (2024).
- Contours for 'current surface' from Lidar and 2018 remedial works design.

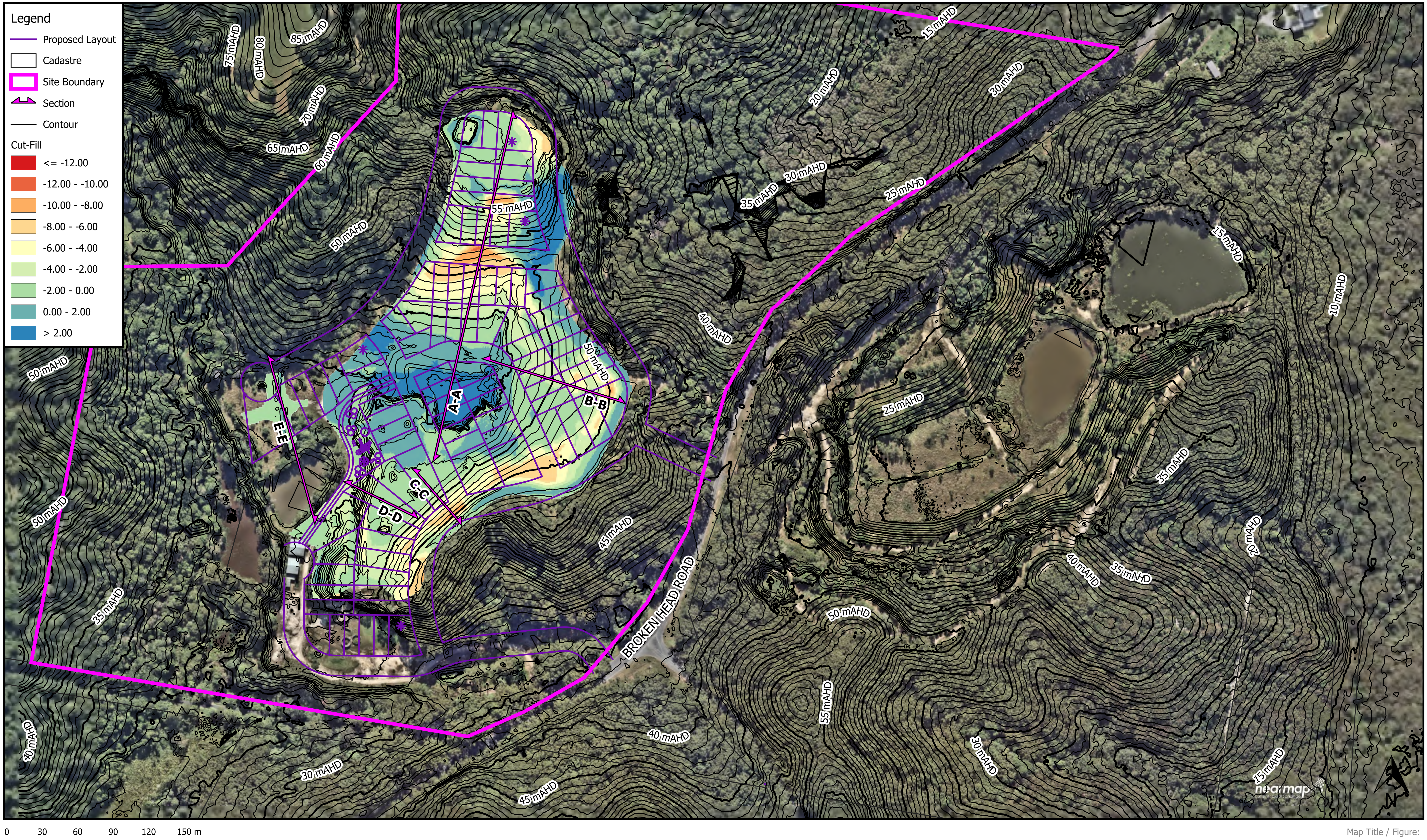
martens
Environment | Water | Geotechnics | Civil | Projects

Map Title / Figure:

Topography

Map 05	Map
Broken Head Road, Suffolk Park NSW - Lot 1 in DP123302 and Lot 2 in DP700806	Site
Geotechnical Assessment	Project
Proposed Land Rezoning and Future Residential Subdivision	Sub-Project
Winton Property Group acting on behalf of Darley Pty atf GWR Trust & Crisjoy Pty Ltd atf The Lighthouse Unit Trust	Client
23/07/2024	Date

Project No: P2410392 Map Set: MS01-R04 EPSG: 7856



1:3000 @ A3

Viewport A

Notes:
- Aerial from Nearmap (2024).
- Cadastre and Site Boundary from NSW Spatial Services Clip & Ship (2024).
- Proposed layout from ADW Johnson (2024).
- Fill depth estimate calculated from former quarry floor data ((provided by client) and 'current surface' from Lidar and 2018 remedial works design (shown as contours).

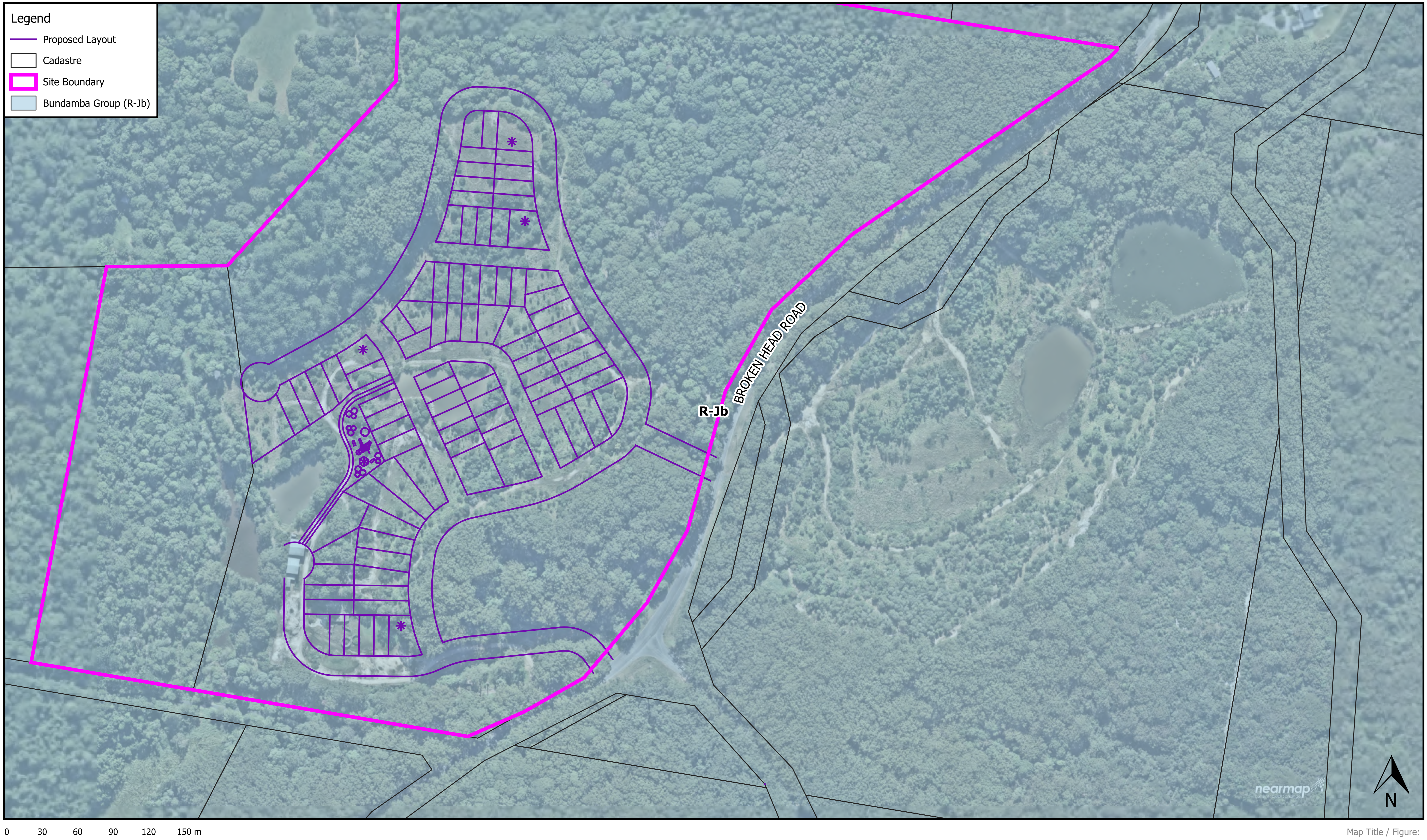
Map Title / Figure:

Estimated Quarry Rehabilitation Fill Depth

Map 06	Map
Broken Head Road, Suffolk Park NSW - Lot 1 in DP123302 and Lot 2 in DP700806	Site
Geotechnical Assessment	Project
Proposed Land Rezoning and Future Residential Subdivision	Sub-Project
Winton Property Group acting on behalf of Darley Pty atf GWR Trust & Crisjoy Pty Ltd atf The Lighthouse Unit Trust	Client
23/07/2024	Date

Project No: P2410392 Map Set: MS01-R04 EPSG: 7856

martens
Environment | Water | Geotechnics | Civil | Projects



1:3000 @ A3

Viewport A

Notes:
- Aerial from Nearmap (2024).
- Cadastre and Site Boundary from NSW Spatial Services Clip & Ship (2024).
- Proposed layout from ADW Johnson (2024).
- Geology from Brunker R.L., Cameron R.G., Tweedale G. and Reiser R., 1972, Tweed Heads 1:250 000 Geological Sheet SH/56-03, 1st edition, Geological Survey of New South Wales, Sydney accesed via NSW Geoscience (2024).

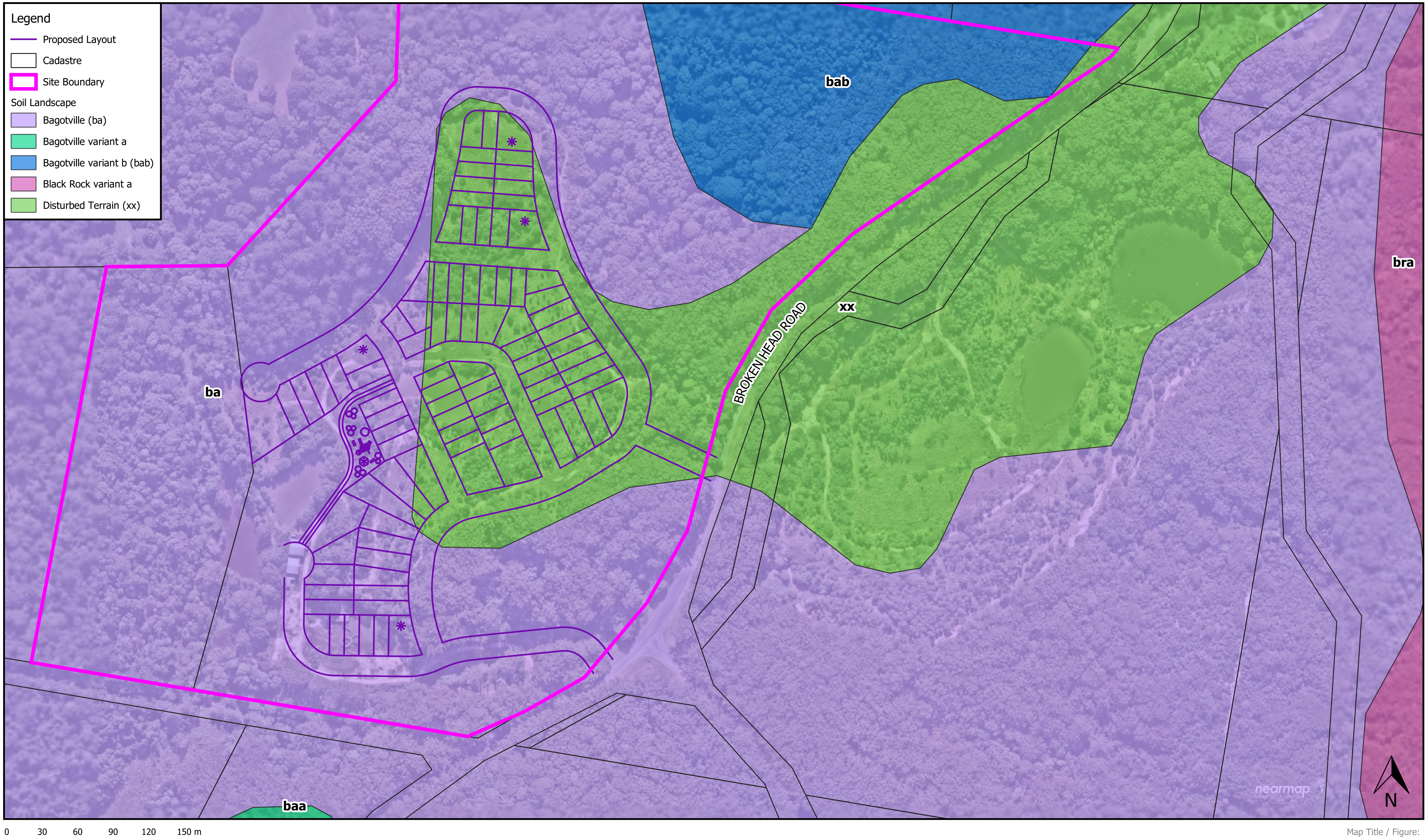
martens
Environment | Water | Geotechnics | Civil | Projects

Map Title / Figure:

Geology

Map 07	Map
Broken Head Road, Suffolk Park NSW - Lot 1 in DP123302 and Lot 2 in DP700806	Site
Geotechnical Assessment	Project
Proposed Land Rezoning and Future Residential Subdivision	Sub-Project
Winton Property Group acting on behalf of Darley Pty atf GWR Trust & Crisjoy Pty Ltd atf The Lighthouse Unit Trust	Client
23/07/2024	Date

Project No: P2410392 Map Set: MS01-R04 EPSG: 7856



1:3000 @ A3

Viewport A

Notes:
- Aerial from Nearmap (2024).
- Cadastre and Site Boundary from NSW Spatial Services Clip & Ship (2024).
- Proposed layout from ADW Johnson (2024).
- Soil Landscape from NSW Department of Planning, Industry and Environment SEED (2024).

Map Title / Figure:

Soil Landscape

Map 08	Map
Broken Head Road, Suffolk Park NSW - Lot 1 in DP123302 and Lot 2 in DP700806	Site
Geotechnical Assessment	Project
Proposed Land Rezoning and Future Residential Subdivision	Sub-Project
Winton Property Group acting on behalf of Darley Pty atf GWR Trust & Crisjoy Pty Ltd atf The Lighthouse Unit Trust	Client
23/07/2024	Date

martens
Environment | Water | Geotechnics | Civil | Projects

Project No: P2410392 Map Set: MS01-R04 EPSG: 7856

1:3000 @ A3

Viewport A

Notes:
- Aerial from Nearmap (2024).
- Cadastre and Site Boundary from NSW Spatial Services Clip & Ship (2024).

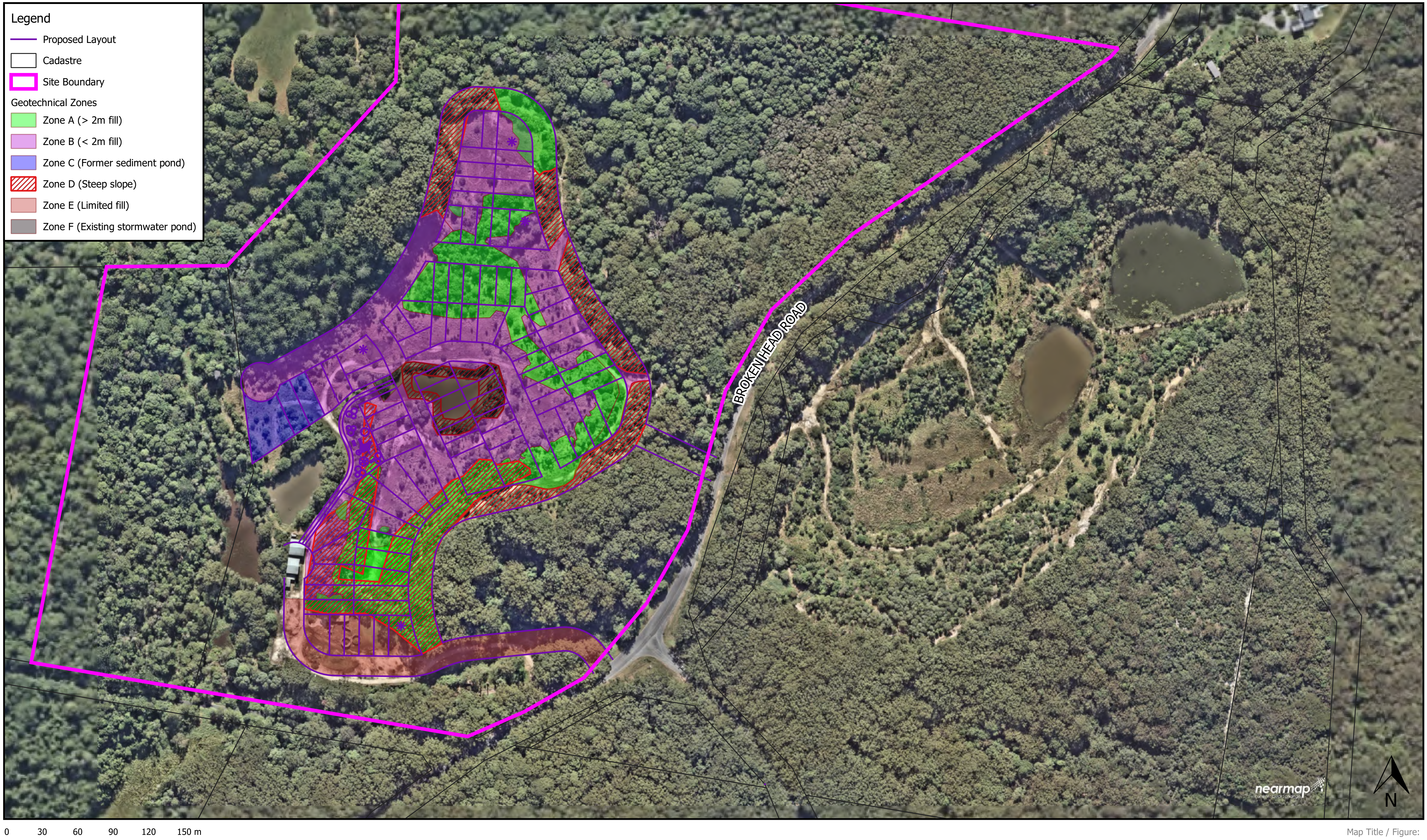
Map Title / Figure:

Site Features

Map 09	Map
Broken Head Road, Suffolk Park NSW - Lot 1 in DP123302 and Lot 2 in DP700806	Site
Geotechnical Assessment	Project
Proposed Land Rezoning and Future Residential Subdivision	Sub-Project
Winton Property Group acting on behalf of Darley Pty atf GWR Trust & Crisjoy Pty Ltd atf The Lighthouse Unit Trust	Client
23/07/2024	Date

martens
Environment | Water | Geotechnics | Civil | Projects

Project No: P2410392 Map Set: MS01-R04 EPSG: 7856



1:3000 @ A3

Viewport A

Notes:
- Aerial from Nearmap (2024).
- Cadastre and Site Boundary from NSW Spatial Services Clip & Ship (2024).
- Proposed layout from ADW Johnson (2024).

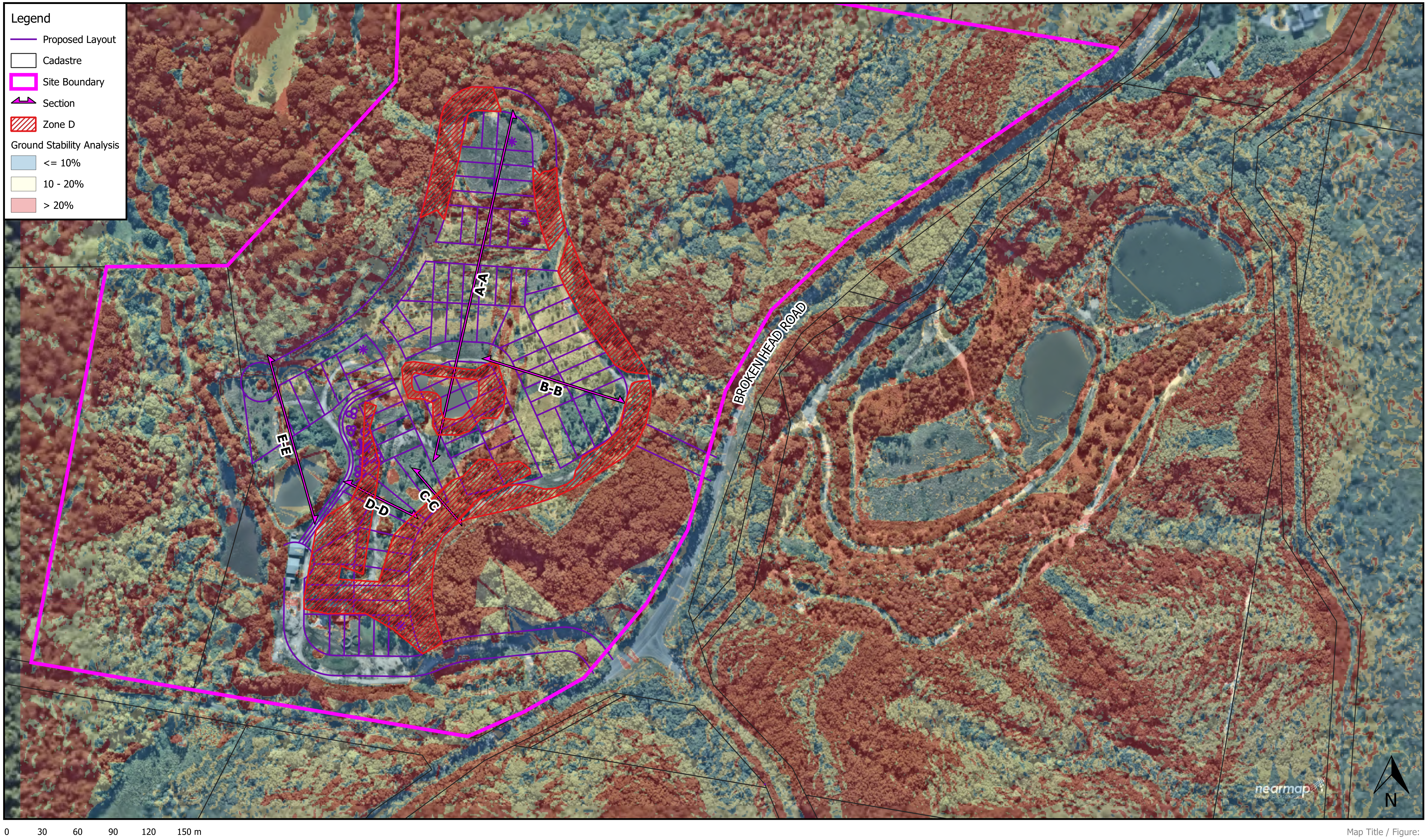
Map Title / Figure:

Geotechnical Zones

Map 10	Map
Broken Head Road, Suffolk Park NSW - Lot 1 in DP123302 and Lot 2 in DP700806	Site
Geotechnical Assessment	Project
Proposed Land Rezoning and Future Residential Subdivision	Sub-Project
Winton Property Group acting on behalf of Darley Pty atf GWR Trust & Crisjoy Pty Ltd atf The Lighthouse Unit Trust	Client
23/07/2024	Date

martens
Environment | Water | Geotechnics | Civil | Projects

Project No: P2410392 Map Set: MS01-R04 EPSG: 7856



1:3000 @ A3

Viewport A

Notes:
- Aerial from Nearmap (2024).
- Cadastre and Site Boundary from NSW Spatial Services Clip & Ship (2024).
- Proposed layout from ADW Johnson (2024).

Map Title / Figure:

Ground Stability Analysis Plan

Map 11	Map
Broken Head Road, Suffolk Park NSW - Lot 1 in DP123302 and Lot 2 in DP700806	Site
Geotechnical Assessment	Project
Proposed Land Rezoning and Future Residential Subdivision	Sub-Project
Winton Property Group acting on behalf of Darley Pty atf GWR Trust & Crisjoy Pty Ltd atf The Lighthouse Unit Trust	Client
23/07/2024	Date

martens
Environment | Water | Geotechnics | Civil | Projects

Project No: P2410392 Map Set: MS01-R04 EPSG: 7856

1:3000 @ A3

Viewport A

Notes:
- Aerial from Nearmap (2024).
- Cadastre and Site Boundary from NSW Spatial Services Clip & Ship (2024).
- Proposed layout from ADW Johnson (2024).

Map Title / Figure:

Geotechnical Investigation Plan

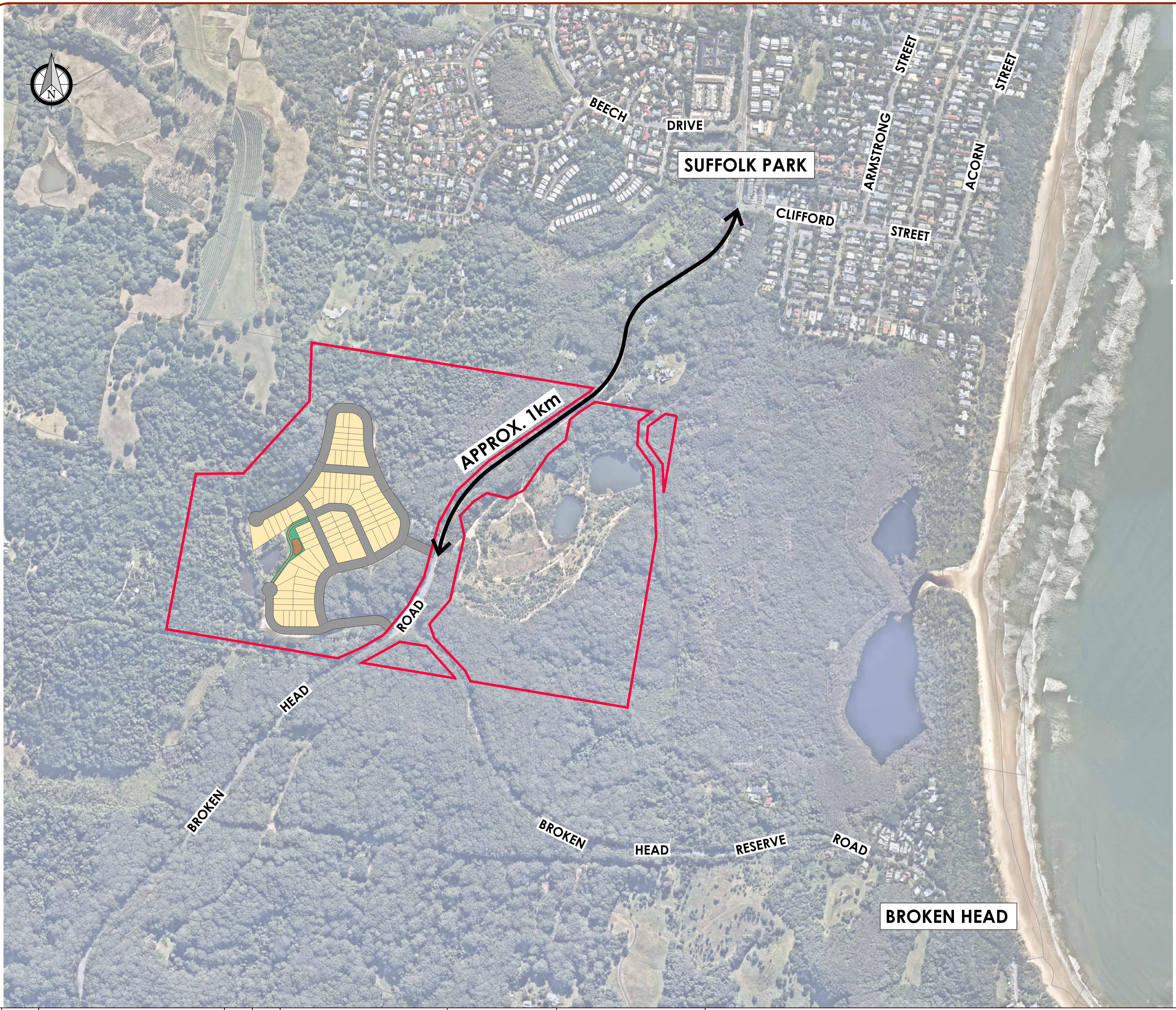
Map 12	Map
Broken Head Road, Suffolk Park NSW - Lot 1 in DP123302 and Lot 2 in DP700806	Site
Geotechnical Assessment	Project
Proposed Land Rezoning and Future Residential Subdivision	Sub-Project
Winton Property Group acting on behalf of Darley Pty atf GWR Trust & Crisjoy Pty Ltd atf The Lighthouse Unit Trust	Client
23/07/2024	Date

martens
Environment | Water | Geotechnics | Civil | Projects

Project No: P2410392 Map Set: MS01-R04 EPSG: 7856

Appendix B – Concept Layout Plans

240392-PSK-001 TO 003[A]



LEGEND

▬	SITE BOUNDARY
—	PROPOSED BOUNDARY
—	EXISTING CADASTRE (DCDB)
▭	PROPOSED LOT
■	PROPOSED ROAD

w o r k i n g b e y o n d e x p e c t a t i o n s

drawing title:

SITE CONTEXT PLAN

location: BROKEN HEAD ROAD
SUFFOLK PARK, NSW

council: BYRON SHIRE COUNCIL

dwg ref: 240392-PSK-001 [A]

client: WINTEN PROPERTY GROUP PTY LTD

adw johnson

central coast office ph: (02) 4305 4300
hunter office ph: (02) 4978 5100
sydney office ph: (02) 8046 7411

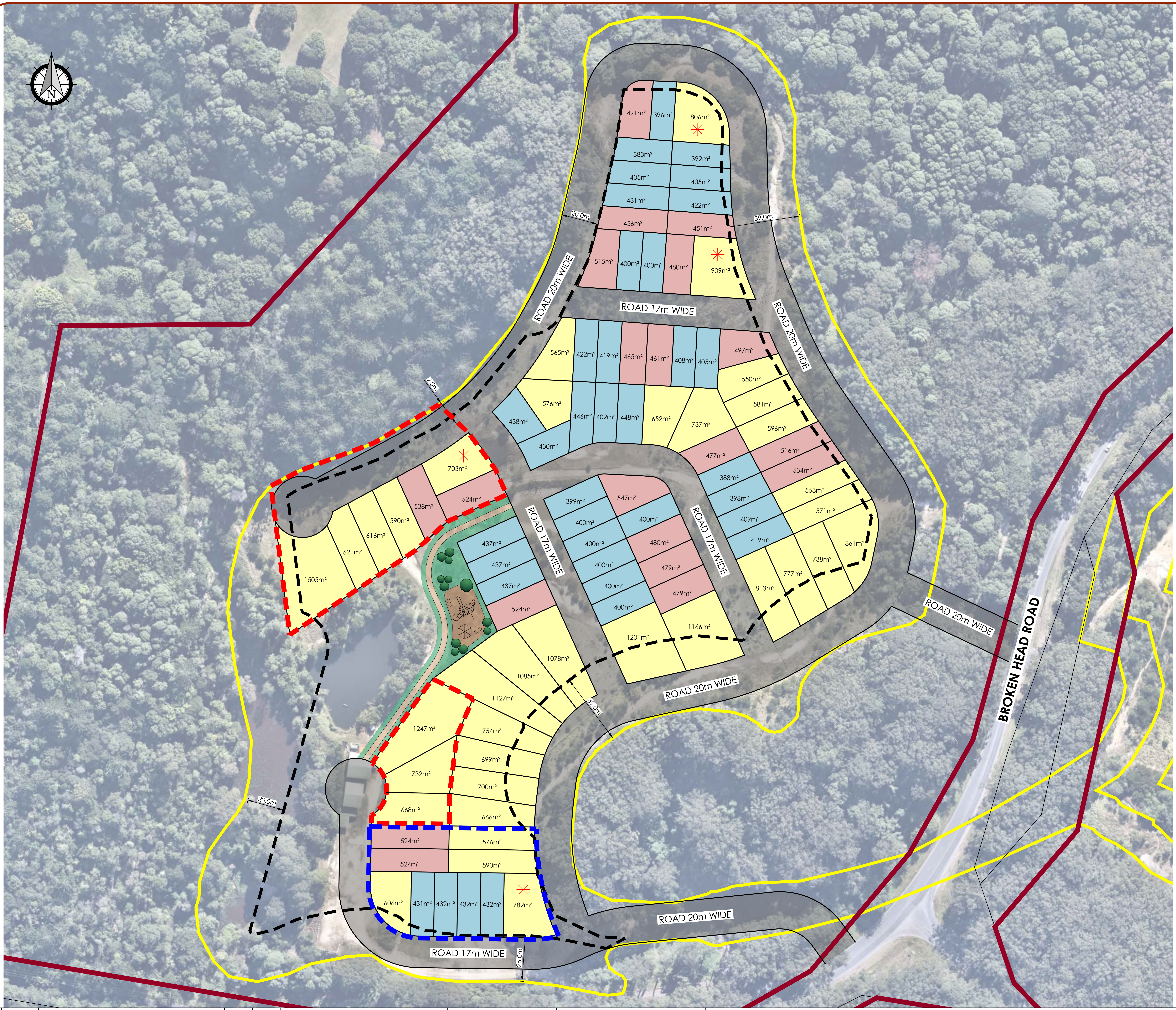
www.adwjohnson.com.au

ver.	date	comment	drawn	pm	co-ordinate information	level information	scale (A1 original size)	notes
A	27.10.2022	INITIAL ISSUE	LS	JBAY	CO-ORDINATE SYSTEM: MGA56 GDA94	DATUM: N/A CONTOUR INTERVAL: N/A	0 100 200m A1 1:4000 A3 1:8000	

• project management • civil engineering • infrastructure • superintendency • economic analysis • social impact • town planning • surveying • development feasibility • visualisation • urban design

Plotted By: Leah Swain Plot Date: 27/10/22 10:29:21AM Cad File: N:\240392\DWG\PLANNING\PSK\240392-PSK-001 TO 003[A].DWG

This plan includes coloured information. If you have a black and white copy you do not have all of the information. This note is coloured RED.



LEGEND

▬	SITE BOUNDARY
—	PROPOSED BOUNDARY
—	EXISTING CADASTRE (DCDB)
▬	EXISTING ZONE BOUNDARY
- - -	ASSET PROTECTION ZONE (APZ)
- - -	POTENTIAL MEDIUM DENSITY SITE
- - -	POTENTIAL AFFORDABLE HOUSING SITE
▭	PROPOSED PATH
🟦	AREA <450m^2 (36 LOTS)
🟥	AREA 450-550m^2 (20 LOTS)
🟨	AREA >550m^2 (36 LOTS)
✳	POTENTIAL DUPLEX LOTS

working beyond expectations

drawing title:

CONCEPT LAYOUT
PLAN

location: BROKEN HEAD ROAD
SUFFOLK PARK, NSW

council: BYRON SHIRE COUNCIL

dwg ref: 240392-PSK-002[A]

client:

WINTEN PROPERTY GROUP
PTY LTD

adw johnson

ver.	date	comment	drawn	pm	co-ordinate information	level information	scale (A1 original size)	notes
A	27.10.2022	INITIAL ISSUE	LS	JBAY	CO-ORDINATE SYSTEM: MGA56 GDA94	DATUM: N/A CONTOUR INTERVAL: N/A	A1 1:2000 0 50 100m A3 1:4000	

• project management • civil engineering • infrastructure • superintendency • economic analysis • social impact • town planning • surveying • development feasibility • visualisation • urban design

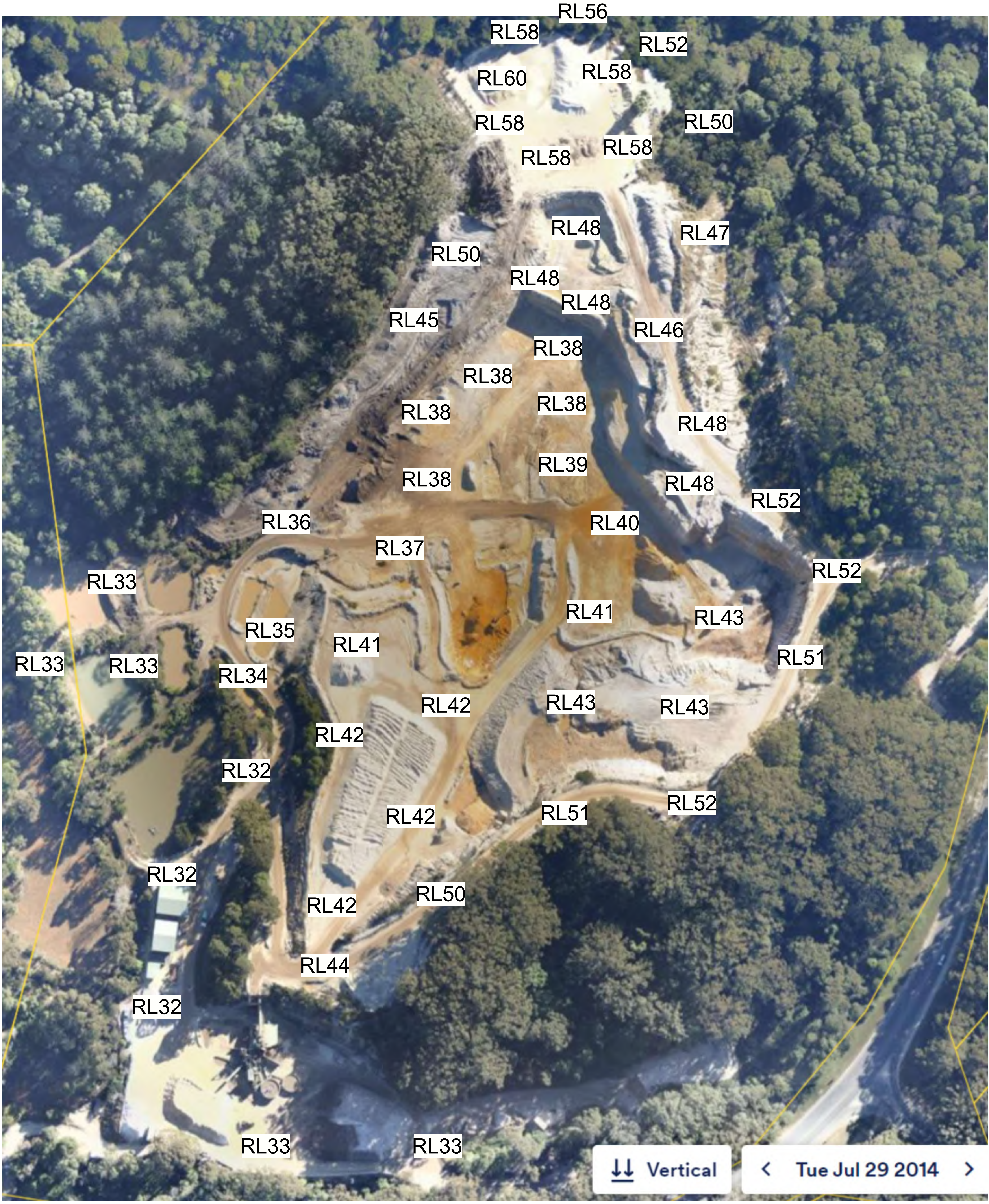
central coast office ph: (02) 4305 4300
hunter office ph: (02) 4978 5100
sydney office ph: (02) 8046 7411

www.adwjohnson.com.au

Plotted By: Leah Swain Plot Date: 27/10/22 10:29:26AM Cad File: N:\240392\DWG\PLANNING\PSK\240392-PSK-001 TO 003[A].DWG

This plan includes coloured information. If you have a black and white copy you do not have all of the information. This note is coloured RED.

Appendix C – Quarry Floor Survey Levels (2014)


RL56
RL58
RL52
RL60
RL58
RL58
RL50
RL58
RL58
RL48
RL47
RL50
RL48
RL48
RL45
RL46
RL38
RL38
RL38
RL38
RL48
RL39
RL38
RL48
RL52
RL36
RL40
RL37
RL52
RL33
RL41
RL43
RL35
RL41
RL51
RL33
RL33
RL34
RL42
RL43
RL43
RL42
RL32
RL42
RL51
RL52
RL32
RL50
RL42
RL44
RL32
RL33
RL33
Vertical
Tue Jul 29 2014

Appendix D – Borehole Logs

CLIENT	Darley P/L atf GWR Trust & Crisjoy P/L atf The Lighthouse Unit Trust	COMMENCED	04/07/2024	COMPLETED	04/07/2024	**REF BH101**
PROJECT	Geotechnical Investigation	LOGGED	AK	CHECKED	WB	Sheet 1 OF 1
SITE	Broken Head Road, Suffolk Park NSW - lot 1 DPI123302	GEOLOGY	Bundamba Group	VEGETATION	Grass	PROJECT NO. P2410392
EQUIPMENT	Geo 601	LONGITUDE	153.60017	RL SURFACE	48.7 m	DATUM AHD
EXCAVATION DIMENSIONS	Ø100 mm x 6.95 m depth	LATITUDE	-28.69573	ASPECT	West	SLOPE 10 - 20 %

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
AD/T	L	Not Encountered		48.70	0.2-0.5/S/1 D 0.20-0.50 m		☒	CI	FILL: Silty CLAY; medium plasticity; brown, dark brown; trace fine to medium gravels and fine grained sand; inferred poorly compacted.	M (<PL)	S - F	FILL
				0.50 48.20	0.5-1/S/1 D 0.50-1.00 m		☒	SC-SM	FILL: Silty Clayey SAND; medium to coarse grained; pale brown, grey; with mixed gravels (fine to medium grained); inferred poorly compacted.	M	VL - L	
			1	1.00 47.70	SPT 1.00-1.45 m 5, 1, 3 N = 4 1.0-1.45/S/1 D 1.00-1.45 m 1.5-2.0/S/1 D 1.50-2.00 m		☒	SC-SM	FILL: Clayey Silty SAND; medium to coarse grained; dark grey, grey; with mixed gravels (fine to medium grained); inferred poorly compacted.		F	
	M		2	2.00 46.70	2.0-2.5/S/1 D 2.00-2.50 m SPT 2.50-2.95 m 3, 2, 3 N = 5 2.5-2.95/S/1 D 2.50-2.95 m		☒		Gravels increasing in size, with cobbles.			2.50: Anthropogenic inclusions observed.
	M-H		3				☒					3.00: Possible boulders.
	L-M		4	3.20 45.50	3.5-4.0/S/1 D 3.50-4.00 m SPT 4.00-4.45 m 1, 1, 1 N = 2 4.0-4.45/S/1 D 4.00-4.45 m		☒	SP	FILL: SAND; medium to coarse grained; brown, yellow; with clay and silt; trace gravels; inferred poorly compacted.	M - D	VL	
			5	4.50 44.20	4.5-5.0/S/1 D 4.50-5.00 m 5.0-5.5/S/1 D 5.00-5.50 m		☒	SC-SM	FILL: Silty Clayey SAND; medium to coarse grained; dark grey; with fine to coarse gravels; inferred poorly compacted.			
	L		6	5.60 43.10	SPT 5.50-5.95 m 2, 1, 1 N = 2 5.5-5.95/S/1 D 5.50-5.95 m 6.0-3.5/S/1 D 6.00-6.50 m SPT 6.50-6.95 m 2, 2, 2 N = 4		☒	SM	FILL: Silty SAND; medium to coarse grained; brown, yellow; trace medium to coarse gravels; inferred poorly compacted.	D		
			7	6.95					Hole Terminated at 6.95 m Collapse			
			8									

EXCAVATION LOG TO BE READ IN CONJUCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS

MARTENS & ASSOCIATES PTY LTD
Suite 201, 20 George St. Hornsby, NSW 2077 Australia
Phone: (02) 9476 9999 Fax: (02) 9476 8767
mail@martens.com.au WEB: http://www.martens.com.au

Engineering Log - BOREHOLE

CLIENT	Darley P/L atf GWR Trust & Crisjoy P/L atf The Lighthouse Unit Trust	COMMENCED	02/07/2024	COMPLETED	02/07/2024	**REF BH102**
PROJECT	Geotechnical Investigation	LOGGED	AK	CHECKED	WB	Sheet 1 OF 1
SITE	Broken Head Road, Suffolk Park NSW - lot 1 DPI123302	GEOLOGY	Bundamba Group	VEGETATION	Grass	PROJECT NO. P2410392
EQUIPMENT	Geo 601	LONGITUDE	153.5996	RL SURFACE	45 m	DATUM: AHD
EXCAVATION DIMENSIONS	Ø100 mm x 9.50 m depth	LATITUDE	-28.69595	ASPECT	Northwest	SLOPE: 10 - 20 %

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
AD/T	L			45.00	0.2-0.5/S/1 D 0.20-0.50 m	■	▨	SC-SM	FILL: Silty Clayey SAND; fine to medium grained; dark grey; with mixed fine to coarse gravels; inferred loose; inferred poorly compacted.	M	L	FILL
WB	M-H L-M H	▽	1 2	1.00 44.00	SPT 1.00-1.45 m 9, 10, 5 N=15 1.0-1.45/S/1 D 1.00-1.45 m	■	▨	CL-CI	FILL: Clayey Silty SAND; fine to medium grained; grey, brown; with mixed medium to coarse gravels; SPT impacted by coarse gravels; inferred poorly to moderately compacted.			FILL POSSIBLY RESIDUAL SOIL 1.50: Possible boulder or weak rock layer. 1.70: Total water loss.
	L-M		3	2.30 42.70	SPT 2.50-2.95 m 7, 9, 9 N = 18 2.5-2.95/S/1 D 2.50-2.95 m	■	∴	SP	SAND; fine to medium grained; dark grey, dark brown; with gravels, clay and silt; sand is fine to medium grained, gravels are mixed and fine to coarse gravels; inferred poorly compacted.	M - W	MD - D	RESIDUAL SOIL
			4	4.00 41.00	SPT 4.00-4.45 m 6, 6, 4 N = 10 4.0-4.45/S/1 D 4.00-4.45 m	■	✕∘	SC-SM	Silty Clayey Gravelly SAND; fine to medium grained; pale brown, grey; gravels are fine to coarse and mixed; inferred poorly compacted.		MD	
	L L-M		5 6	5.00 40.00	SPT 5.50-5.95 m 1, 3, 1 N = 4 5.5-5.95/S/1 D 5.50-5.95 m	■	∴	SP	SAND; fine to medium grained; brown grey, pale yellow; with gravel, clay and silt; sand is medium to coarse, gravels are fine to coarse and mixed; inferred poorly compacted.	M	L	
			7	7.00 38.00	SPT 7.00-7.45 m 4, 4, 6 N = 10 7.0-7.45/S/1 D 7.00-7.45 m	■	✕∘	SM	Gravelly Silty SAND; fine to medium grained; pale brown, brown; trace clay; gravels are quartz and subrounded; inferred poorly compacted.		MD	
	M		8 9	8.00 37.00 9.50	SPT 8.50-8.95 m 18 / 120 DB N = Refusal 8.5-8.95/S/1 D 8.50-8.95 m	■	∵		SANDSTONE: fine to medium grained; whitish, pale yellow; extremely to highly weathered; inferred extremely low to very low strength.			WEATHERED ROCK
			10						Hole Terminated at 9.50 m			

EXCAVATION LOG TO BE READ IN CONJUCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS

martens

MARTENS & ASSOCIATES PTY LTD
Suite 201, 20 George St. Hornsby, NSW 2077 Australia
Phone: (02) 9476 9999 Fax: (02) 9476 8767
mail@martens.com.au WEB: http://www.martens.com.au

Engineering Log - BOREHOLE

CLIENT	Darley P/L atf GWR Trust & Crisjoy P/L atf The Lighthouse Unit Trust	COMMENCED	03/07/2024	COMPLETED	03/07/2024	**REF BH103**
PROJECT	Geotechnical Investigation	LOGGED	AK	CHECKED	WB	Sheet 1 OF 1
SITE	Broken Head Road, Suffolk Park NSW - lot 1 DPI123302	GEOLOGY	Bundamba Group	VEGETATION	Nil	PROJECT NO. P2410392
EQUIPMENT	Geo 601	LONGITUDE	153.59828	RL SURFACE	42.5 m	DATUM AHD
EXCAVATION DIMENSIONS	Ø100 mm x 5.78 m depth	LATITUDE	-28.69651	ASPECT	North	SLOPE < 5 %

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
AD/T	M			42.50	0.2-0.3/S/1 D 0.20-0.30 m 0.5-10/S/1 D 0.50-1.00 m			ML	FILL: Gravelly Clayey SILT; low plasticity; pale brown, pale grey, brown; with sand, sand is fine to coarse grained, gravels are mixed and fine to coarse grained; inferred soft to firm; inferred poorly compacted.	M (<PL)	S - F	FILL
	L		1	1.00 41.50	SPT 1.00-1.45 m 1, 1, 1 N = 2 1.0-1.45/S/1 D 1.00-1.45 m 1.5-2.0/S/1 D 1.50-2.00 m			CI-CH	FILL: Silty CLAY; medium to high plasticity; pale brown, reddish brown.	M (=PL)	S	
		▽	2	2.00 40.50	SPT 2.50-2.95 m 0, 1, 1 N = 2 2.5-2.95/S/1 D 2.50-2.95 m SPT 4.00-4.45 m 0, 2, 2 N = 4 4.0-4.45/S/1 D 4.00-4.45 m			CI-CH	Silty CLAY; medium to high plasticity; brown, pale yellow layers.		S F	RESIDUAL SOIL
			3									
			4									
				4.50 38.00					CLAYSTONE / MUDSTONE; medium to coarse grained; pale brown; inferred extremely to highly weathered; inferred extremely low to very low strength.			WEATHERED ROCK
			5	5.00 37.50	5.2-5.5/S/1 D 5.20-5.50 m SPT 5.50-5.78 m 19, 30 / 130 DB N = Refusal 5.5-5.78/S/1 D 5.50-5.78 m				Becoming pale grey, white.			
				5.78					Hole Terminated at 5.78 m			
			6									
			7									
			8									

EXCAVATION LOG TO BE READ IN CONJUCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS

MARTENS & ASSOCIATES PTY LTD
Suite 201, 20 George St. Hornsby, NSW 2077 Australia
Phone: (02) 9476 9999 Fax: (02) 9476 8767
mail@martens.com.au WEB: http://www.martens.com.au

Engineering Log - BOREHOLE

CLIENT	Darley P/L atf GWR Trust & Crisjoy P/L atf The Lighthouse Unit Trust	COMMENCED	03/07/2024	COMPLETED	03/07/2024	**REF BH104**	
PROJECT	Geotechnical Investigation	LOGGED	AK	CHECKED	WB	Sheet 1 OF 1	
SITE	Broken Head Road, Suffolk Park NSW - lot 1 DPI123302	GEOLOGY	Bundamba Group	VEGETATION	Grass	PROJECT NO. P2410392	
EQUIPMENT	Geo 601	LONGITUDE	153.59929	RL SURFACE	54 m	DATUM	AHD
EXCAVATION DIMENSIONS	Ø100 mm x 7.76 m depth	LATITUDE	-28.69249	ASPECT	South	SLOPE	20 %

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
AD/T	L			54.00	0.2-0.5/S/1 D 0.20-0.50 m 0.5-1.0/S/1 D 0.50-1.00 m SPT 1.00-1.45 m 3, 2, 2 N = 4 1.0-1.45/S/1 D 1.00-1.45 m			SM	FILL: Gravelly Silty SAND; medium to coarse grained; brown; with clay and mixed colours; gravels are mixed fine to coarse grained; inferred poorly compacted.	M	F	FILL
				2.50 51.50	SPT 2.50-2.95 m 2, 2, 1 N = 3 2.5-2.6/S/1 D 2.50-2.60 m 2.5-2.95/S/1 D 2.50-2.95 m 3.0-3.5/S/1 D 3.00-3.50 m 3.5-4.0/S/1 D 3.50-4.00 m SPT 4.00-4.45 m 1, 2, 2 N = 4 4.0-4.45/S/1 D 4.00-4.45 m			GP	Sandy GRAVEL; fine to coarse grained; dark brown; with silt and clay.		VL - L	2.50: New layer, possibly Silty Clayey Gravelly SAND pending PSD.
		▽		5.00 49.00					Gravels increasing in size.	M - W		5.00: SPT was over filled due to collapse.
	M			5.50 48.50	SPT 5.50-5.95 m 11, 24, 32 N = 56 5.5-5.95/S/1 D 5.50-5.95 m			SM	Silty SAND (extremely weathered sandstone); medium to coarse grained; yellow.			RESIDUAL SOIL
				6.50 47.50	SPT 7.34-7.76 m 19, 30, 24 / 120 DB N = Refusal 7.34-7.76/S/1 D 7.34-7.76 m				Grading to whitish.	M	MD - D	
				7.76					Hole Terminated at 7.76 m			7.76: SPT refusal on inferred very low strength sandstone.

1 2 3 4 5 6 7 8

EXCAVATION LOG TO BE READ IN CONJUCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS

MARTENS & ASSOCIATES PTY LTD
Suite 201, 20 George St. Hornsby, NSW 2077 Australia
Phone: (02) 9476 9999 Fax: (02) 9476 8767
mail@martens.com.au WEB: http://www.martens.com.au

Engineering Log - BOREHOLE

MARTENS 2.00 LIB.GLB Log MARTENS BOREHOLE P2410392BH101 V2.GPJ <<DrawingFile>> 18/07/2024 16:43 10.02.00.04 Datgel Lab and In Situ Tool - DGD | Lib: Martens 2.00 2016-11-13 Prj: Martens 2.00 2016-11-13

CLIENT	Darley P/L atf GWR Trust & Crisjoy P/L atf The Lighthouse Unit Trust	COMMENCED	04/07/2024	COMPLETED	04/07/2024	**REF BH105**	
PROJECT	Geotechnical Investigation	LOGGED	AK	CHECKED	WB	Sheet 1 OF 1	
SITE	Broken Head Road, Suffolk Park NSW - lot 1 DPI123302	GEOLOGY	Bundamba Group	VEGETATION	Grass	PROJECT NO. P2410392	
EQUIPMENT	Geo 601	LONGITUDE	153.5975	RL SURFACE	33.6 m	DATUM	AHD
EXCAVATION DIMENSIONS	Ø100 mm x 5.50 m depth	LATITUDE	-28.69568	ASPECT	South	SLOPE	< 5 %

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
AD/T	M			33.60 0.40	0.2-0.5/S/1 D 0.20-0.50 m	■	☒	CI	FILL: Gravelly Silty CLAY; medium plasticity; brown, dark brown, grey; with fine to medium grained sand; gravels are mixed and fine to coarse grained; inferred poorly compacted.			FILL
	H	▽	1	33.20 1.40	0.5-1.0/S/1 D 0.50-1.00 m SPT 1.00-1.45 m 10, 30, 17 N = 47 1.0-1.45/S/1 D 1.00-1.45 m	■	☒	CI-CH	FILL: Silty CLAY; medium to high plasticity; dark brown; trace sand; inferred poorly to moderately compacted.	M (<PL) M (=PL)	S - F	
			2 3 4	32.20 4.20	1.5-2.0/S/1 D 1.50-2.00 m	■	☒	GM	FILL: Silty GRAVEL; fine to coarse mixed gravels; mixed; with fine to medium sand; pale brown; inferred poorly to moderately compacted.	W	L	1.40: Possible boulder. 2.40: SPT's not possible due to borehole collapse.
	L		5	29.40 5.50	4.2-5.5/S/1 D 4.20-5.50 m	■	☒	CL-CI	FILL: Silty CLAY; low to medium plasticity; pale grey, brown; with fine to medium grained sand; inferred poorly compacted.	M (<PL)	S - F	
			6 7 8						Hole Terminated at 5.50 m Collapse			

EXCAVATION LOG TO BE READ IN CONJUCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS

martens

MARTENS & ASSOCIATES PTY LTD
Suite 201, 20 George St. Hornsby, NSW 2077 Australia
Phone: (02) 9476 9999 Fax: (02) 9476 8767
mail@martens.com.au WEB: http://www.martens.com.au

Engineering Log - BOREHOLE

CLIENT	Darley P/L atf GWR Trust & Crisjoy P/L atf The Lighthouse Unit Trust	COMMENCED	01/07/2024	COMPLETED	01/07/2024	**REF BH106**	
PROJECT	Geotechnical Investigation	LOGGED	AK	CHECKED	WB	Sheet	1 OF 1
SITE	Broken Head Road, Suffolk Park NSW - lot 1 DPI123302	GEOLOGY	Bundamba Group	VEGETATION	Grass	PROJECT NO. P2410392	
EQUIPMENT	Geo 601	LONGITUDE	153.59931	RL SURFACE	44 m	DATUM	AHD
EXCAVATION DIMENSIONS	Ø100 mm x 7.30 m depth	LATITUDE	-28.69498	ASPECT	South	SLOPE	15 %

Drilling				Sampling		Field Material Description				
METHOD	PENETRATION RESISTANCE	WATER	DEPTH RL	SAMPLE OR FIELD TEST	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
AD/T	L	Not Encountered	44.00	0.2-0.5/S/1 D 0.20-0.50 m 0.5-1.0/S/1 D 0.50-1.00 m	SC-SM	FILL: Silty Clayey SAND; fine to medium grained; pale brown, red; trace fine mixed gravels; inferred poorly compacted.	M	L	FILL
			1.00 43.00	SPT 1.00-1.45 m 4, 5, 5 N = 10 1.0-1.45/S/1 D 1.00-1.45 m 1.5-1.7/S/1 D 1.50-1.70 m	SM	FILL: Silty SAND; fine to medium grained; grey, dark grey; with fine to coarse mixed gravels and clay; inferred poorly to moderately compacted.		MD	
			1.70 42.30		SP	FILL: SAND; fine to medium grained; dark brown; with silt and clay; trace fine grained sand and fine mixed gravels; inferred poorly compacted.		S - F	
			2.30 41.70	2.3-2.5/S/1 D 2.30-2.50 m SPT 2.50-2.95 m 2, 2, 2 N = 4	SP	FILL: Silty SAND; fine to medium grained; grey, dark grey; with fine to coarse mixed gravels and clay; inferred poorly compacted.		L	
			2.80 41.20	2.5-2.95/S/1 D 2.50-2.95 m 3.5-4.0/S/1 D 3.50-4.00 m	CL-CI	FILL: Sandy Silty CLAY; low to medium plasticity; brown; with fine to coarse mixed gravels; sand is fine to medium grained; inferred poorly compacted.	M (<PL)	F	
			4.00 40.00	SPT 4.00-4.45 m 1, 2, 3 N = 5 4.0-4.45/S/1 D 4.00-4.45 m	CL-CI	FILL: Sandy Silty CLAY; low to medium plasticity; yellow, pale brown; with fine to coarse gravels; sand is fine to medium grained; inferred poorly compacted.			
			4.50 39.50	5.0-5.5/S/1 D 5.00-5.50 m	CL-CI	FILL: Silty CLAY; pale grey, grey, yellow; with sand and fine to coarse grained mixed gravel and cobbles; inferred firm;			
			5.50 38.50	SPT 5.50-5.95 m 2, 3, 5 N = 8 5.5-5.95/S/1 D 5.50-5.95 m 6.0-6.5/S/1 D 6.00-6.50 m	CL-CI	FILL: Silty CLAY; low to medium plasticity; pale grey, yellow; with sand; trace gravels; inferred moderately compacted.		St	RESIDUAL SOIL
	M		6.50 37.50	6.5-7.0/S/1 D 6.50-7.00 m SPT 7.00-7.45 m 4, 30, DB N = Refusal 7.0-7.3/S/1 D 7.00-7.30 m		CLAYSTONE / MUDSTONE; yellow; inferred extremely to highly weathered; inferred extremely low to very low strength.			WEATHERED ROCK
			7.30			Hole Terminated at 7.30 m			

EXCAVATION LOG TO BE READ IN CONJUCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS

martens

MARTENS & ASSOCIATES PTY LTD
Suite 201, 20 George St. Hornsby, NSW 2077 Australia
Phone: (02) 9476 9999 Fax: (02) 9476 8767
mail@martens.com.au WEB: http://www.martens.com.au

Engineering Log - BOREHOLE

CLIENT	Darley P/L atf GWR Trust & Crisjoy P/L atf The Lighthouse Unit Trust	COMMENCED	04/07/2024	COMPLETED	04/07/2024	**REF TP101**
PROJECT	Geotechnical Investigation	LOGGED	AK	CHECKED	WB	Sheet 1 OF 1
SITE	Broken Head Road, Suffolk Park NSW - lot 1 DPI123302	GEOLOGY	Bundamba Group	VEGETATION	Grass	PROJECT NO. P2410392
EQUIPMENT	5 Tonne Excavator	LONGITUDE	153.59881	RL SURFACE	40 m	DATUM AHD
EXCAVATION DIMENSIONS	3.00 m depth	LATITUDE	-28.69516	ASPECT	South	SLOPE 10 - 20 %

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E	L	▷	1	40.00			▨	CL-CI	FILL: Gravelly Sandy Silty CLAY; low to medium plasticity; dark grey, green, pale grey; gravels are fine to coarse; with boulders (small to medium); sand is fine to coarse grained; inferred poorly compacted.	M (<PL)	S - F	FILL
				1.20 38.80			▨	SP-SM	FILL: Gravelly Silty SAND; coarse grained; pale yellow, pale grey; inferred poorly compacted.	M - W	L	
	M H		2	2.00 38.00	2.5-3.0/S/1 D 2.50-3.00 m	■	⁚		SANDSTONE; white; inferred highly weathered; inferred very low strength.			WEATHERED ROCK
			3	3.00					Hole Terminated at 3.00 m			
			4 5 6 7 8									

EXCAVATION LOG TO BE READ IN CONJUCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS

martens

MARTENS & ASSOCIATES PTY LTD
Suite 201, 20 George St. Hornsby, NSW 2077 Australia
Phone: (02) 9476 9999 Fax: (02) 9476 8767
mail@martens.com.au WEB: http://www.martens.com.au

Engineering Log - TEST PIT

CLIENT	Darley P/L atf GWR Trust & Crisjoy P/L atf The Lighthouse Unit Trust	COMMENCED	04/07/2024	COMPLETED	04/07/2024	**REF TP102**	
PROJECT	Geotechnical Investigation	LOGGED	AK	CHECKED	WB	Sheet 1 OF 1	
SITE	Broken Head Road, Suffolk Park NSW - lot 1 DPI123302	GEOLOGY	Bundamba Group	VEGETATION	Grass	PROJECT NO. P2410392	
EQUIPMENT	5 Tonne Excavator	LONGITUDE	153.59881	RL SURFACE	34 m	DATUM	AHD
EXCAVATION DIMENSIONS	3.00 m depth	LATITUDE	-28.69516	ASPECT	West	SLOPE	< 5 %

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E	L			34.00				CL-CI	FILL: Sandy Silty CLAY; low to medium plasticity; dark grey, grey, brown; with fine to coarse mixed gravels; inferred poorly compacted.	M (<PL)	S - F	FILL
			1	0.50 33.50				SM-SC	FILL: Silty Clayey SAND; medium to coarse grained; dark grey, grey, brown; with fine to coarse mixed gravels; inferred poorly compacted.	M - W	VL - L	
	M			1.50 1.60 32.40	1.5-1.6/S/1 D 1.50-1.60 m			ML	FILL: SILT; pale grey, dark grey; trace clay; inferred poorly compacted.	M (=PL)	S	
				1.80 32.20	1.7-1.8/S/1 D 1.70-1.80 m			SP	FILL: SAND; medium to coarse grained; pale grey; with fine to coarse grained gravels; inferred poorly compacted.	M	L	
	M L		2		2.0-2.2/S/1 D 2.00-2.20 m 2.2-2.8/S/1 D 2.20-2.80 m			CI-CH	FILL: Silty CLAY; medium to high plasticity; pale grey, pale brown, white; with medium to coarse grained sand and fine to medium grained gravels; with soft bands / layers of silt; inferred poorly compacted.	M (<PL) M (=PL)	F	2.40: Bands / layers of soft silt.
			3 4 5 6 7 8	3.00					Hole Terminated at 3.00 m Collapse.			

EXCAVATION LOG TO BE READ IN CONJUCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS

martens

MARTENS & ASSOCIATES PTY LTD
Suite 201, 20 George St. Hornsby, NSW 2077 Australia
Phone: (02) 9476 9999 Fax: (02) 9476 8767
mail@martens.com.au WEB: http://www.martens.com.au

Engineering Log - TEST PIT

Appendix E – Summary of Subsurface Conditions

Table 8: Summary of subsurface units within BH101 to BH106, TP101 and TP102.

Units	Material	Depth (mbgl/mAHD)							
		BH101 (49.0 mAHD)	BH102 (45.0 mAHD)	BH103 (42.0 mAHD)	BH104 (54.0 mAHD)	BH105 (33.0 mAHD)	BH106 (44.0 mAHD)	TP101 (40.0 mAHD)	TP102 (34.0 mAHD)
Unit A	Fill: Silty CLAY / Gravelly Sandy Silty CLAY / SILT / Sandy Silty CLAY (soft to firm, moist and wet)	0.0 – 0.5	NE[4]	0.0 – 2.0	0.0 – 2.5	0.0 – 1.4 & 4.2 – 5.5[3]	2.8 – 5.5	0.0 – 1.2	0.0 – 0.5 & 1.8 – 3.0[1,3]
	Fill: Silty SAND / Silty Clayey SAND / Silty Clayey Gravelly SAND (very loose to loose, moist and wet)	0.5 – 6.95[3]	0.0 – 2.3	NE[4]	2.5 – 5.5	1.4 – 4.2	0.0 – 2.8[2]	1.2 – 2.0	0.5 – 1.8[2]
Unit B1	Residual: Silty SAND / Silty Clayey Gravelly SAND / Gravelly Silty SAND (medium dense to dense, moist and wet)	NE[4]	2.3 – 8.0	NE[4]	5.5 – 7.76[3]	NE[4]	NE[4]	NE[4]	NE[4]
Unit B2	Residual: Silty CLAY / Gravelly Sandy Silty CLAY (soft to firm, moist and wet)	NE[4]	5.0 – 7.0	2.0 – 4.5	NE[4]	NE[4]	NE[4]	NE[4]	NE[4]
Unit C1	WEATHERED ROCK: SANDSTONE (extremely to highly weathered, extremely low to very low)	NE[4]	8.0 – 9.5[3]	NE[4]	> 7.76	NE[4]	NE[4]	2.0 – 3.0[3]	NE[4]
Unit C2	WEATHERED ROCK: MUDSTONE / CLAYSTONE (extremely to highly weathered, extremely low to very low)	NE[4]	NE[4]	4.5 – 5.78[3]	NE[4]	NE[4]	6.5 – 7.3[3]	NE[4]	NE[4]

Notes:

1. Contains a thin silty clayey sand layer.
2. Contains interbedded soft silt bands / layers.
3. Borehole termination depth.
4. Not encountered.

Appendix F – Laboratory Test Certificates

resource laboratories
AGGREGATE, ROCK, AND SOIL TESTING
ABN: 25 131 532 020
Sydney: 12/1 Boden Road Seven Hills NSW 2147 | PO Box 45 Pendle Hill NSW 2145
Ph: (02) 9674 7711 | **Email:** info@resourcelab.com.au

Test Report

Customer: Martens & Associates Pty Ltd
Address: Suite 201, 20 George Street, Hornsby NSW 2077
Project: P2410392
Project Location: Former Broken Head Quarry, Broken Head, NSW

Job number: 24-0066
Report number: 1
Page: 1 of 1

Soil Index Properties

Sampling method: Sample(s) provided by customer, results apply to the sample(s) as received.
Test method(s): AS 1289.1.1, 2.1.1, 3.1.2, 3.2.1, 3.3.1, 3.4.1
Date tested: 09/07/2024 to 16/07/2024

	Results				
Laboratory sample no.	34927	34929	34932	34933	34936
Customer sample no.	10392/BH101/S/ 1.5 - 2.0	10392/BH102/ SPT/1.0 - 1.45	10392/BH103/ SPT/2.5 - 2.95	10392/BH104/ SPT/1.0 - 1.45	10392/BH106/S/ 5.0 - 5.5
Date sampled	01/07/2024 to 05/07/2024	01/07/2024 to 05/07/2024	01/07/2024 to 05/07/2024	01/07/2024 to 05/07/2024	01/07/2024 to 05/07/2024
Material description	clayey silty SAND, trace of gravel, brown/dark grey	clayey silty SAND, trace of gravel, dark brown/dark grey	silty CLAY, trace of sand, brown/ yellow-brown/ pale brown	gravelly silty SAND, with clay, dark brown	silty CLAY, trace of gravel and sand, yellow-brown/pale grey
Liquid limit (%)	23	27	53	27	39
Plastic limit (%)	12	14	26	16	16
Plasticity index (%)	11	13	27	11	23
Linear shrinkage (%)	4.5	5.5	11.0	5.5	9.0
Cracking / Curling / Crumbling	No	No	No	No	No
Sample history	Air dried	Air dried	Air dried	Air dried	Air dried
Preparation	Dry sieved	Dry sieved	Dry sieved	Dry sieved	Dry sieved

Notes: 34933 - 125mm linear shrinkage mould

Approved Signatory: C. Greely

Date: 16/07/2024

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

NATA Accredited Laboratory Number: **17062**

resource laboratories
AGGREGATE, ROCK, AND SOIL TESTING
ABN: 25 131 532 020
Sydney: 12/1 Boden Road Seven Hills NSW 2147 | PO Box 45 Pendle Hill NSW 2145
Ph: (02) 9674 7711 | **Email:** info@resourcelab.com.au

Test Report

Customer: Martens & Associates Pty Ltd
Address: Suite 201, 20 George Street, Hornsby NSW 2077
Project: P2410392
Project Location: Former Broken Head Quarry, Broken Head, NSW

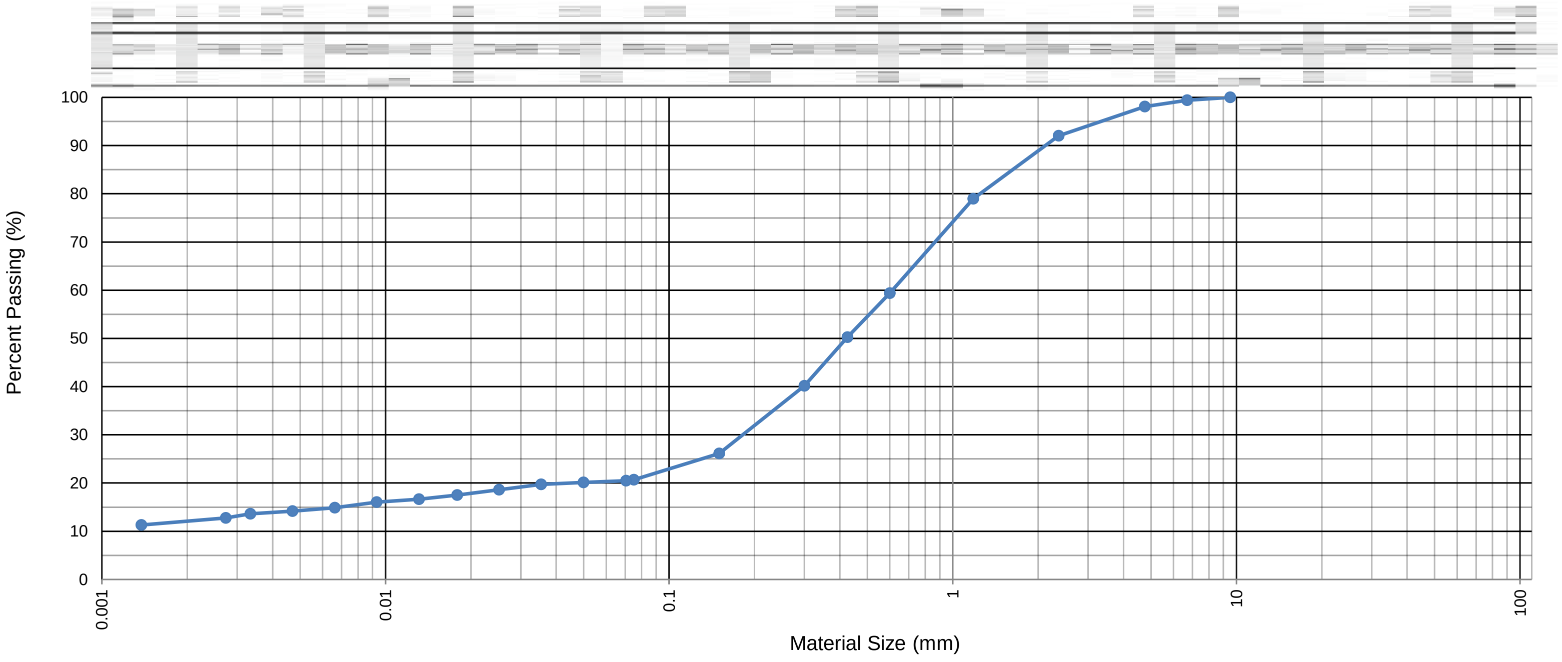
Job number: 24-0066
Report number: 2
Page: 1 of 5

Particle Size Distribution

Sampling method: Sample(s) provided by customer, results apply to the sample(s) as received.
Test method(s): AS 1289.1.1, 2.1.1, 3.5.1, 3.6.1, 3.6.3
Date tested: 09/07/2024 to 17/07/2024

Laboratory sample no.: 34928 **Customer sample no.:** 10392/BH101/S/3.5 - 4.0 **Date sampled:** 01/07/2024 to 05/07/2024

Material description: SAND, with clay and silt, trace of gravel, yellow-brown/brown



AS Sieve	% Passing
9.5mm	100
6.7mm	99
4.75mm	98
2.36mm	92
1.18mm	79
600µm	59
425µm	50
300µm	40
150µm	26
75µm	21
Particle Diameter*(mm)	**% Finer**
0.0704	20
0.0499	20
0.0353	20
0.0251	19
0.0179	18
0.0131	17
0.0093	16
0.0066	15
0.0047	14
0.0033	14
0.0027	13
0.0014	11

Notes: * Results obtained by hydrometer analysis, Hydrometer type: g/L. Method of dispersion: Mechanical. Method of preparation: as received natural state. Particle density: 2.65 g/cm3.

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Approved Signatory: L. Coleman

Date: 17/07/2024

NATA Accredited Laboratory Number: **17062**

resource laboratories
AGGREGATE, ROCK, AND SOIL TESTING
ABN: 25 131 532 020
Sydney: 12/1 Boden Road Seven Hills NSW 2147 | PO Box 45 Pendle Hill NSW 2145
Ph: (02) 9674 7711 | **Email:** info@resourcelab.com.au

Test Report

Customer: Martens & Associates Pty Ltd
Address: Suite 201, 20 George Street, Hornsby NSW 2077
Project: P2410392
Project Location: Former Broken Head Quarry, Broken Head, NSW

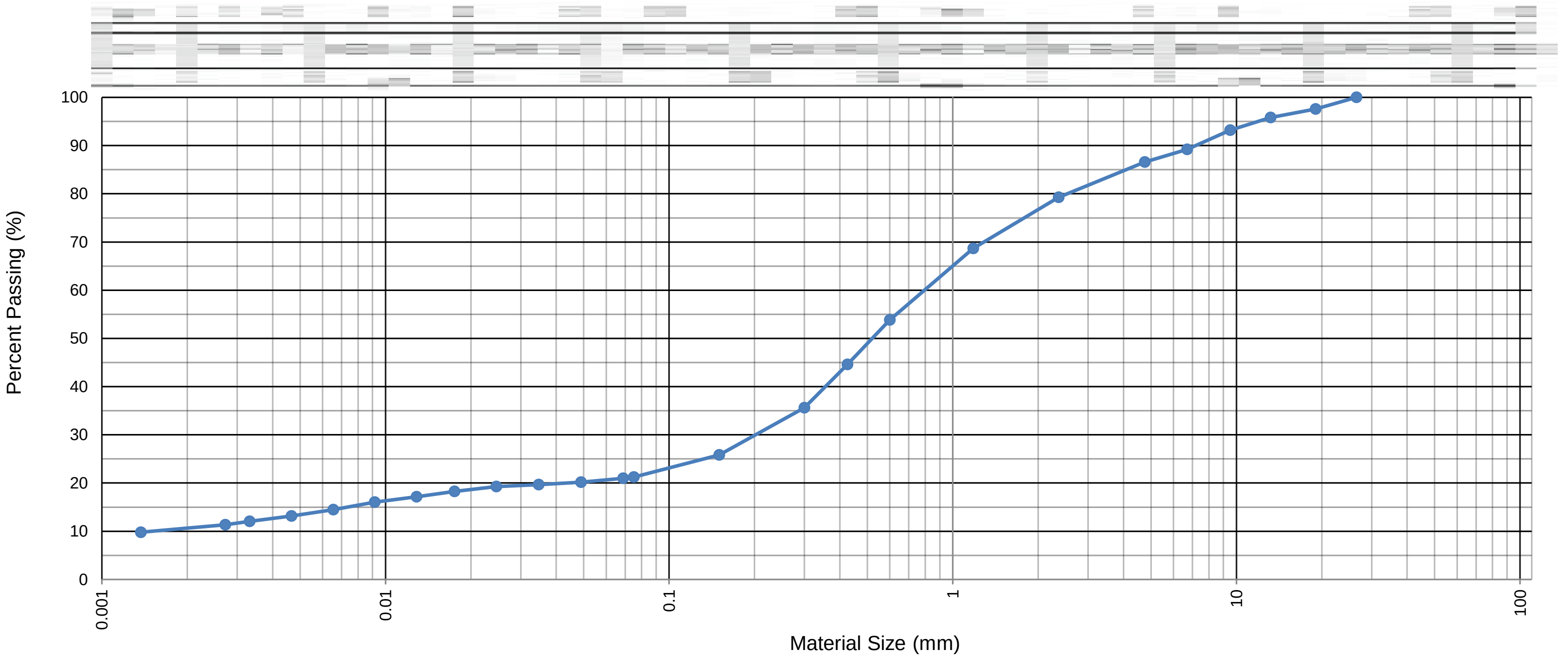
Job number: 24-0066
Report number: 2
Page: 2 of 5

Particle Size Distribution

Sampling method: Sample(s) provided by customer, results apply to the sample(s) as received.
Test method(s): AS 1289.1.1, 2.1.1, 3.5.1, 3.6.1, 3.6.3
Date tested: 09/07/2024 to 17/07/2024

Laboratory sample no.: 34930 **Customer sample no.:** 10392/BH102/S/ 2.5 - 4.5 **Date sampled:** 01/07/2024 to 05/07/2024

Material description: SAND, with gravel, clay and silt, pale grey/dark brown



AS Sieve	% Passing
26.5mm	100
19.0mm	98
13.2mm	96
9.5mm	93
6.7mm	89
4.75mm	87
2.36mm	79
1.18mm	69
600µm	54
425µm	45
300µm	36
150µm	26
75µm	21
Particle Diameter*(mm)	**% Finer**
0.0688	21
0.0489	20
0.0347	20
0.0246	19
0.0175	18
0.0129	17
0.0092	16
0.0065	14
0.0047	13
0.0033	12
0.0027	11
0.0014	10

Notes: * Results obtained by hydrometer analysis, Hydrometer type: g/L. Method of dispersion: Mechanical. Method of preparation: as received natural state. Particle density: 2.64 g/cm3.

Approved Signatory: L. Coleman

Date: 17/07/2024

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Results relate only to items tested and/or sampled.
This report shall not be reproduced except in full.
Accredited for compliance with ISO/IEC 17025 - Testing.

NATA Accredited Laboratory Number: **17062**

resource laboratories
AGGREGATE, ROCK, AND SOIL TESTING
ABN: 25 131 532 020
Sydney: 12/1 Boden Road Seven Hills NSW 2147 | PO Box 45 Pendle Hill NSW 2145
Ph: (02) 9674 7711 | **Email:** info@resourcelab.com.au

Test Report

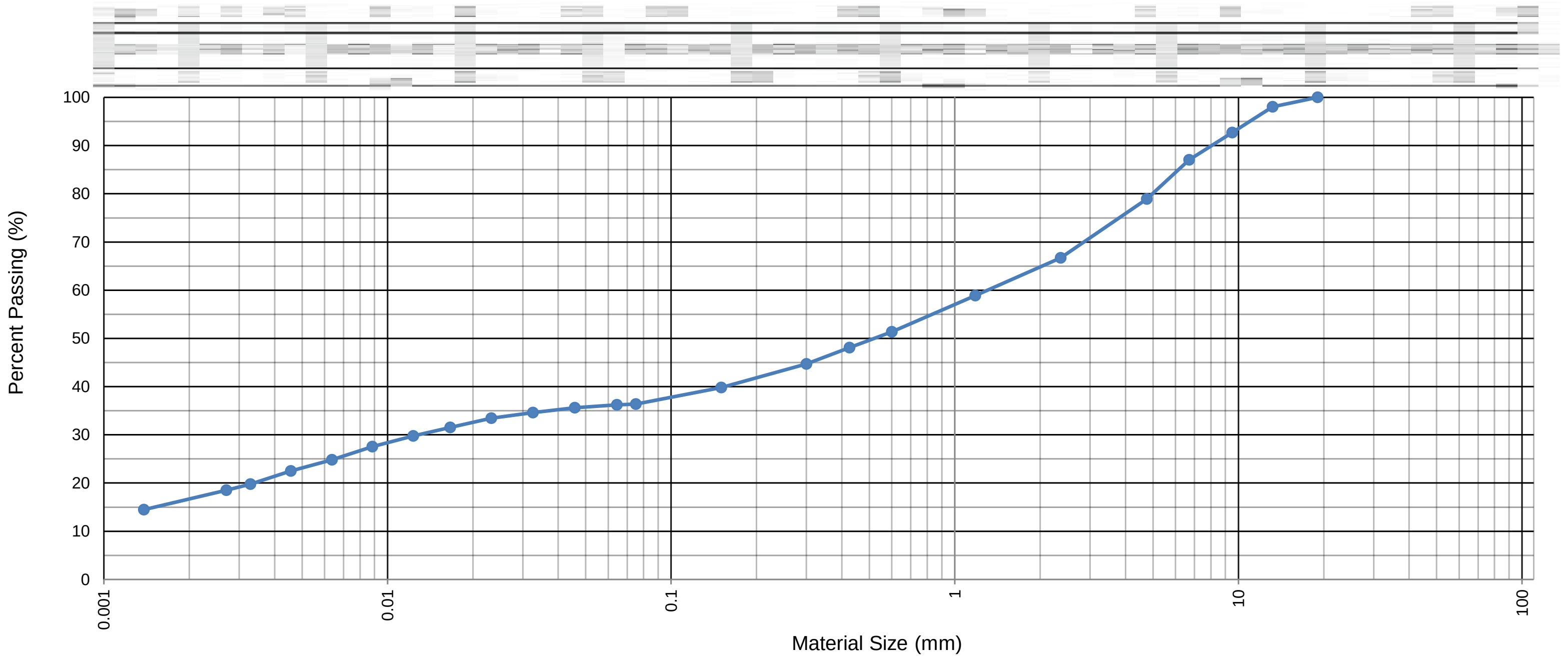
Customer: Martens & Associates Pty Ltd
Address: Suite 201, 20 George Street, Hornsby NSW 2077
Project: P2410392
Project Location: Former Broken Head Quarry, Broken Head, NSW

Job number: 24-0066
Report number: 2
Page: 3 of 5

Particle Size Distribution

Sampling method: Sample(s) provided by customer, results apply to the sample(s) as received.
Test method(s): AS 1289.1.1, 2.1.1, 3.5.1, 3.6.1, 3.6.3
Date tested: 09/07/2024 to 17/07/2024

Laboratory sample no.: 34931 **Customer sample no.:** 10392/BH103/S/0.2 - 1.0 **Date sampled:** 01/07/2024 to 05/07/2024
Material description: gravelly clayey SILT, with sand, brown



AS Sieve	% Passing
19.0mm	100
13.2mm	98
9.5mm	93
6.7mm	87
4.75mm	79
2.36mm	67
1.18mm	59
600µm	51
425µm	48
300µm	45
150µm	40
75µm	36
Particle Diameter*(mm)	**% Finer**
0.0644	36
0.0457	36
0.0326	35
0.0232	33
0.0166	32
0.0123	30
0.0088	28
0.0064	25
0.0046	23
0.0033	20
0.0027	18
0.0014	14

Notes: * Results obtained by hydrometer analysis, Hydrometer type: g/L. Method of dispersion: Mechanical. Method of preparation: as received natural state. Particle density: 2.61 g/cm3.

Approved Signatory: L. Coleman **Date:** 17/07/2024

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Results relate only to items tested and/or sampled.
This report shall not be reproduced except in full.
Accredited for compliance with ISO/IEC 17025 - Testing.

NATA Accredited Laboratory Number: **17062**

Test Report

Customer: Martens & Associates Pty Ltd
Address: Suite 201, 20 George Street, Hornsby NSW 2077
Project: P2410392
Project Location: Former Broken Head Quarry, Broken Head, NSW

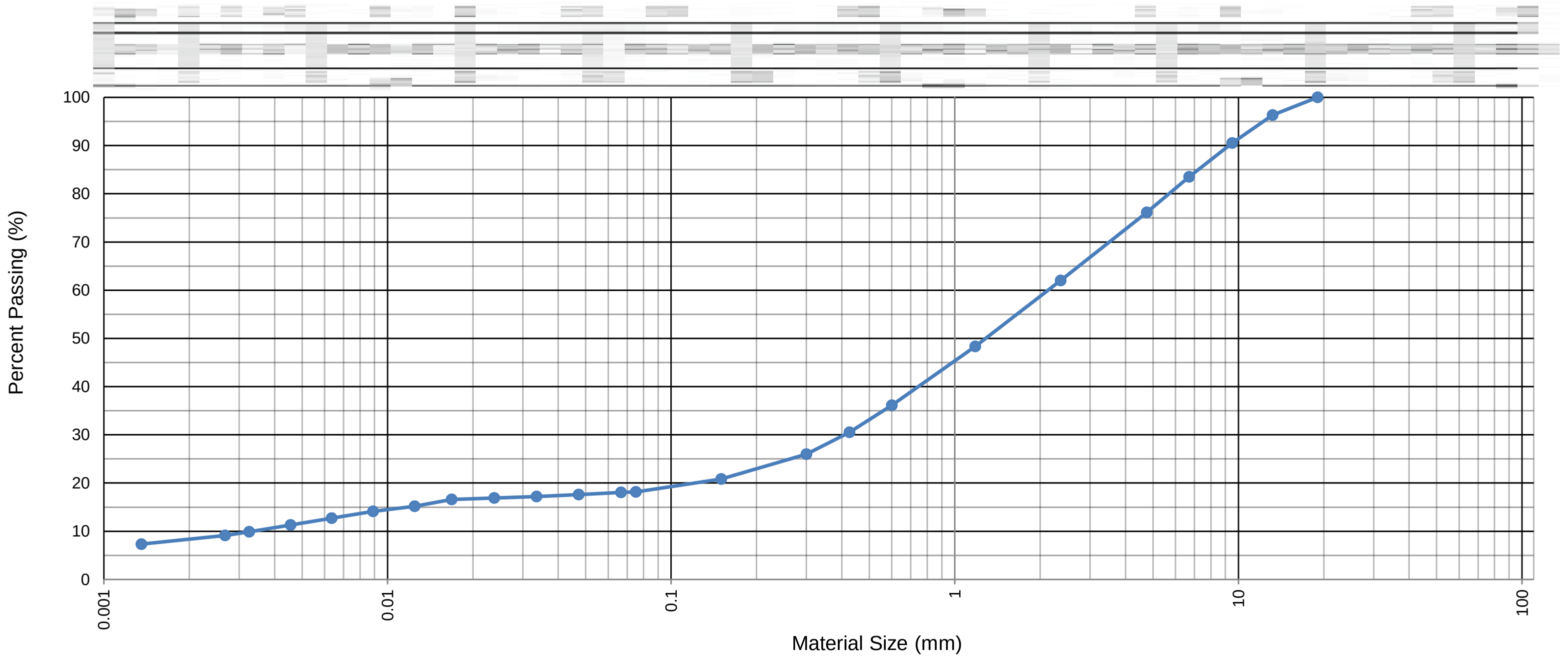
Job number: 24-0066
Report number: 2
Page: 4 of 5

Particle Size Distribution

Sampling method: Sample(s) provided by customer, results apply to the sample(s) as received.
Test method(s): AS 1289.1.1, 2.1.1, 3.5.1, 3.6.1, 3.6.3
Date tested: 09/07/2024 to 17/07/2024

Laboratory sample no.: 34934 **Customer sample no.:** 10392/BH104/S/3.0 - 4.0 **Date sampled:** 01/07/2024 to 05/07/2024

Material description: sandy GRAVEL, with silt and clay, dark brown



AS Sieve	% Passing
19.0mm	100
13.2mm	96
9.5mm	91
6.7mm	83
4.75mm	76
2.36mm	62
1.18mm	48
600µm	36
425µm	31
300µm	26
150µm	21
75µm	18
Particle Diameter*(mm)	**% Finer**
0.0665	18
0.0472	18
0.0335	17
0.0237	17
0.0168	17
0.0124	15
0.0089	14
0.0064	13
0.0045	11
0.0033	10
0.0027	9
0.0014	7

Notes: * Results obtained by hydrometer analysis, Hydrometer type: g/L. Method of dispersion: Mechanical**.** Method of preparation: as received natural state. Particle density: 2.63 g/cm3.

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Approved Signatory: L. Coleman

Date: 17/07/2024

Results relate only to items tested and/or sampled.
This report shall not be reproduced except in full.
Accredited for compliance with ISO/IEC 17025 - Testing.

NATA Accredited Laboratory Number: **17062**

Test Report

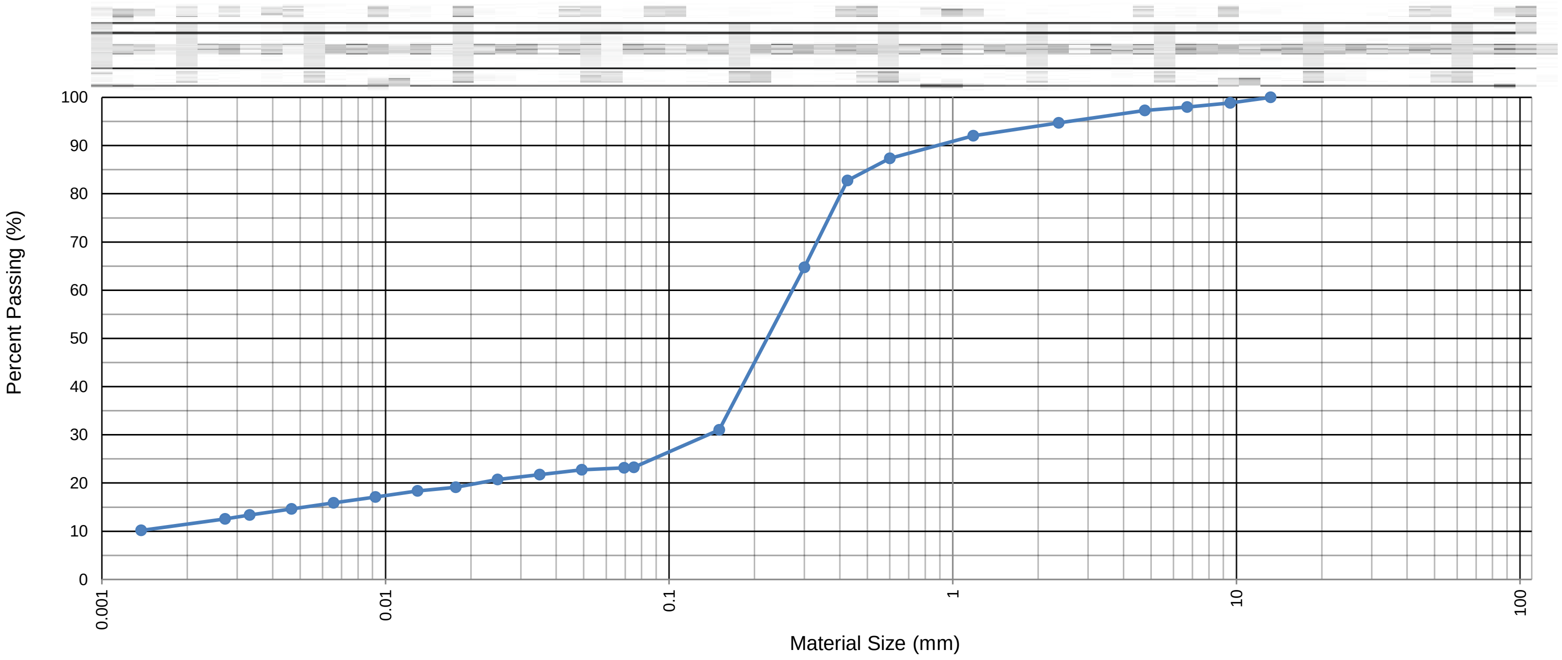
Customer: Martens & Associates Pty Ltd
Address: Suite 201, 20 George Street, Hornsby NSW 2077
Project: P2410392
Project Location: Former Broken Head Quarry, Broken Head, NSW

Job number: 24-0066
Report number: 2
Page: 5 of 5

Particle Size Distribution

Sampling method: Sample(s) provided by customer, results apply to the sample(s) as received.
Test method(s): AS 1289.1.1, 2.1.1, 3.5.1, 3.6.1, 3.6.3
Date tested: 09/07/2024 to 17/07/2024

Laboratory sample no.: 34935
Customer sample no.: 10392/BH106/S/1.5 - 2.5
Date sampled: 01/07/2024 to 05/07/2024
Material description: SAND, with silt and clay, trace of gravel, grey/yellow-brown



AS Sieve	% Passing
13.2mm	100
9.5mm	99
6.7mm	98
4.75mm	97
2.36mm	95
1.18mm	92
600µm	87
425µm	83
300µm	65
150µm	31
75µm	23
Particle Diameter*(mm)	**% Finer**
0.0694	23
0.0491	23
0.0349	22
0.0248	21
0.0177	19
0.0130	18
0.0092	17
0.0066	16
0.0047	15
0.0033	13
0.0027	13
0.0014	10

Notes: * Results obtained by hydrometer analysis, Hydrometer type: g/L. Method of dispersion: Mechanical**.** Method of preparation: as received natural state. Particle density: 2.64 g/cm3.

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

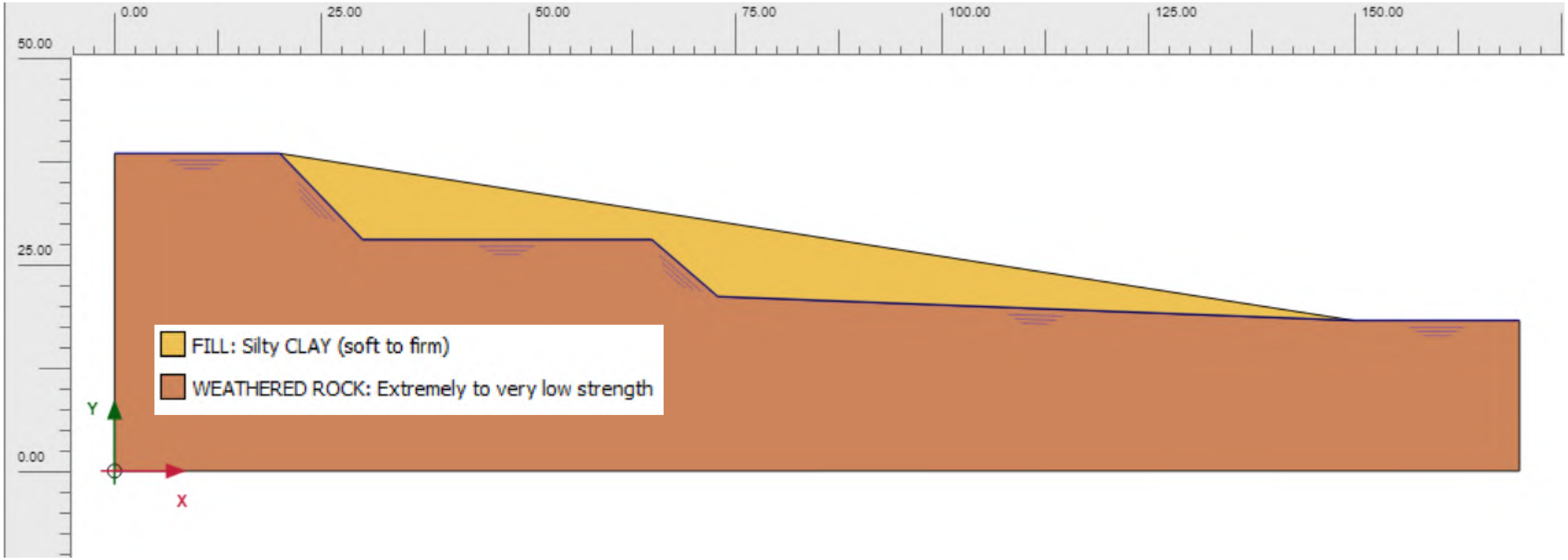
Approved Signatory: L. Coleman

Date: 17/07/2024

Results relate only to items tested and/or sampled.
This report shall not be reproduced except in full.
Accredited for compliance with ISO/IEC 17025 - Testing.

NATA Accredited Laboratory Number: **17062**

Appendix G – Results of Plaxis Analysis



Martens & Associates Pty Ltd ABN 85 070 240 890

Environment | Water | Wastewater | Geotechnical | Civil | Management

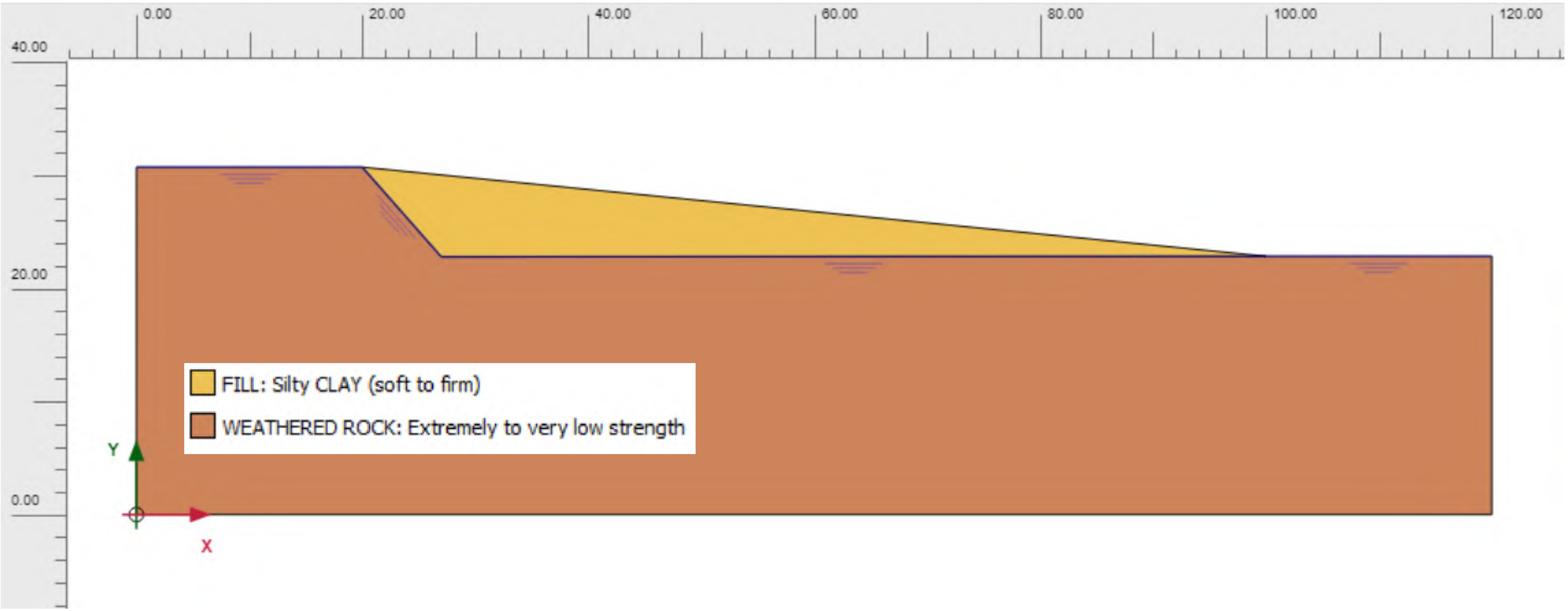
Drawn:	WB
Approved:	RE
Date:	23.07.2024
Scale:	NA

GEOTECHNICAL MODEL (Section A-A)
Former Broken Head Quarry - Broken Head Road, Suffolk Park, NSW

Drawing:
FIGURE 1

File No: P2410392JR01V02

martens



Martens & Associates Pty Ltd ABN 85 070 240 890

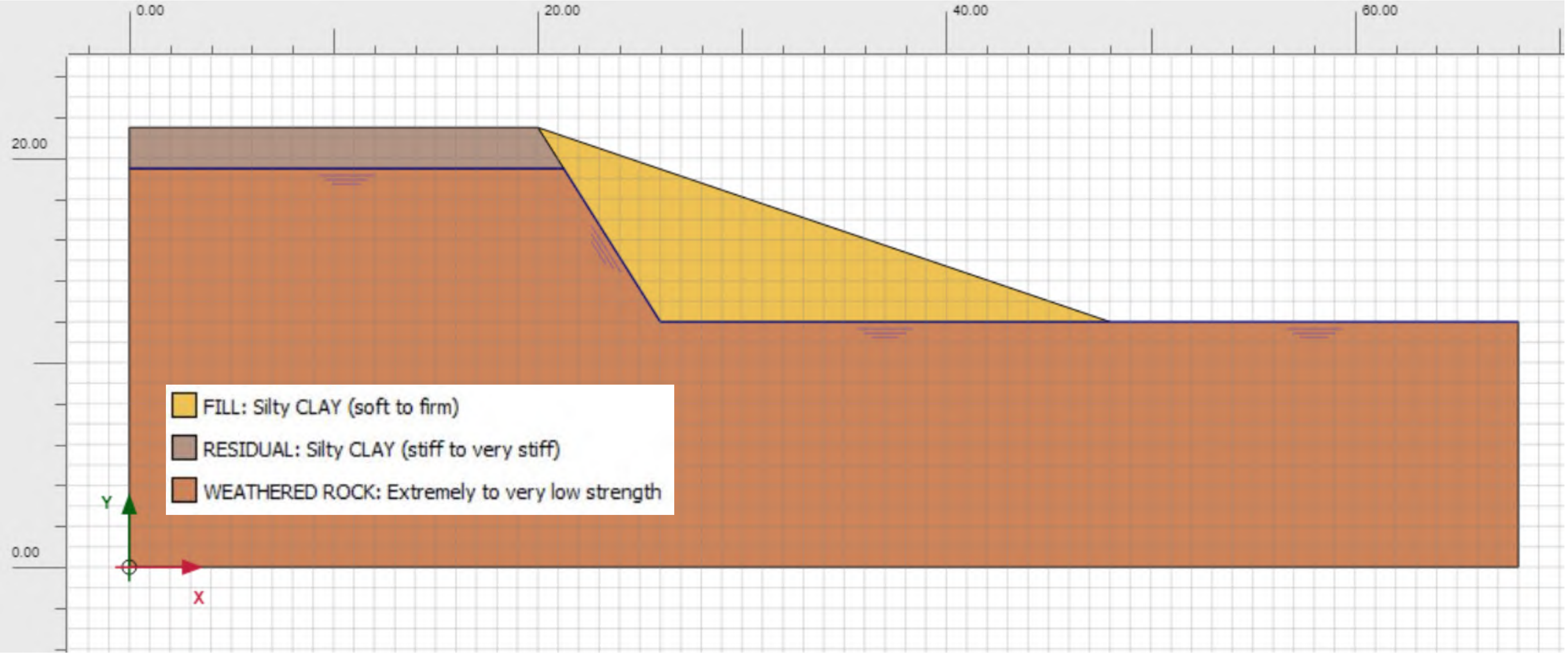
Environment | Water | Wastewater | Geotechnical | Civil | Management

Drawn:	WB
Approved:	RE
Date:	23.07.2024
Scale:	NA

GEOTECHNICAL MODEL (Section B-B)
Former Broken Head Quarry - Broken Head Road, Suffolk Park, NSW

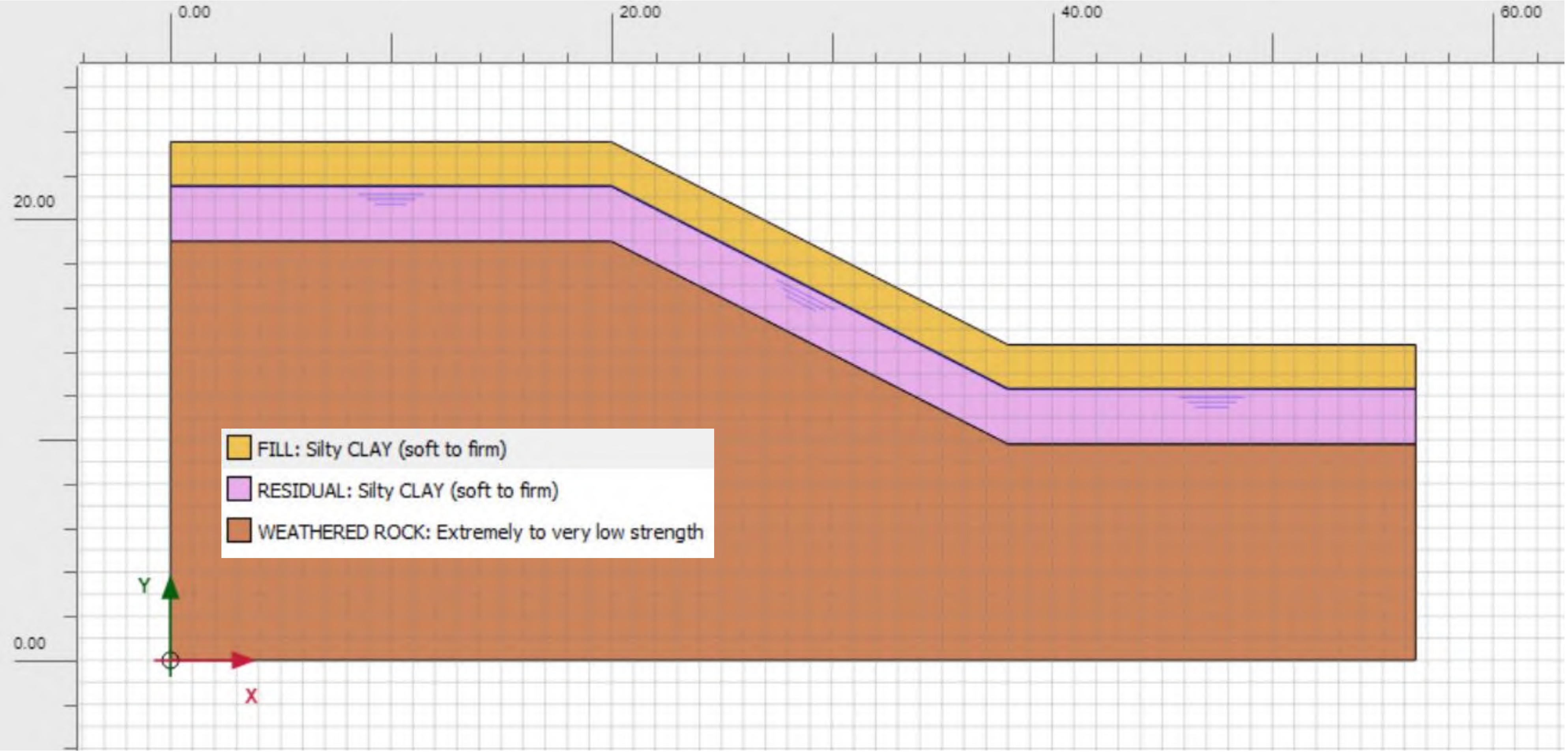
Drawing:
FIGURE 2

File No: P2410392JR01V02



martens

Martens & Associates Pty Ltd	ABN 85 070 240 890	**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	WB	**GEOTECHNICAL MODEL (Section C-C)** **Former Broken Head Quarry - Broken Head Road, Suffolk Park, NSW**	Drawing: **FIGURE 3**
Approved:	RE		
Date:	23.07.2024		File No: P2410392JR01V02
Scale:	NA		



Martens & Associates Pty Ltd ABN 85 070 240 890

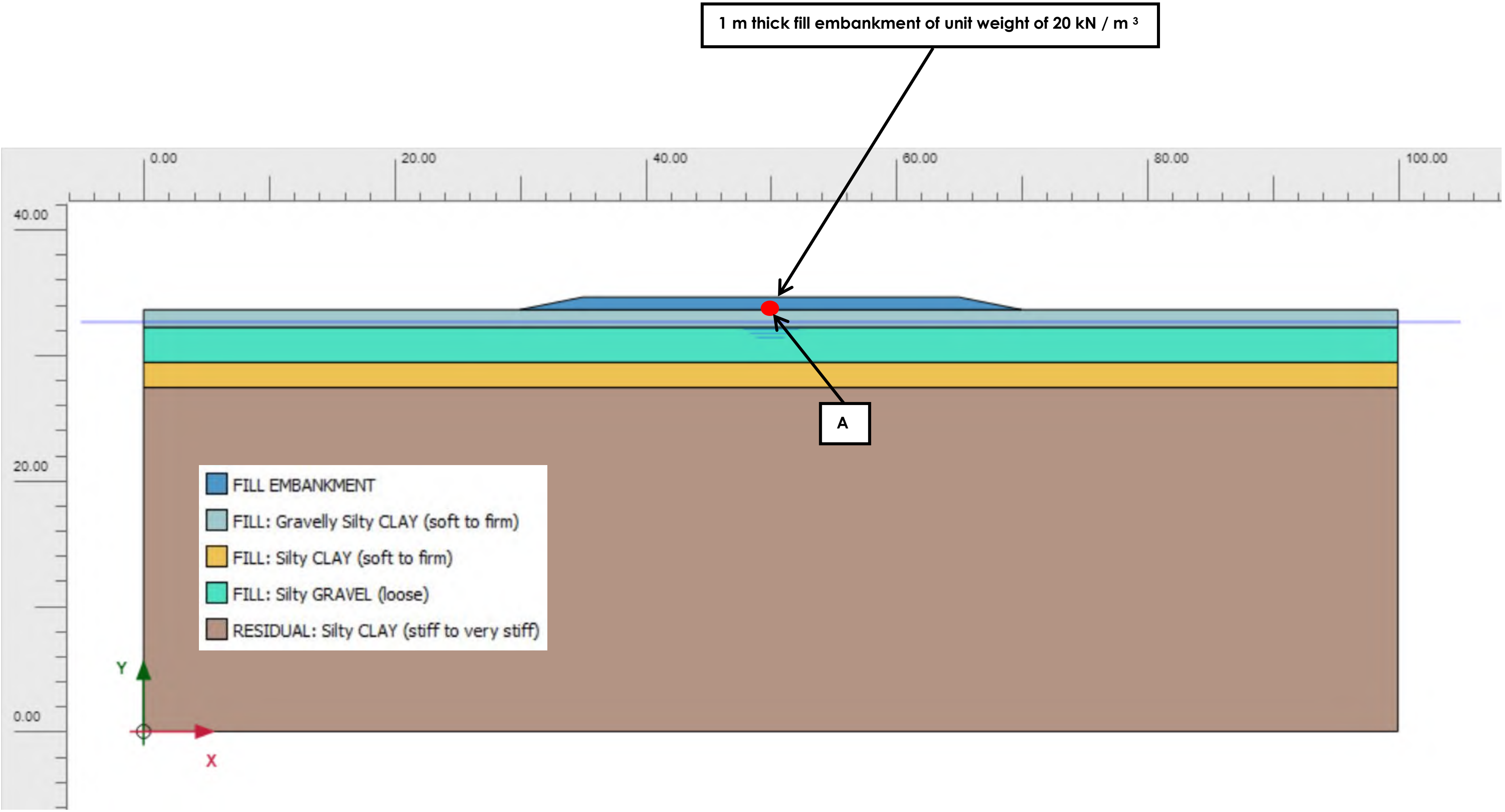
Environment | Water | Wastewater | Geotechnical | Civil | Management

Drawn:	WB
Approved:	RE
Date:	23.07.2024
Scale:	NA

GEOTECHNICAL MODEL (Section D-D)
Former Broken Head Quarry - Broken Head Road, Suffolk Park, NSW

Drawing:
FIGURE 4

File No: P2410392JR01V02



Martens & Associates Pty Ltd ABN 85 070 240 890

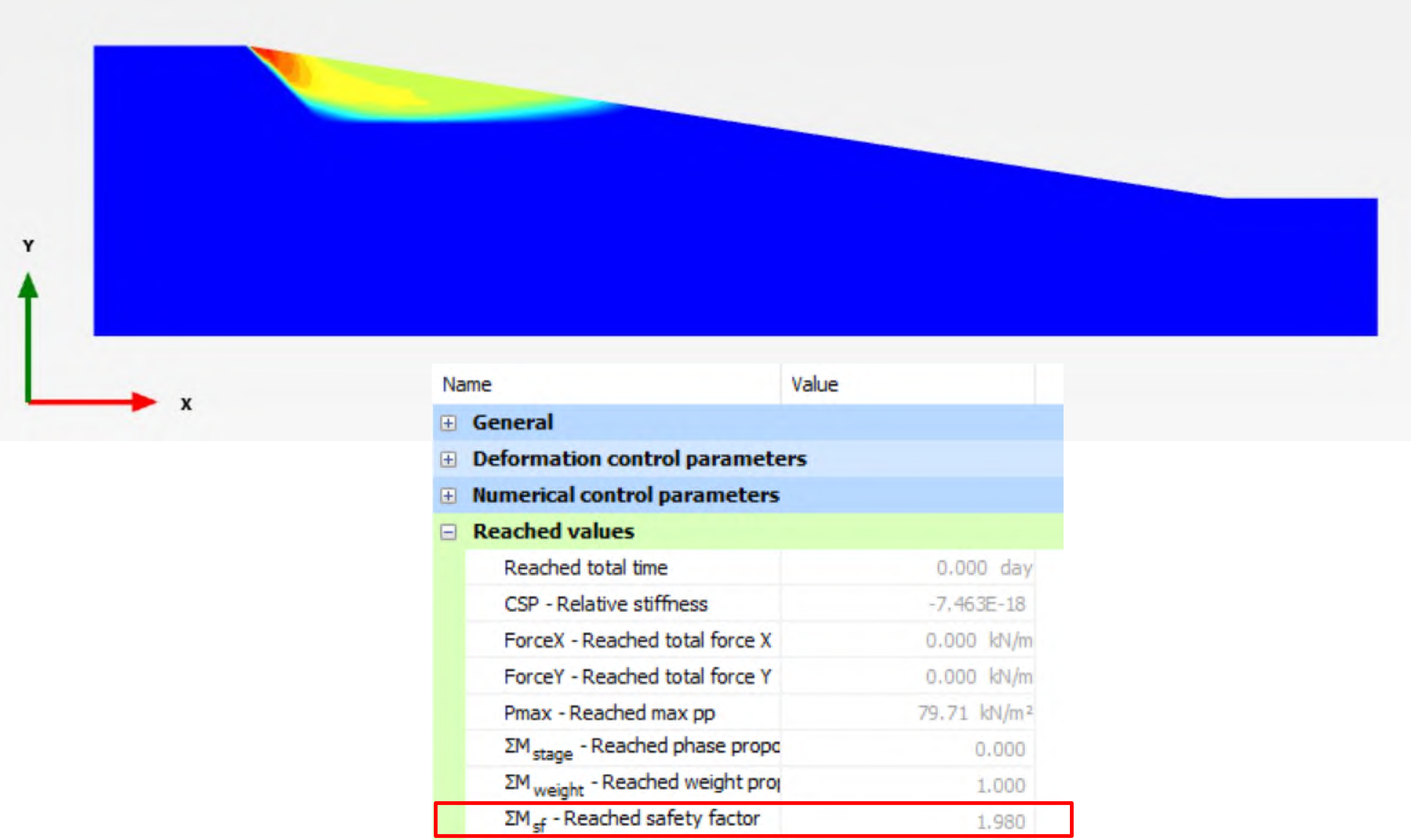
Environment | Water | Wastewater | Geotechnical | Civil | Management

Drawn: WB
Approved: RE
Date: 23.07.2024
Scale: NA

GEOTECHNICAL MODEL (Section E-E)
Former Broken Head Quarry - Broken Head Road, Suffolk Park, NSW

Drawing:
FIGURE 5

File No: P2410392JR01V02



Name	Value
General	
Deformation control parameters	
Numerical control parameters	
Reached values	
Reached total time	0.000 day
CSP - Relative stiffness	-7.463E-18
ForceX - Reached total force X	0.000 kN/m
ForceY - Reached total force Y	0.000 kN/m
Pmax - Reached max pp	79.71 kN/m²
ΣM_{stage} - Reached phase propc	0.000
ΣM_{weight} - Reached weight pro|	1.000
ΣM_{sf} - Reached safety factor	1.980

Martens & Associates Pty Ltd ABN 85 070 240 890

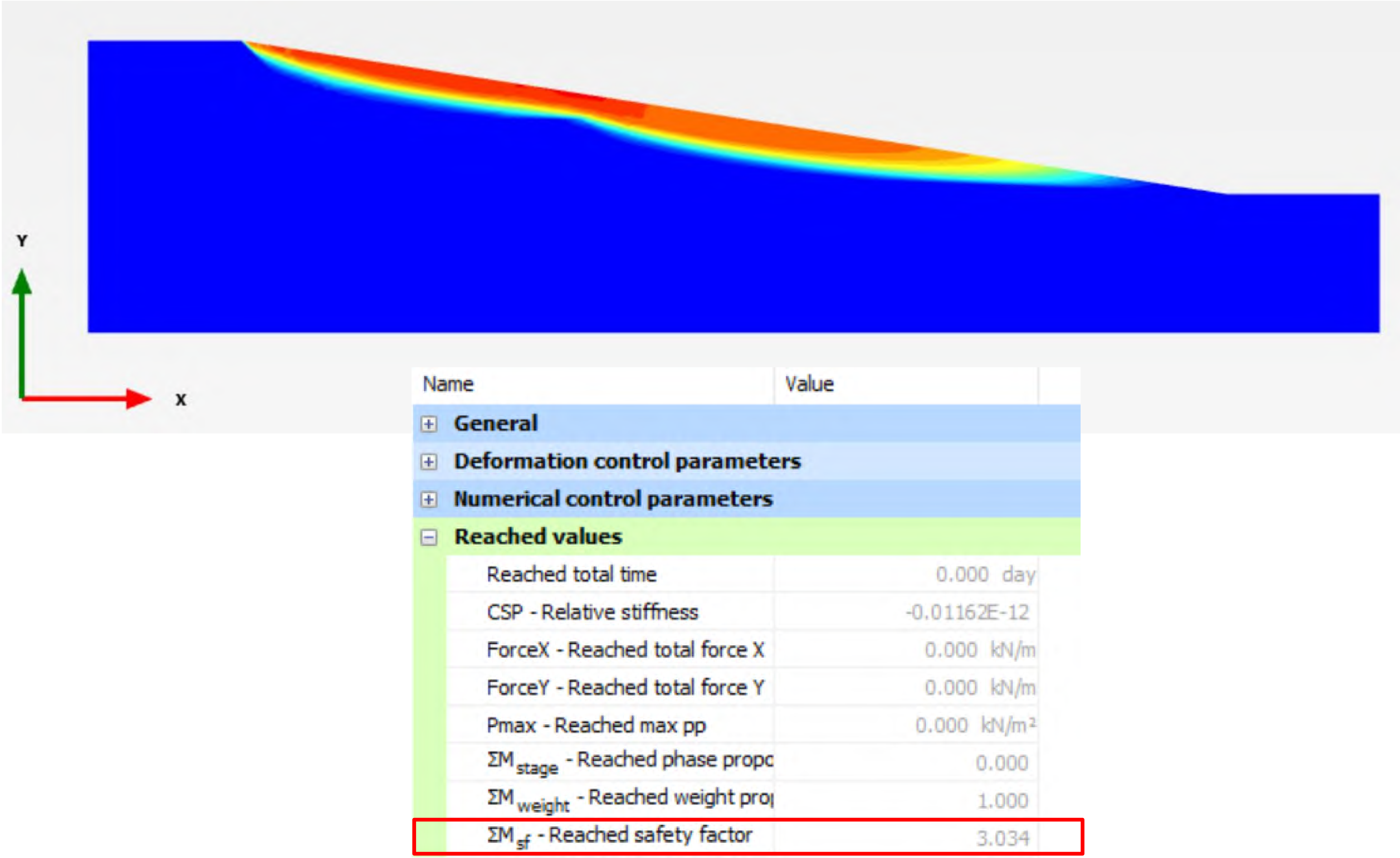
Environment | Water | Wastewater | Geotechnical | Civil | Management

Drawn:	WB
Approved:	RE
Date:	23.07.2024
Scale:	NA

FAILURE ENVELOPE & MINMUM SHORT TERM GLOBAL FOS (Section A-A)
Former Broken Head Quarry - Broken Head Road, Suffolk Park, NSW

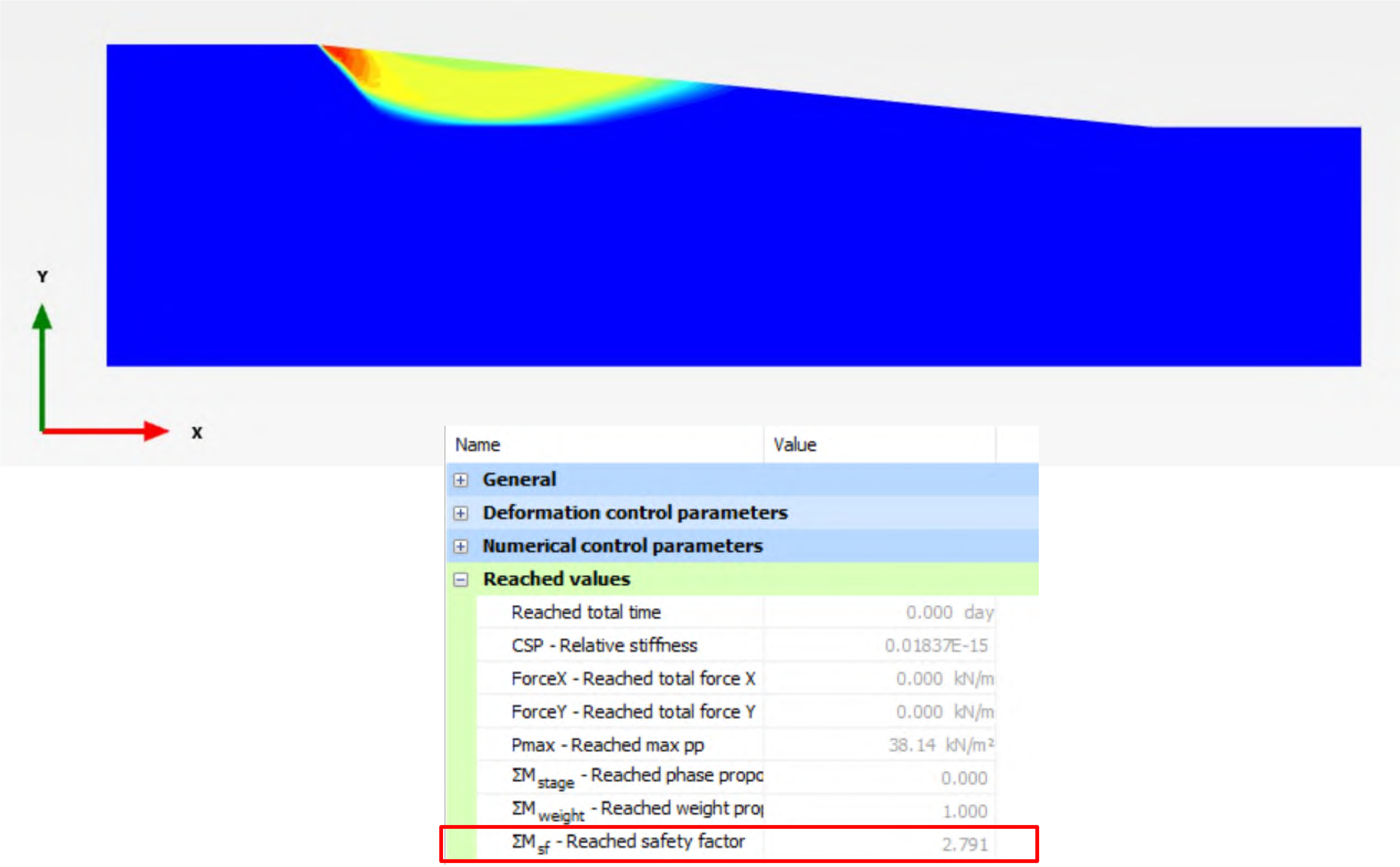
Drawing:
FIGURE 6

File No: P2410392JR01V02



Name	Value
⊞ **General**	
⊞ **Deformation control parameters**	
⊞ **Numerical control parameters**	
⊟ **Reached values**	
Reached total time	0.000 day
CSP - Relative stiffness	-0.01162E-12
ForceX - Reached total force X	0.000 kN/m
ForceY - Reached total force Y	0.000 kN/m
Pmax - Reached max pp	0.000 kN/m²
ΣM_{stage} - Reached phase propc	0.000
ΣM_{weight} - Reached weight proj	1.000
ΣM_{sf} - Reached safety factor	3.034

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	WB	**FAILURE ENVELOPE & MINMUM LONG TERM GLOBAL FOS (Section A-A)** **Former Broken Head Quarry - Broken Head Road, Suffolk Park, NSW**	Drawing: **FIGURE 7**
Approved:	RE		
Date:	23.07.2024		
Scale:	NA		File No: P2410392JR01V02



Name	Value
General	
Deformation control parameters	
Numerical control parameters	
Reached values	
Reached total time	0.000 day
CSP - Relative stiffness	0.01837E-15
ForceX - Reached total force X	0.000 kN/m
ForceY - Reached total force Y	0.000 kN/m
Pmax - Reached max pp	38.14 kN/m²
ΣM_{stage} - Reached phase propo	0.000
ΣM_{weight} - Reached weight pro	1.000
ΣM_{sf} - Reached safety factor	2.791

Martens & Associates Pty Ltd ABN 85 070 240 890

Environment | Water | Wastewater | Geotechnical | Civil | Management

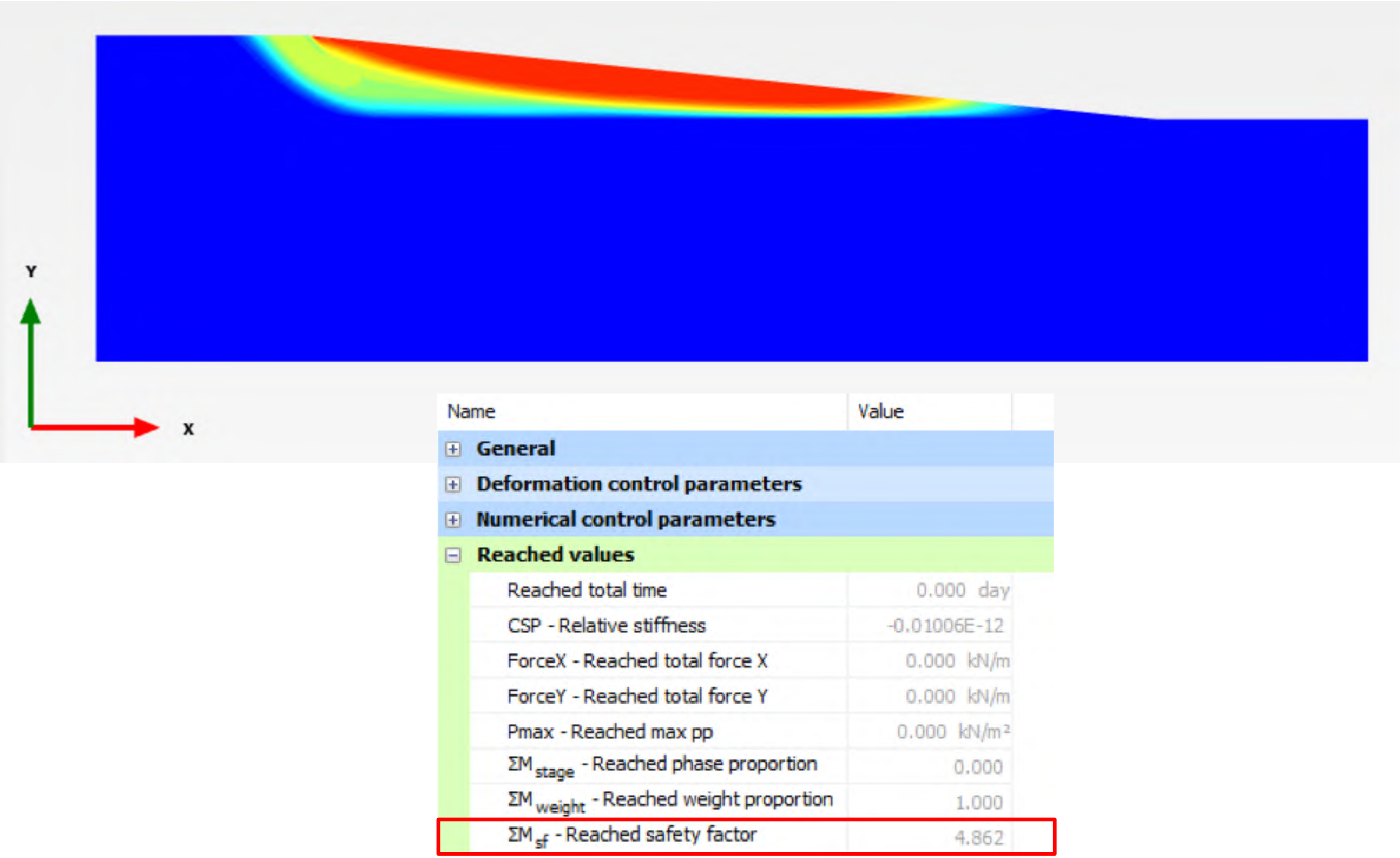
Drawn:	WB
Approved:	RE
Date:	23.07.2024
Scale:	NA

FAILURE ENVELOPE & MINMUM SHORT TERM GLOBAL FOS (Section B-B)
Former Broken Head Quarry - Broken Head Road, Suffolk Park, NSW

Drawing:

FIGURE 8

File No: P2410392JR01V02



Name	Value
⊞ **General**	
⊞ **Deformation control parameters**	
⊞ **Numerical control parameters**	
⊟ **Reached values**	
Reached total time	0.000 day
CSP - Relative stiffness	-0.01006E-12
ForceX - Reached total force X	0.000 kN/m
ForceY - Reached total force Y	0.000 kN/m
Pmax - Reached max pp	0.000 kN/m²
ΣM_{stage} - Reached phase proportion	0.000
ΣM_{weight} - Reached weight proportion	1.000
ΣM_{sf} - Reached safety factor	4.862

Martens & Associates Pty Ltd ABN 85 070 240 890

Environment | Water | Wastewater | Geotechnical | Civil | Management

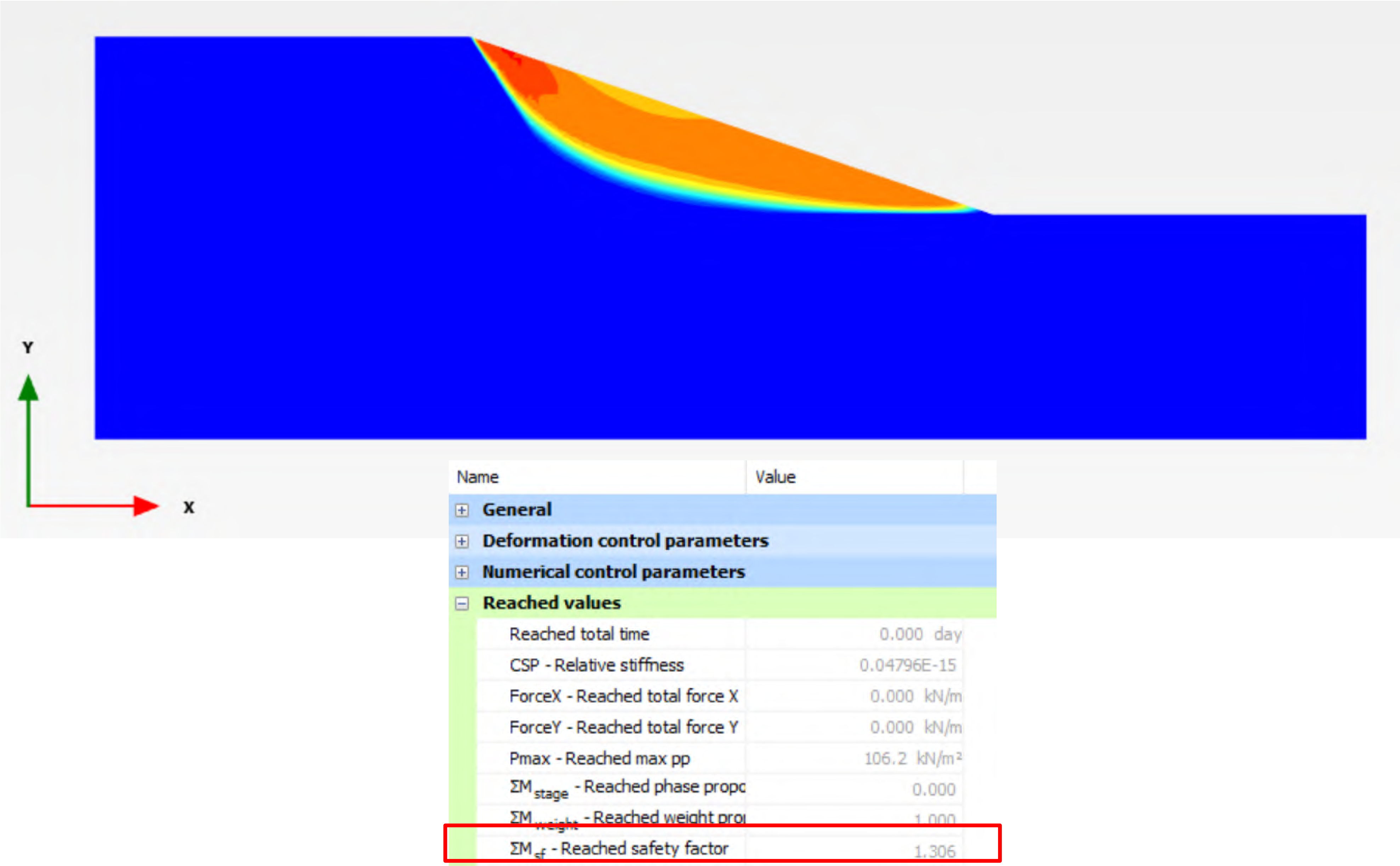
Drawn:	WB
Approved:	RE
Date:	23.07.2024
Scale:	NA

FAILURE ENVELOPE & MINMUM LONG TERM GLOBAL FOS (Section B-B)
Former Broken Head Quarry - Broken Head Road, Suffolk Park, NSW

Drawing:

FIGURE 9

File No: P2410392JR01V02



Name	Value
⊞ **General**	
⊞ **Deformation control parameters**	
⊞ **Numerical control parameters**	
⊟ **Reached values**	
Reached total time	0.000 day
CSP - Relative stiffness	0.04796E-15
ForceX - Reached total force X	0.000 kN/m
ForceY - Reached total force Y	0.000 kN/m
Pmax - Reached max pp	106.2 kN/m²
ΣM_{stage} - Reached phase propc	0.000
ΣM_{weight} - Reached weight pro	1.000
ΣM_{sf} - Reached safety factor	1.306

Martens & Associates Pty Ltd ABN 85 070 240 890

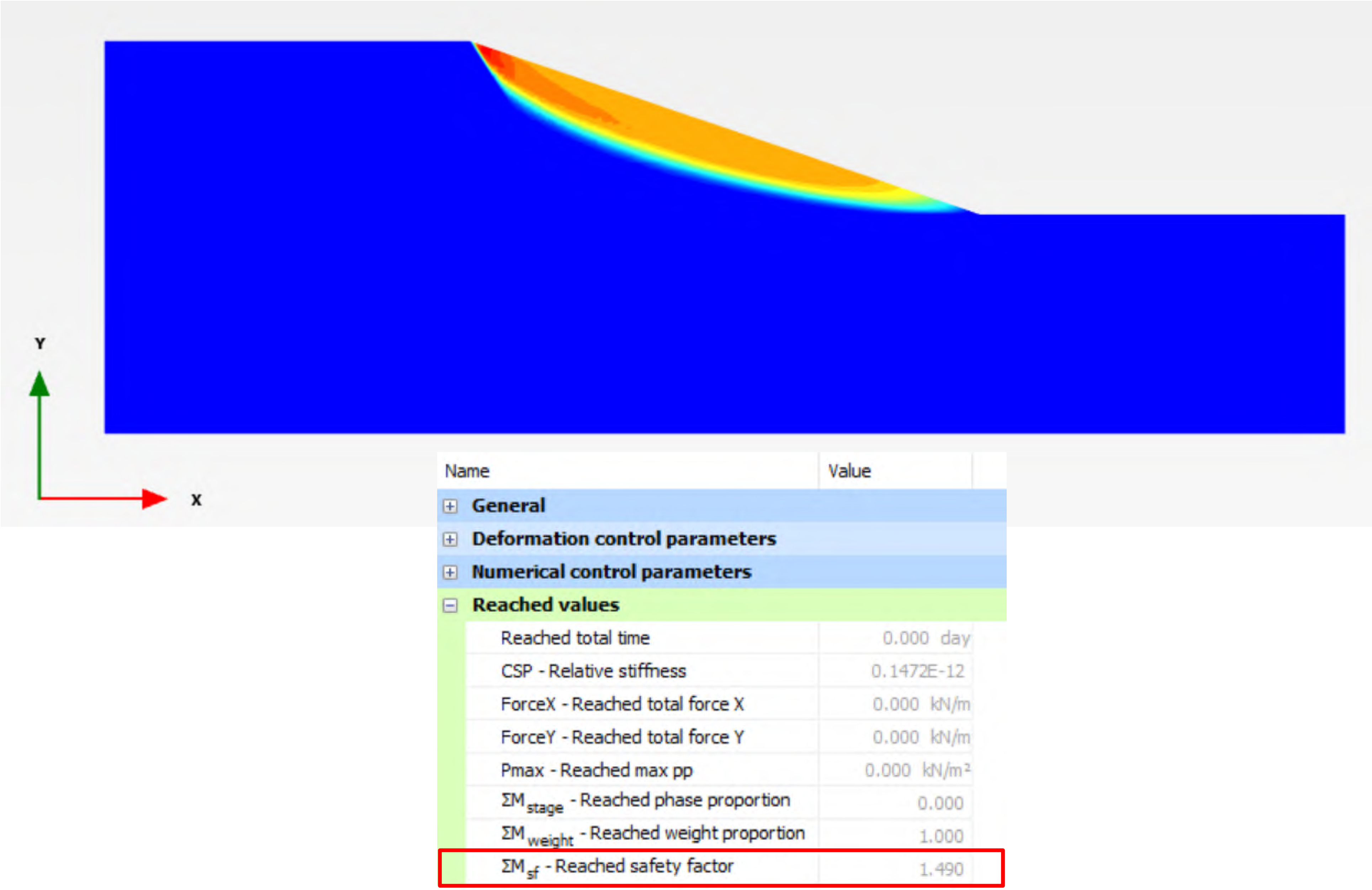
Environment | Water | Wastewater | Geotechnical | Civil | Management

Drawn:	WB
Approved:	RE
Date:	23.07.2024
Scale:	NA

FAILURE ENVELOPE & MINMUM SHORT TERM GLOBAL FOS (Section C-C)
Former Broken Head Quarry - Broken Head Road, Suffolk Park, NSW

Drawing:
FIGURE 10

File No: P2410392JR01V02



Name	Value
⊞ **General**	
⊞ **Deformation control parameters**	
⊞ **Numerical control parameters**	
⊟ **Reached values**	
Reached total time	0.000 day
CSP - Relative stiffness	0.1472E-12
ForceX - Reached total force X	0.000 kN/m
ForceY - Reached total force Y	0.000 kN/m
Pmax - Reached max pp	0.000 kN/m²
ΣM_{stage} - Reached phase proportion	0.000
ΣM_{weight} - Reached weight proportion	1.000
ΣM_{sf} - Reached safety factor	1.490

Martens & Associates Pty Ltd ABN 85 070 240 890

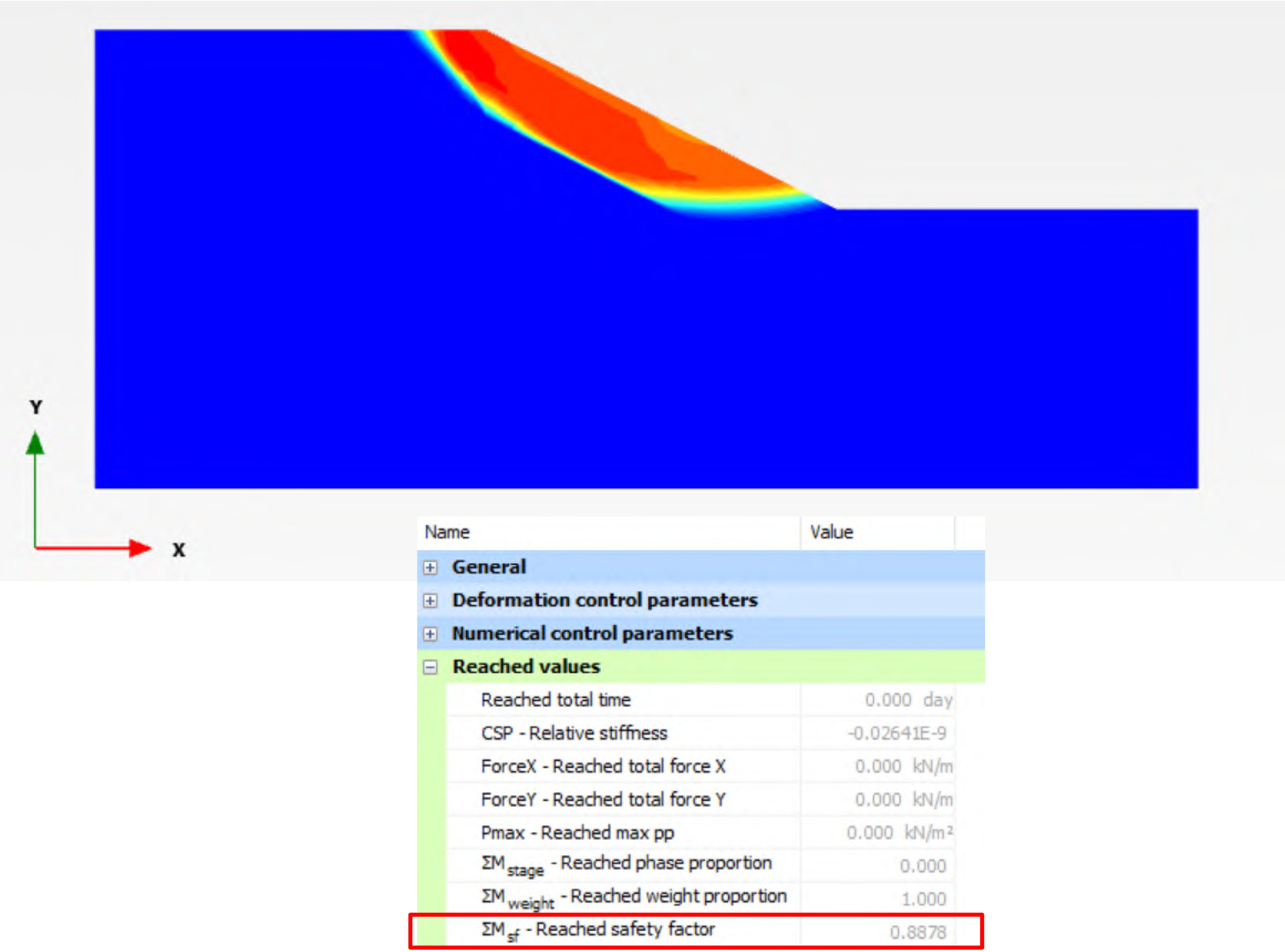
Environment | Water | Wastewater | Geotechnical | Civil | Management

Drawn:	WB
Approved:	RE
Date:	23.07.2024
Scale:	NA

FAILURE ENVELOPE & MINMUM LONG TERM GLOBAL FOS (Section C-C)
Former Broken Head Quarry - Broken Head Road, Suffolk Park, NSW

Drawing:
FIGURE 11

File No: P2410392JR01V02



Name	Value
⊞ **General**	
⊞ **Deformation control parameters**	
⊞ **Numerical control parameters**	
⊟ **Reached values**	
Reached total time	0.000 day
CSP - Relative stiffness	-0.02641E-9
ForceX - Reached total force X	0.000 kN/m
ForceY - Reached total force Y	0.000 kN/m
Pmax - Reached max pp	0.000 kN/m²
ΣM_{stage} - Reached phase proportion	0.000
ΣM_{weight} - Reached weight proportion	1.000
ΣM_{sf} - Reached safety factor	0.8878

Martens & Associates Pty Ltd ABN 85 070 240 890

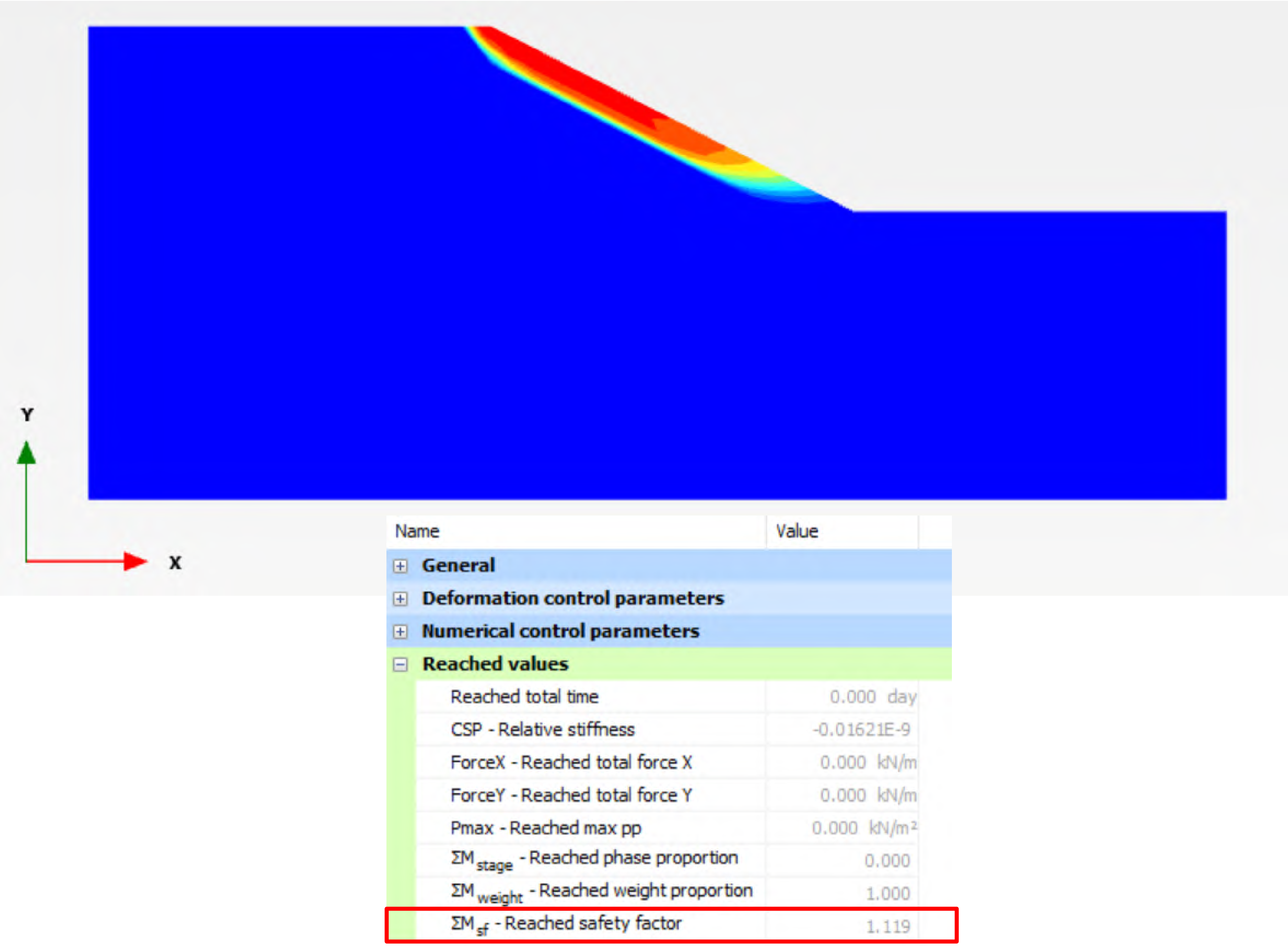
Environment | Water | Wastewater | Geotechnical | Civil | Management

Drawn:	WB
Approved:	RE
Date:	23.07.2024
Scale:	NA

FAILURE ENVELOPE & MINMUM SHORT TERM GLOBAL FOS (Section D-D)
Former Broken Head Quarry - Broken Head Road, Suffolk Park, NSW

Drawing:
FIGURE 12

File No: P2410392JR01V02



Name	Value
General	
Deformation control parameters	
Numerical control parameters	
Reached values	
Reached total time	0.000 day
CSP - Relative stiffness	-0.01621E-9
ForceX - Reached total force X	0.000 kN/m
ForceY - Reached total force Y	0.000 kN/m
Pmax - Reached max pp	0.000 kN/m²
ΣM_{stage} - Reached phase proportion	0.000
ΣM_{weight} - Reached weight proportion	1.000
ΣM_{sf} - Reached safety factor	1.119

Martens & Associates Pty Ltd ABN 85 070 240 890

Environment | Water | Wastewater | Geotechnical | Civil | Management

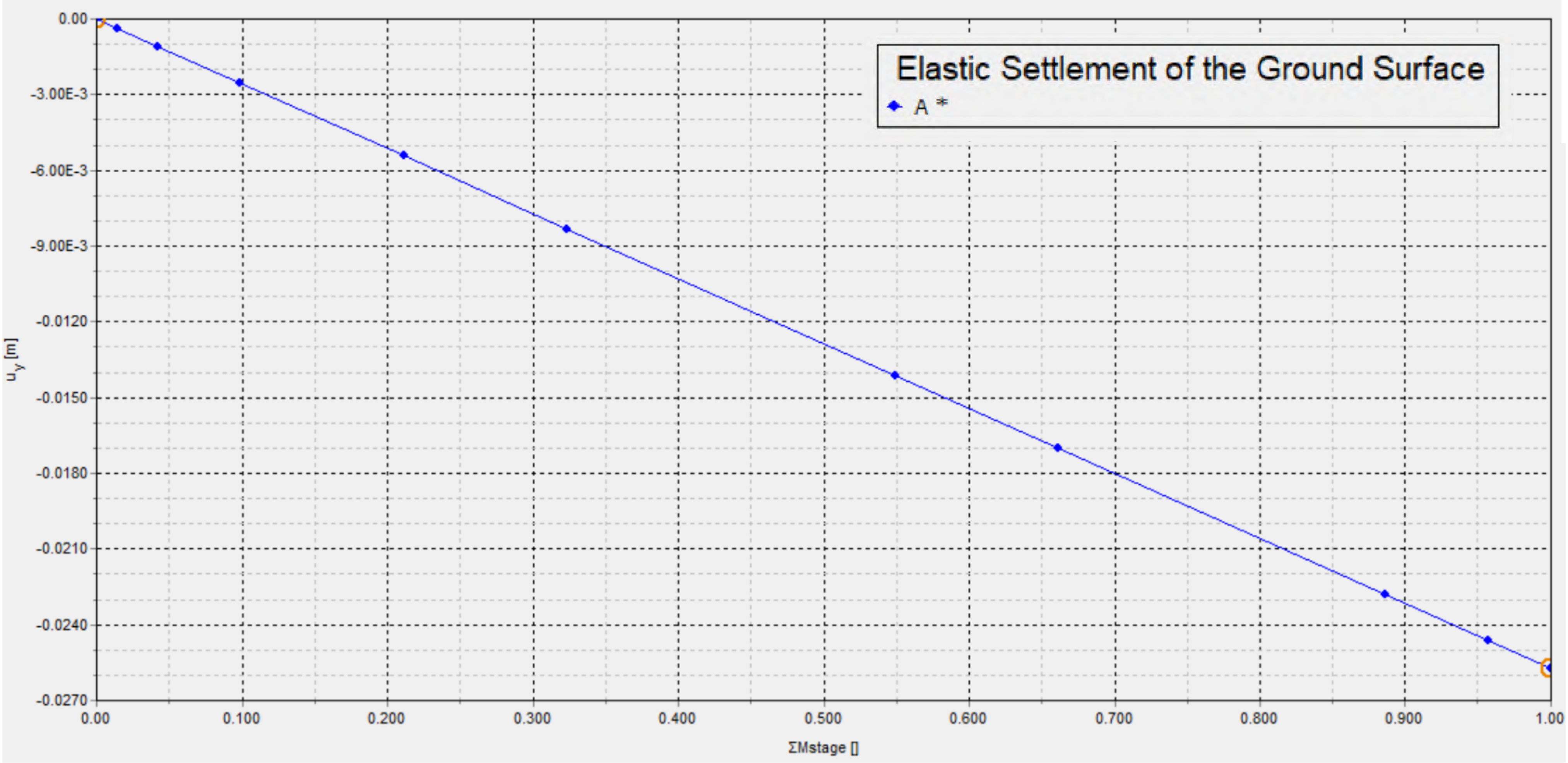
Drawn:	WB
Approved:	RE
Date:	23.07.2024
Scale:	NA

FAILURE ENVELOPE & MINMUM LONG TERM GLOBAL FOS (Section D-D)
Former Broken Head Quarry - Broken Head Road, Suffolk Park, NSW

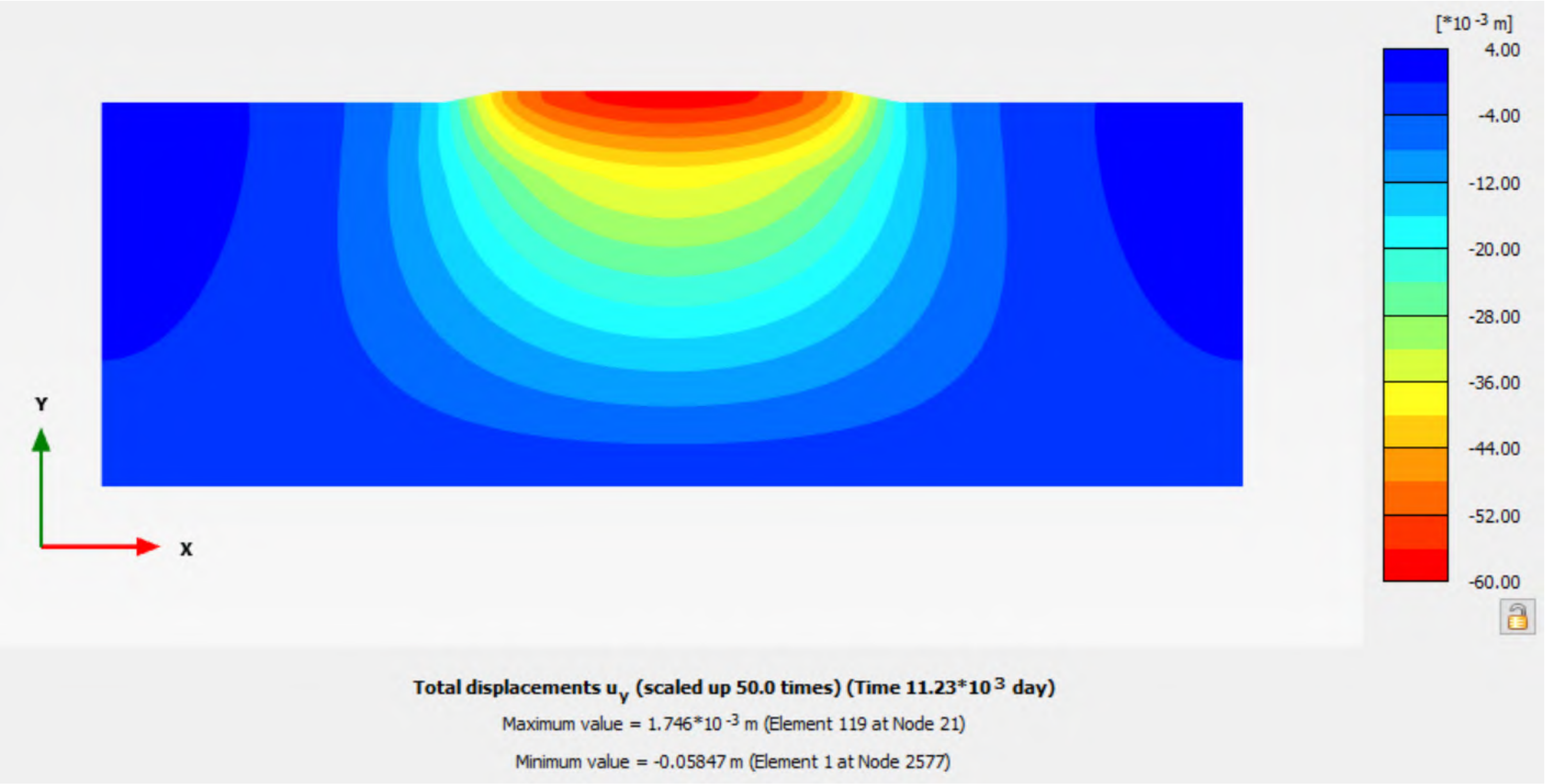
Drawing:

FIGURE 13

File No: P2410392JR01V02



Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	WB	**MAXIMUM ELASTIC SETTLEMENT OF THE GROUND SURFACE (Section E-E)** **Former Broken Head Quarry - Broken Head Road, Suffolk Park, NSW**	Drawing: **FIGURE 14**
Approved:	RE		
Date:	23.07.2024		
Scale:	NA		File No: P2410392JR01V02



Total displacements u_y (scaled up 50.0 times) (Time $11.23*10^3$ day)

Maximum value = $1.746*10^{-3}$ m (Element 119 at Node 21)

Minimum value = -0.05847 m (Element 1 at Node 2577)

Martens & Associates Pty Ltd ABN 85 070 240 890

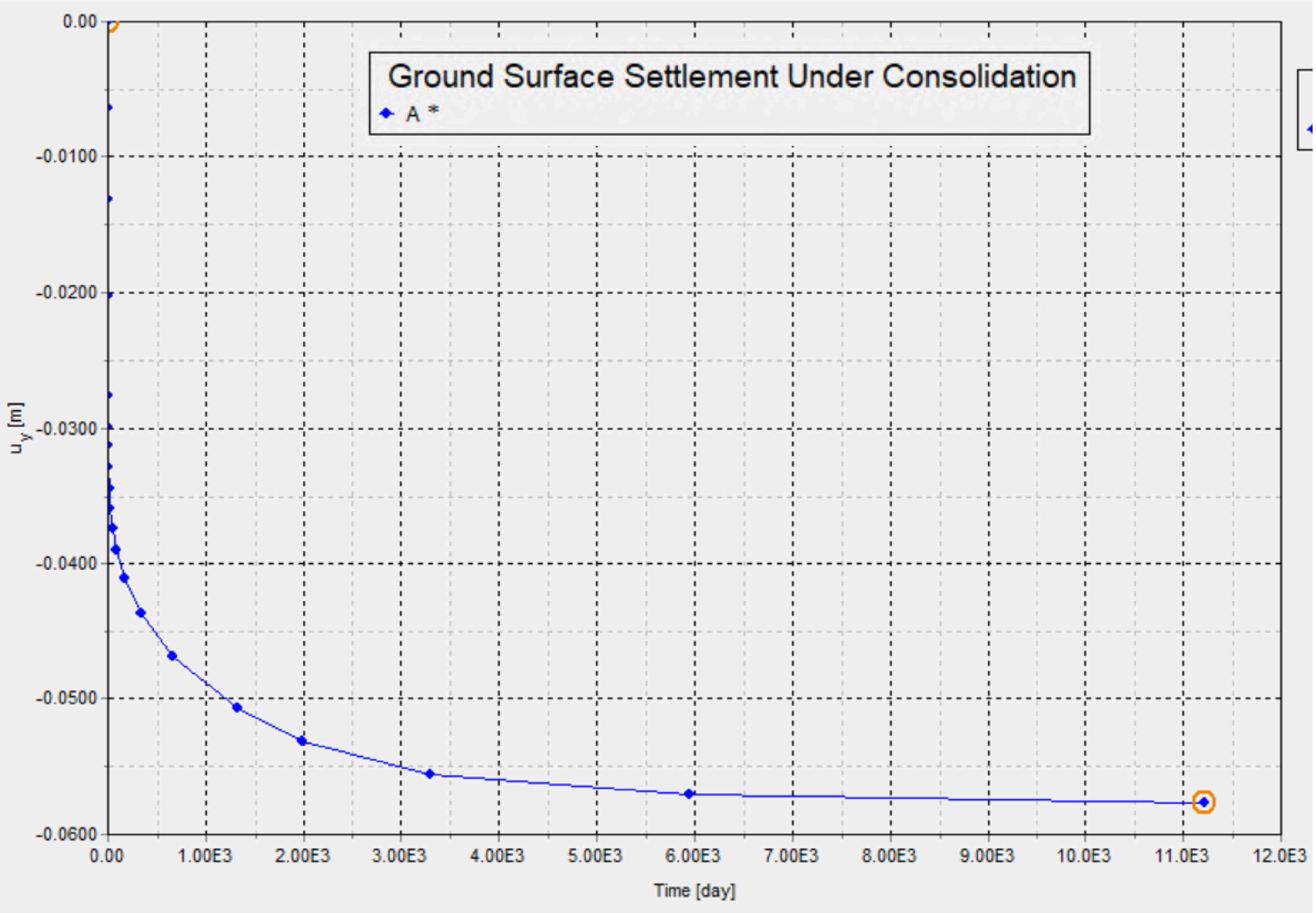
Environment | Water | Wastewater | Geotechnical | Civil | Management

Drawn:	WB
Approved:	RE
Date:	23.07.2024
Scale:	NA

LONG TERM CONSOLIDATION SETTLEMENT (Section E-E)
Former Broken Head Quarry - Broken Head Road, Suffolk Park, NSW

Drawing:
FIGURE 15

File No: P2410392JR01V02



Martens & Associates Pty Ltd ABN 85 070 240 890		Environment | Water | Wastewater | Geotechnical | Civil | Management	
Drawn:	WB	**GROUND SURFACE SETTLEMNT UNDER CONSOLIDATION (Section E-E)** **Former Broken Head Quarry - Broken Head Road, Suffolk Park, NSW**	Drawing: **FIGURE 16**
Approved:	RE		
Date:	23.07.2024		
Scale:	NA		File No: P2410392JR01V02

Appendix H – General Geotechnical Recommendations

Geotechnical Recommendations

Important Recommendations About Your Site (1 of 2)

These general geotechnical recommendations have been prepared by Martens to help you deliver a safe work site, to comply with your obligations, and to deliver your project. Not all are necessarily relevant to this report but are included as general reference. Any specific recommendations made in the report will override these recommendations.

Batter Slopes

Excavations in soil and extremely low to very low strength rock exceeding 0.75 m depth should be battered back at grades of no greater than 1 Vertical (V) : 2 Horizontal (H) for temporary slopes (unsupported for less than 1 month) and 1 V : 3 H for longer term unsupported slopes.

Vertical excavation may be carried out in medium or higher strength rock, where encountered, subject to inspection and confirmation by a geotechnical engineer. Long term and short term unsupported batters should be protected against erosion and rock weathering due to, for example, stormwater run-off.

Batter angles may need to be revised depending on the presence of bedding partings or adversely oriented joints in the exposed rock, and are subject to on-site inspection and confirmation by a geotechnical engineer. Unsupported excavations deeper than 1.0 m should be assessed by a geotechnical engineer for slope instability risk.

Any excavated rock faces should be inspected during construction by a geotechnical engineer to determine whether any additional support, such as rock bolts or shotcrete, is required.

Earthworks

Earthworks should be carried out following removal of any unsuitable materials and in accordance with AS3798 (2007). A qualified geotechnical engineer should inspect the condition of prepared surfaces to assess suitability as foundation for future fill placement or load application.

Earthworks inspections and compliance testing should be carried out in accordance with Sections 5 and 8 of AS3798 (2007), with testing to be carried out by a National Association of Testing Authorities (NATA) accredited testing laboratory.

Excavations

All excavation work should be completed with reference to the *Work Health and Safety (Excavation Work) Code of Practice (2015)*, by Safe Work Australia. Excavations into rock may be undertaken as follows:

1. Extremely low to low strength rock - conventional hydraulic earthmoving equipment.

2. Medium strength or stronger rock - hydraulic earthmoving equipment with rock hammer or ripping tyne attachment.

Exposed rock faces and loose boulders should be monitored to assess risk of block / boulder movement, particularly as a result of excavation vibrations.

Fill

Subject to any specific recommendations provided in this report, any fill imported to site is to comprise approved material with maximum particle size of two thirds the final layer thickness. Fill should be placed in horizontal layers of not more than 300 mm loose thickness, however, the layer thickness should be appropriate for the adopted compaction plant.

Foundations

All exposed foundations should be inspected by a geotechnical engineer prior to footing construction to confirm encountered conditions satisfy design assumptions and that the base of all excavations is free from loose or softened material and water. Water that has ponded in the base of excavations and any resultant softened material is to be removed prior to footing construction.

Footings should be constructed with minimal delay following excavation. If a delay in construction is anticipated, we recommend placing a concrete blinding layer of at least 50 mm thickness in shallow footings or mass concrete in piers / piles to protect exposed foundations.

A geotechnical engineer should confirm any design bearing capacity values, by further assessment during construction, as necessary.

Shoring - Anchors

Where there is a requirement for either soil or rock anchors, or soil nailing, and these structures penetrate past a property boundary, appropriate permission from the adjoining land owner must be obtained prior to the installation of these structures.

Shoring - Permanent

Permanent shoring techniques may be used as an alternative to temporary shoring. The design of such structures should be in accordance with the findings of this report and any further testing recommended by this report. Permanent shoring may include [but not be limited to] reinforced block work walls, contiguous and semi contiguous pile walls, secant pile walls and soldier pile walls with or without reinforced shotcrete infill panels. The choice of shoring system will depend on the type of structure, project budget and site specific geotechnical conditions.

Permanent shoring systems are to be engineer designed and backfilled with suitable granular material and free-draining drainage material. Backfill should be placed in maximum 100 mm thick layers compacted using a hand operated compactor. Care should be taken to ensure excessive compaction stresses are not transferred to retaining walls.

Shoring design should consider any surcharge loading from sloping / raised ground behind shoring structures, live loads, new structures, construction equipment, backfill compaction and static water pressures. All shoring systems shall be provided with adequate foundation designs.

Suitable drainage measures, such as geotextile enclosed 100 mm agricultural pipes embedded in free-draining gravel, should be included to redirect water that may collect behind the shoring structure to a suitable discharge point.

Shoring - Temporary

In the absence of providing acceptable excavation batters, excavations should be supported by suitably designed and installed temporary shoring / retaining structures to limit lateral deflection of excavation faces and associated ground surface settlements.

Soil Erosion Control

Removal of any soil overburden should be performed in a manner that reduces the risk of sedimentation occurring in any formal stormwater drainage system, on neighbouring land and in receiving waters. Where possible, this may be achieved by one or more of the following means:

1. Maintain vegetation where possible
2. Disturb minimal areas during excavation
3. Revegetate disturbed areas if possible

All spoil on site should be properly controlled by erosion control measures to prevent transportation of sediments off-site. Appropriate soil erosion control methods in accordance with Landcom (2004) shall be required.

Trafficability and Access

Consideration should be given to the impact of the proposed works and site subsurface conditions on trafficability within the site e.g. wet clay soils will lead to poor trafficability by tyred plant or vehicles.

Where site access is likely to be affected by any site works, construction staging should be organised such that any impacts on adequate access are minimised as best as possible.

Vibration Management

Where excavation is to be extended into medium or higher strength rock, care will be required when using a rock hammer to limit potential structural distress from excavation-induced vibrations where nearby structures may be affected by the works.

To limit vibrations, we recommend limiting rock hammer size and set frequency, and setting the hammer parallel to bedding planes and along defect planes, where possible, or as advised by a geotechnical engineer. We recommend limiting vibration peak particle velocities (PPV) caused by construction equipment or resulting from excavation at the site to 5 mm/s (AS 2187.2, 2006, Appendix J).

Waste – Spoil and Water

Soil to be disposed off-site should be classified in accordance with the relevant State Authority guidelines and requirements.

Any collected waste stormwater or groundwater should also be tested prior to discharge to ensure contaminant levels (where applicable) are appropriate for the nominated discharge location.

MA can complete the necessary classification and testing if required. Time allowance should be made for such testing in the construction program.

Water Management - Groundwater

If the proposed works are likely to intersect ephemeral or permanent groundwater levels, the management of any potential acid soil drainage should be considered. If groundwater tables are likely to be lowered, this should be further discussed with the relevant State Government Agency.

Water Management – Surface Water

All surface runoff should be diverted away from excavation areas during construction works and prevented from accumulating in areas surrounding any retaining structures, footings or the base of excavations.

Any collected surface water should be discharged into a suitable Council approved drainage system and not adversely impact downslope surface and subsurface conditions.

All site discharges should be passed through a filter material prior to release. Sump and pump methods will generally be suitable for collection and removal of accumulated surface water within any excavations.

Contingency Plan

In the event that proposed development works cause an adverse impact on geotechnical hazards, overall site stability or adjacent properties, the following actions are to be undertaken:

1. Works shall cease immediately.
2. The nature of the impact shall be documented and the reason(s) for the adverse impact investigated.
3. A qualified geotechnical engineer should be consulted to provide further advice in relation to the issue.

Appendix I – Notes about this Report

Important Information About Your Report (1 of 2)

These notes have been prepared by Martens to help you interpret and understand the limitations of your report. Not all are necessarily relevant to all reports but are included as general reference.

Engineering Reports - Limitations

The recommendations presented in this report are based on limited investigations and include specific issues to be addressed during various phases of the project. If the recommendations presented in this report are not implemented in full, the general recommendations may become inapplicable and Martens & Associates accept no responsibility whatsoever for the performance of the works undertaken.

Occasionally, sub-surface conditions between and below the completed boreholes or other tests may be found to be different (or may be interpreted to be different) from those expected. Variation can also occur with groundwater conditions, especially after climatic changes. If such differences appear to exist, we recommend that you immediately contact Martens & Associates.

Relative ground surface levels at borehole locations may not be accurate and should be verified by on-site survey.

Engineering Reports – Project Specific Criteria

Engineering reports are prepared by qualified personnel. They are based on information obtained, on current engineering standards of interpretation and analysis, and on the basis of your unique project specific requirements as understood by Martens. Project criteria typically include the general nature of the project; its size and configuration; the location of any structures on the site; other site improvements; the presence of underground utilities; and the additional risk imposed by scope-of-service limitations imposed by the Client.

Where the report has been prepared for a specific design proposal (e.g. a three storey building), the information and interpretation may not be relevant if the design proposal is changed (e.g. to a twenty storey building). Your report should not be relied upon, if there are changes to the project, without first asking Martens to assess how factors, which changed subsequent to the date of the report, affect the report's recommendations. Martens will not accept responsibility for problems that may occur due to design changes, if not consulted.

Engineering Reports – Recommendations

Your report is based on the assumption that site conditions, as may be revealed through selective point sampling, are indicative of actual conditions throughout an area. This assumption often cannot be substantiated until project implementation has commenced. Therefore your site investigation report recommendations should only be regarded as preliminary.

Only Martens, who prepared the report, are fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered as the project develops. If another party undertakes the implementation of the recommendations of this report, there is a risk that the report will be misinterpreted and Martens cannot be held responsible for such misinterpretation.

Engineering Reports – Use for Tendering Purposes

Where information obtained from investigations is provided for tendering purposes, Martens recommend that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document.

Martens would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Engineering Reports – Data

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

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

Engineering Reports – Other Projects

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

Subsurface Conditions - General

Every care is taken with the report in relation to interpretation of subsurface conditions, discussion of geotechnical aspects, relevant standards and recommendations or suggestions for design and construction. However, the Company cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions - the potential will depend partly on test point (eg. excavation or borehole) spacing and sampling frequency, which are often limited by project imposed budgetary constraints.

- Changes in guidelines, standards and policy or interpretation of guidelines, standards and policy by statutory authorities.
- The actions of contractors responding to commercial pressures.
- Actual conditions differing somewhat from those inferred to exist, because no professional, no matter how qualified, can reveal precisely what is hidden by earth, rock and time.

  The actual interface between logged materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions.

If these conditions occur, Martens will be pleased to assist with investigation or providing advice to resolve the matter.

Subsurface Conditions - Changes

Natural processes and the activity of man create subsurface conditions. For example, water levels can vary with time, fill may be placed on a site and pollutants may migrate with time. Reports are based on conditions which existed at the time of the subsurface exploration / assessment.

Decisions should not be based on a report whose adequacy may have been affected by time. If an extended period of time has elapsed since the report was prepared, consult Martens to be advised how time may have impacted on the project.

Subsurface Conditions - Site Anomalies

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

Report Use by Other Design Professionals

To avoid potentially costly misinterpretations when other design professionals develop their plans based on a Martens report, retain Martens to work with other project professionals affected by the report. This may involve Martens explaining the report design implications and then reviewing plans and specifications produced to see how they have incorporated the report findings.

Subsurface Conditions – Geo-environmental Issues

Your report generally does not relate to any findings, conclusions, or recommendations about the potential for hazardous or contaminated materials existing at the site unless specifically required to do so as part of Martens' proposal for works.

Specific sampling guidelines and specialist equipment, techniques and personnel are typically used to perform geo-environmental or site contamination assessments. Contamination can create major health, safety and environmental risks. If you have no information about the potential for your site to be contaminated or create an environmental hazard, you are advised to contact Martens for information relating to such matters.

Responsibility

Geo-environmental reporting relies on interpretation of factual information based on professional judgment and opinion and has an inherent level of uncertainty attached to it and is typically far less exact than the design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded.

To help prevent this problem, a number of clauses have been developed for use in contracts, reports and other documents. Responsibility clauses do not transfer appropriate liabilities from Martens to other parties but are included to identify where Martens' responsibilities begin and end. Their use is intended to help all parties involved to recognise their individual responsibilities. Read all documents from Martens closely and do not hesitate to ask any questions you may have.

Site Inspections

Martens will always be pleased to provide engineering inspection services for aspects of work to which this report relates. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site. Martens is familiar with a variety of techniques and approaches that can be used to help reduce risks for all parties to a project, from design to construction.

Definitions

In engineering terms, soil includes every type of uncemented or partially cemented inorganic or organic material found in the ground. In practice, if the material does not exhibit any visible rock properties and can be remoulded or disintegrated by hand in its field condition or in water, it is described as a soil. Other materials are described using rock description terms.

The methods of description and classification of soils and rocks used in this report are typically based on Australian Standard 1726 and the Unified Soil Classification System (USCS) – refer Soil Data Explanation of Terms (2 of 3). In general, descriptions cover the following properties: strength or density, colour, moisture, structure, soil or rock type and inclusions.

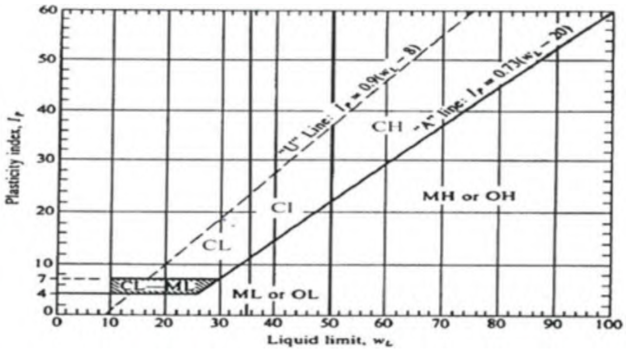
Particle Size

Soil types are described according to the predominating particle size, qualified by the grading of other particles present (e.g. sandy CLAY). Unless otherwise stated, particle size is described in accordance with the following table.

Division	**Subdivision**		**Particle Size (mm)**
Oversized	BOULDERS		>200
	COBBLES		63 to 200
Coarse Grained Soil	GRAVEL	Coarse	19 to 63
		Medium	6.7 to 19
		Fine	2.36 to 6.7
	SAND	Coarse	0.6 to 2.36
		Medium	0.21 to 0.6
		Fine	0.075 to 0.21
Fine Grained Soil	SILT		0.002 to 0.075
	CLAY		< 0.002

Plasticity Properties

Plasticity properties of cohesive soils can be assessed in the field by tactile properties or by laboratory procedures.



Soil Moisture Condition

Coarse Grained (Granular) Soil:

Dry (D):	Looks and feels dry. Cemented soils are hard, friable or powdery. Uncemented soils run freely through fingers.
Moist (M):	Feels cool and damp and is darkened in colour. Particles tend to cohere.
Wet (W):	As for moist but with free water forming on hands when handled.

Fine Grained (Cohesive) Soil:

Moist, dry of plastic limit[1] (w < PL):	Looks and feels dry. Hard, friable or powdery.
Moist, near plastic limit (w ≈ PL):	Can be moulded, feels cool and damp, is darkened in colour, at a moisture content approximately equal to the PL.
Moist, wet of plastic limit (w > PL):	Usually weakened and free water forms on hands when handled.
Wet, near liquid limit[2] (w ≈ LL)	
Wet, wet of liquid limit (w > LL)	

[1] Plastic Limit (PL): Moisture content at which soil becomes too dry to be in a plastic condition.

[2] Liquid Limit (LL): Moisture content at which soil passes from plastic to liquid state.

Consistency of Cohesive Soils

Cohesive soils refer to predominantly clay materials.
(Note: consistency is affected by soil moisture condition at time of measurement)

Term	**C_u (kPa)**	**Field Guide**
Very Soft (VS)	≤12	A finger can be pushed well into the soil with little effort. Sample exudes between fingers when squeezed in fist.
Soft (S)	>12 and ≤25	A finger can be pushed into the soil to about 25mm depth. Easily moulded by light finger pressures.
Firm (F)	>25 and ≤50	The soil can be indented about 5mm with the thumb, but not penetrated. Can be moulded by strong figure pressure.
Stiff (St)	>50 and ≤100	The surface of the soil can be indented with the thumb, but not penetrated. Cannot be moulded by fingers.
Very Stiff (VSt)	>100 and ≤200	The surface of the soil can be marked, but not indented with thumb pressure. Difficult to cut with a knife. Thumbnail can readily indent.
Hard (H)	> 200	The surface of the soil can only be marked with the thumbnail. Brittle. Tends to break into fragments.
Friable (Fr)	-	Crumbles or powders when scraped by thumbnail. Can easily be crumbled or broken into small pieces by hand.

Density of Granular Soils

Non-cohesive soils are classified on the basis of relative density, generally from standard penetration test (SPT) or Dutch cone penetrometer test (CPT) results as below:

Relative Density	**%**	**SPT 'N' Value* (blows/300mm)**	**CPT Cone Value (q_c MPa)**
Very loose	≤15	< 5	< 2
Loose	>15 and ≤35	5 - 10	2 - 5
Medium dense	>35 and ≤65	10 - 30	5 - 15
Dense	>65 and ≤85	30 - 50	15 - 25
Very dense	> 85	> 50	> 25

* Values may be subject to corrections for overburden pressures and equipment type and influenced by soil moisture condition at time of measurement.

Minor Components

Minor components in soils may be present and readily detectable, but have little bearing on general geotechnical classification. Terms include:

Description of components	**Proportion of component in:**					
	coarse grained soil				**fine grained soil**	
	% Fines	**Terminology**	**% Accessory coarse fraction**	**Terminology**	**% Sand/ gravel**	**Terminology**
Minor	≤5	Trace clay / silt, as applicable	≤15	Trace sand / gravel, as applicable	≤15	Trace sand / gravel, as applicable
	>5,≤12	With clay / silt, as applicable	>15,≤30	With sand / gravel, as applicable	>5,≤30	With sand / gravel, as applicable
Secondary	>12	Prefix soil name as 'silty' or 'clayey', as applicable	>30	Prefix soil name as 'sandy' or 'gravelly', as applicable	>30	Prefix soil name as 'sandy' or 'gravelly', as applicable

Soil Data

Explanation of Terms (2 of 3)

Symbols for Soils and Other

SOILS

- ▨ COBBLES/BOULDERS
- ▨ GRAVEL (GP or GW)
- ▨ Silty GRAVEL (GM)
- ▨ Clayey GRAVEL (GC)
- ▨ SAND (SP or SW)
- ▨ Silty SAND (SM)
- ▨ Clayey SAND (SC)
- ▨ SILT (ML or MH)
- ▨ ORGANIC SILT or CLAY (OH or OL)
- ▨ CLAY (CL, CI or CH)
- ▨ Silty CLAY
- ▨ Sandy CLAY
- ▨ PEAT (Pt)
- ▨ Gravelly CLAY

OTHER

- ▨ FILL
- ▨ TALUS
- ■ ASPHALT
- ▨ CONCRETE
- ▨ TOPSOIL

Unified Soil Classification Scheme (USCS)

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 63 mm and basing fractions on estimated mass)					USCS	Primary Name
COARSE GRAINED SOILS More than 65 % of material less than 63 mm is larger than 0.075 mm	(A 0.075 mm particle is about the smallest particle visible to the naked eye)	GRAVELS More than half of coarse fraction is larger than 2.36 mm.	GRAVEL and GRAVEL-SAND Mixtures (≤ 5% fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes; not enough fines to bind coarse grains; no dry strength	GW	GRAVEL
				Predominantly one size or a range of sizes with some intermediate sizes missing; not enough fines to bind coarse grains; no dry strength	GP	GRAVEL
			GRAVEL-SILT and GRAVEL-SAND-SILT mixtures (≥12% fines)[1]	With excess non-plastic fines (for identification procedures see ML below); zero to medium dry strength; may also contain sand	GM	Silty GRAVEL
				With excess plastic fines (for identification procedures see CL below); medium to high dry strength; may also contain sand	GC	Clayey GRAVEL
		SANDS More than half of coarse fraction is smaller than 2.36 mm	SAND and GRAVEL-SAND mixtures (≤5% fines)	Wide range in grain sizes and substantial amounts of all intermediate sizes; not enough fines to bind coarse grains; no dry strength.	SW	SAND
				Predominantly one size or a range of sizes with some intermediate sizes missing; not enough fines to bind coarse grains; no dry strength	SP	SAND
			SAND-SILT and SAND-CLAY mixtures (≥12% fines)[1]	With excess non-plastic fines (for identification procedures see ML below); zero to medium dry strength;	SM	Silty SAND
				With excess plastic fines (for identification procedures see CL below); medium to high dry strength	SC	Clayey SAND

		IDENTIFICATION PROCEDURES ON FRACTIONS < 0.2 MM					
		DRY STRENGTH (Crushing Characteristics)	**DILATANCY**	**TOUGHNESS**	**DESCRIPTION**	**USCS**	**Primary Name**
FINE GRAINED SOILS More than 35 % of material less than 63 mm is smaller than 0.075 mm	(A 0.075 mm particle is about the smallest particle visible to the naked eye)	None to Low	Quick to Slow	Low	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or silt with low plasticity[2]	ML	SILT[3]
		Medium to High	None to Slow	Medium	Inorganic clays of low to medium plasticity, gravely clays, sandy clays, silty clays, lean clays	CL (or CI[4])	CLAY
		Low to Medium	Slow	Low	Organic slits and organic silty clays of low plasticity	OL	Organic SILT or CLAY
		Low to Medium	None to Slow	Low to Medium	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	MH	SILT[3]
		High to Very High	None	High	Inorganic clays of high plasticity, fat clays	CH	CLAY
		Medium to High	None to Very Slow	Low to Medium	Organic clays of medium to high plasticity, organic silt of high plasticity	OH	Organic SILT or CLAY
HIGHLY ORGANIC SOILS		Readily identified by colour, odour, spongy feel and frequently by fibrous texture				Pt	PEAT

Notes:

1. Between 5% and 12% - dual classification, e.g. GP-GM.
2. Low Plasticity Clay – Liquid Limit W_L ≤35%; Medium Plasticity Clay – Liquid limit W_L >35%, ≤50%; High Plasticity Clay - Liquid limit W_L > 50%.
3. Low Plasticity Silt – Liquid Limit W_L ≤50%; High Plasticity Silt - Liquid limit W_L > 50%.
4. CI may be adopted for clay of medium plasticity to distinguish from clay of low plasticity.

Soil Agricultural Classification Scheme

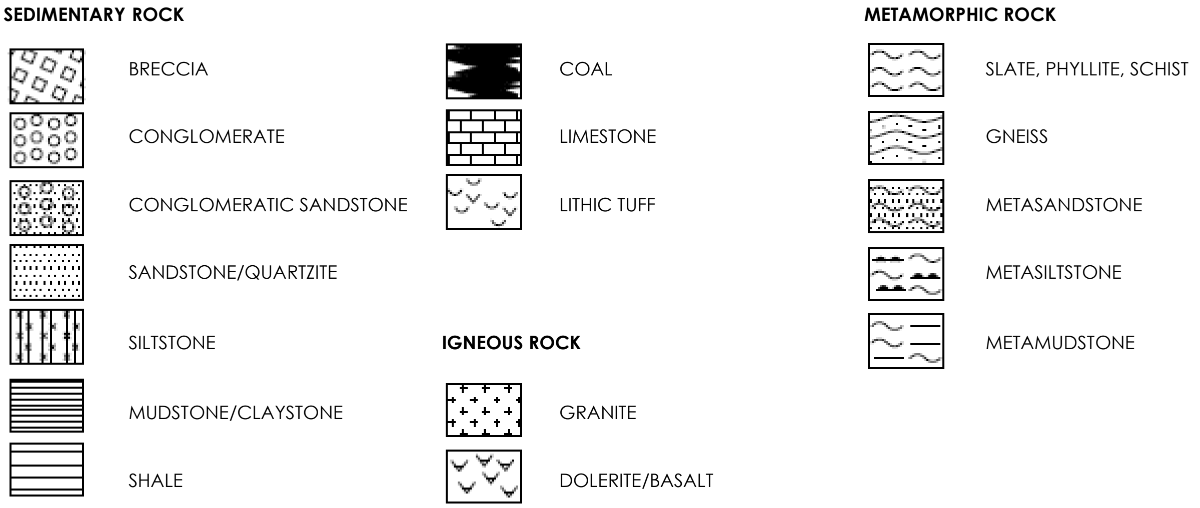
In some situations, such as where soils are to be used for effluent disposal purposes, soils are often more appropriately classified in terms of traditional agricultural classification schemes. Where a Martens report provides agricultural classifications, these are undertaken in accordance with descriptions by Northcote, K.H. (1979) *The factual key for the recognition of Australian Soils*, Rellim Technical Publications, NSW, p 26 - 28.

Symbol	Field Texture Grade	Behaviour of moist bolus	Ribbon length	Clay content (%)
S	Sand	Coherence nil to very slight; cannot be moulded; single grains adhere to fingers	0 mm	< 5
LS	Loamy sand	Slight coherence; discolours fingers with dark organic stain	6.35 mm	5
CLS	Clayey sand	Slight coherence; sticky when wet; many sand grains stick to fingers; discolours fingers with clay stain	6.35mm - 1.3cm	5 - 10
SL	Sandy loam	Bolus just coherent but very sandy to touch; dominant sand grains are of medium size and are readily visible	1.3 - 2.5	10 - 15
FSL	Fine sandy loam	Bolus coherent; fine sand can be felt and heard	1.3 - 2.5	10 - 20
SCL^{-}	Light sandy clay loam	Bolus strongly coherent but sandy to touch, sand grains dominantly medium size and easily visible	2.0	15 - 20
L	Loam	Bolus coherent and rather spongy; smooth feel when manipulated but no obvious sandiness or silkiness; may be somewhat greasy to the touch if much organic matter present	2.5	25
Lfsy	Loam, fine sandy	Bolus coherent and slightly spongy; fine sand can be felt and heard when manipulated	2.5	25
SiL	Silt loam	Coherent bolus, very smooth to silky when manipulated	2.5	25 + > 25 silt
SCL	Sandy clay loam	Strongly coherent bolus sandy to touch; medium size sand grains visible in a finer matrix	2.5 - 3.8	20 - 30
CL	Clay loam	Coherent plastic bolus; smooth to manipulate	3.8 - 5.0	30 - 35
SiCL	Silty clay loam	Coherent smooth bolus; plastic and silky to touch	3.8 - 5.0	30- 35 + > 25 silt
FSCL	Fine sandy clay loam	Coherent bolus; fine sand can be felt and heard	3.8 - 5.0	30 - 35
SC	Sandy clay	Plastic bolus; fine to medium sized sands can be seen, felt or heard in a clayey matrix	5.0 - 7.5	35 - 40
SiC	Silty clay	Plastic bolus; smooth and silky	5.0 - 7.5	35 - 40 + > 25 silt
LC	Light clay	Plastic bolus; smooth to touch; slight resistance to shearing	5.0 - 7.5	35 - 40
LMC	Light medium clay	Plastic bolus; smooth to touch, slightly greater resistance to shearing than LC	7.5	40 - 45
MC	Medium clay	Smooth plastic bolus, handles like plasticine and can be moulded into rods without fracture, some resistance to shearing	> 7.5	45 - 55
HC	Heavy clay	Smooth plastic bolus; handles like stiff plasticine; can be moulded into rods without fracture; firm resistance to shearing	> 7.5	> 50

Rock Data

Explanation of Terms (1 of 2)

Symbols for Rock



Definitions

Descriptive terms used for Rock by Martens are based on AS1726 and encompass rock substance, defects and mass.

Rock Material	The intact rock that is bounded by defects.
Rock Defect	Discontinuity, fracture, break or void in the material or minerals across which there is little or no tensile strength.
Rock Structure	The nature and configuration of the different defects within the rock mass and their relationship to each other.
Rock Mass	The entirety of the system formed by all of the rock material and all of the defects that are present.

Degree of Weathering

Rock weathering is defined as the degree of decline in rock structure and grain property and can be determined in the field.

Term	Symbol	Definition
Residual soil[1]	RS	Material is weathered to such an extent that it has soil properties. Mass structure, material texture, and fabric of original rock are no longer visible, but the soil has not been significantly transported.
Extremely weathered[1]	XW	Material is weathered to such an extent that it has soil properties - i.e. it can be remoulded and can be classified according to the Unified Classification System. Mass structure and material texture and fabric of original rock are still visible.
Highly weathered[2]	HW	The whole of the rock material is discoloured, usually by iron staining or bleaching to the extent that the original colour of the rock is not recognisable. Rock strength is significantly changed by weathering. Some primary minerals have weathered to clay minerals. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores.
Moderately weathered[2]	MW	The whole of the rock material is discoloured, usually by iron staining or bleaching to the extent that the colour of the rock is not recognisable. Rock strength shows little or no change from fresh rock.
Slightly weathered	SW	Rock is partially discoloured with staining or bleaching along joints but shows little or no change of strength from fresh rock.
Fresh	FR	Rock substance unaffected by weathering. No sign of decomposition of individual materials or colour changes.

Notes:

1 RS and EW material is described using soil descriptive terms.

2. The term "Distinctly Weathered" (DW) may be used to cover the range of substance weathering between EW and SW

Rock Strength

Rock strength is defined by the Point Load Strength Index (Is 50) and refers to the strength of the rock substance in the direction normal to the loading. The test procedure is described by the International Society of Rock Mechanics.

Term (Strength)	I_s (50) MPa	Uniaxial Compressive Strength MPa	Field Guide	Symbol
Very low	>0.03 ≤0.1	0.6 – 2	May be crumbled in the hand. Sandstone is 'sugary' and friable.	VL
Low	>0.1 ≤0.3	2 – 6	Core 150mm long x 50mm diameter may be broken by hand and easily scored with a knife. Sharp edges of core may be friable and break during handling.	L
Medium	>0.3 ≤1.0	6 – 20	Core 150mm long x 50mm diameter can be broken by hand with considerable difficulty. Readily scored with a knife.	M
High	>1 ≤3	20 – 60	Core 150mm long x 50mm diameter cannot be broken by unaided hands, can be slightly scratched or scored with a knife. Breaks with single blow from pick.	H
Very high	>3 ≤10	60 – 200	Core 150mm long x 50mm diameter, broken readily with hand held hammer. Cannot be scratched with knife. Breaks after more than one pick strike.	VH
Extremely high	>10	>200	A piece of core 150mm long x 50mm diameter is difficult to break with hand held hammer. Rings when struck with a hammer.	EH

Rock Data

Explanation of Terms (2 of 2)

Degree of Fracturing

This classification applies to diamond drill cores and refers to the spacing of all types of natural fractures along which the core is discontinuous. These include bedding plane partings, joints and other rock defects, but exclude fractures such as drilling breaks (DB) or handling breaks (HB).

Term	**Description**
Fragmented	The core is comprised primarily of fragments of length less than 20 mm, and mostly of width less than core diameter.
Highly fractured	Core lengths are generally less than 20 mm to 40 mm with occasional fragments.
Fractured	Core lengths are mainly 30 mm to 100 mm with occasional shorter and longer sections.
Slightly fractured	Core lengths are generally 300 mm to 1000 mm, with occasional longer sections and sections of 100 mm to 300 mm.
Unbroken	The core does not contain any fractures.

Rock Core Recovery

TCR = Total Core Recovery

$$= \frac{\text{Length of core recovered}}{\text{Length of core run}} \times 100\,\%$$

SCR = Solid Core Recovery

$$= \frac{\sum \text{Length of cylindrical core recovered}}{\text{Length of core run}} \times 100\,\%$$

RQD = Rock Quality Designation

$$= \frac{\sum \text{Axial lengths of core} > 100\text{ mm long}}{\text{Length of core run}} \times 100\,\%$$

Rock Strength Tests

▼	Point load strength Index (Is50) - axial test (MPa)
▶	Point load strength Index (Is50) - diametral test (MPa)
●	Uniaxial compressive strength (UCS) (MPa)

Defect Type Abbreviations and Descriptions

Defect Type (with inclination given)	
BP	Bedding plane parting
FL	Foliation
CL	Cleavage
JT	Joint
FC	Fracture
SZ/SS	Sheared zone/ seam (Fault)
CZ/CS	Crushed zone/ seam
DZ/DS	Decomposed zone/ seam
FZ	Fractured Zone
IS	Infilled seam
VN	Vein
CO	Contact
HB	Handling break
DB	Drilling break

Planarity	
Pl	Planar
Cu	Curved
Un	Undulating
St	Stepped
Ir	Irregular
Dis	Discontinuous

Roughness	
Pol	Polished
Sl	Slickensided
Sm	Smooth
Ro	Rough
VR	Very rough

Thickness	
Zone	> 100 mm
Seam	> 2 mm < 100 mm
Plane	< 2 mm

Coating or Filling	
Cn	Clean
Sn	Stain
Ct	Coating
Vnr	Veneer
Fe	Iron Oxide
X	Carbonaceous
Qz	Quartzite
MU	Unidentified mineral

Inclination

Inclination of defect is measured from perpendicular to and down the core axis.

Direction of defect is measured clockwise (looking down core) from magnetic north.

Test, Drill and Excavation Methods

Explanation of Terms (1 of 3)

Sampling

Sampling is carried out during drilling or excavation to allow engineering examination (and laboratory testing where required) of the soil or rock.

Disturbed samples taken during drilling or excavation provide information on colour, type, inclusions and, depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples may be taken by pushing a thin-walled sampling tube, e.g. U_{50} (50 mm internal diameter thin walled tube), into soils and withdrawing a soil sample in a relatively undisturbed state. Such samples yield information on structure and strength and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils. Other sampling methods may be used. Details of the type and method of sampling are given in the report.

Drilling / Excavation Methods

The following is a brief summary of drilling and excavation methods currently adopted by the Company and some comments on their use and application.

Hand Excavation - in some situations, excavation using hand tools, such as mattock and spade, may be required due to limited site access or shallow soil profiles.

Hand Auger - the hole is advanced by pushing and rotating either a sand or clay auger, generally 75-100 mm in diameter, into the ground. The penetration depth is usually limited to the length of the auger pole; however extender pieces can be added to lengthen this.

Test Pits - these are excavated with a backhoe or a tracked excavator, allowing close examination of the in-situ soils and, if it is safe to descend into the pit, collection of bulk disturbed samples. The depth of penetration is limited to about 3 m for a backhoe and up to 6 m for an excavator. A potential disadvantage is the disturbance caused by the excavation.

Large Diameter Auger (e.g. Pengo) - the hole is advanced by a rotating plate or short spiral auger, generally 300 mm or larger in diameter. The cuttings are returned to the surface at intervals (generally of not more than 0.5 m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube sampling.

Continuous Sample Drilling (Push Tube) - the hole is advanced by pushing a 50 - 100 mm diameter socket into the ground and withdrawing it at intervals to extrude the sample. This is the most reliable method of drilling in soils, since moisture content is unchanged and soil structure, strength *etc.* is only marginally affected.

Continuous Spiral Flight Augers - the hole is advanced using 90 - 115 mm diameter continuous spiral flight augers, which are withdrawn at intervals to allow sampling or in-situ testing. This is a relatively economical means of drilling in clays and in sands above the water table. Samples are returned to the surface or, or may be collected after withdrawal of the auger flights, but they are very disturbed and may be contaminated. Information from the drilling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively lower reliability, due to remoulding, contamination or softening of samples by ground water.

Non-core Rotary Drilling - the hole is advanced by a rotary bit, with water being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from 'feel' and rate of penetration.

Rotary Mud Drilling - similar to rotary drilling, but using drilling mud as a circulating fluid. The mud tends to mask the cuttings and reliable identification is again only possible from separate intact sampling (eg. from SPT).

Continuous Core Drilling - a continuous core sample is obtained using a diamond tipped core barrel of usually 50 mm internal diameter. Provided full core recovery is achieved (not always possible in very weak or fractured rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation.

In-situ Testing and Interpretation

Cone Penetrometer Testing (CPT)

Cone penetrometer testing (sometimes referred to as Dutch Cone) described in this report has been carried out using an electrical friction cone penetrometer.

The test is described in AS 1289.6.5.1-1999 (R2013). In the test, a 35 mm diameter rod with a cone tipped end is pushed continuously into the soil, the reaction being provided by a specially designed truck or rig which is fitted with an hydraulic ram system.

Measurements are made of the end bearing resistance on the cone and the friction resistance on a separate 130 mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are connected by electrical wires passing through the push rod centre to an amplifier and recorder unit mounted on the control truck. As penetration occurs (at a rate of approximately 20 mm per second) the information is output on continuous chart recorders. The plotted results given in this report have been traced from the original records. The information provided on the charts comprises:

(i) Cone resistance (q_c) - the actual end bearing force divided by the cross sectional area of the cone, expressed in MPa.

(ii) Sleeve friction (q_f) - the frictional force of the sleeve divided by the surface area, expressed in kPa.

(iii) Friction ratio - the ratio of sleeve friction to cone resistance, expressed in percent.

There are two scales available for measurement of cone resistance. The lower (A) scale (0 - 5 MPa) is used in very soft soils where increased sensitivity is required and is shown in the graphs as a dotted line. The main (B) scale (0 - 50 MPa) is less sensitive and is shown as a full line.

The ratios of the sleeve resistance to cone resistance will vary with the type of soil encountered, with higher relative friction in clays than in sands. Friction ratios of 1 % - 2 % are commonly encountered in sands and very soft clays rising to 4 % - 10 % in stiff clays.

In sands, the relationship between cone resistance and SPT value is commonly in the range:

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

In clays, the relationship between undrained shear strength and cone resistance is commonly in the range:

$$q_c = (12 \text{ to } 18)\ C_u$$

Interpretation of CPT values can also be made to allow estimation of modulus or compressibility values to allow calculation of foundation settlements.

Inferred stratification as shown on the attached reports is assessed from the cone and friction traces and from experience and information from nearby boreholes *etc*. This information is presented for general guidance, but must be regarded as being to some extent interpretive. The test method provides a continuous profile of engineering properties, and where precise information on soil classification is required, direct drilling and sampling may be preferable.

Standard Penetration Testing (SPT)

Standard penetration tests are used mainly in non-cohesive soils, but occasionally also in cohesive soils as a means of determining density or strength and also of obtaining a relatively undisturbed sample.

The test procedure is described in AS 1289.6.3.1-2004. The test is carried out in a borehole by driving a 50 mm diameter split sample tube under the impact of a 63 kg hammer with a free fall of 760 mm. It is normal for the tube to be driven in three successive 150 mm penetration depth increments and the 'N' value is taken as the number of blows for the last two 150 mm depth increments (300 mm total penetration). In dense sands, very hard clays or weak rock, the full 450 mm penetration may not be practicable and the test is discontinued. The test results are reported in the following form:

(i) Where full 450 mm penetration is obtained with successive blow counts for each 150 mm of say 4, 6 and 7 blows:

as 4, 6, 7
N = 13

(ii) Where the test is discontinued, short of full penetration, say after 15 blows for the first 150mm and 30 blows for the next 40mm

as 15, 30/40 mm.

The results of the tests can be related empirically to the engineering properties of the soil. Occasionally, the test method is used to obtain samples in 50 mm diameter thin walled sample tubes in clays. In such circumstances, the test results are shown on the borehole logs in brackets.

Dynamic Cone (Hand) Penetrometers

Hand penetrometer tests are carried out by driving a rod into the ground with a falling weight hammer and measuring the blows for successive 150mm increments of penetration. Normally, there is a depth limitation of 1.2m but this may be extended in certain conditions by the use of extension rods. Two relatively similar tests are used.

Perth sand penetrometer (PSP) - a 16 mm diameter flat ended rod is driven with a 9 kg hammer, dropping 600 mm. The test, described in AS 1289.6.3.3-1997 (R2013), was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.

Cone penetrometer (DCP) - sometimes known as the Scala Penetrometer, a 16 mm rod with a 20 mm diameter cone end is driven with a 9 kg hammer dropping 510 mm. The test, described in AS 1289.6.3.2-1997 (R2013), was developed initially for pavement sub-grade investigations, with correlations of the test results with California Bearing Ratio published by various Road Authorities.

Pocket Penetrometers

The pocket (hand) penetrometer (PP) is typically a light weight spring hand operated device with a stainless steel loading piston, used to estimate unconfined compressive strength, q_u, (UCS in kPa) of a fine grained soil in field conditions. In use, the free end of the piston is pressed into the soil at a uniform penetration rate until a line, engraved near the piston tip, reaches the soil surface level. The reading is taken from a gradation scale, which is attached to the piston via a built-in spring mechanism and calibrated to kilograms per square centimetre (kPa) UCS. The UCS measurements are used to evaluate consistency of the soil in the field moisture condition. The results may be used to assess the undrained shear strength, C_u, of fine grained soil using the approximate relationship:

$$q_u = 2 \times C_u.$$

It should be noted that accuracy of the results may be influenced by condition variations at selected test surfaces. Also, the readings obtained from the PP test are based on a small area of penetration and could give misleading results. They should not replace laboratory test results. The use of the results from this test is typically limited to an assessment of consistency of the soil in the field and not used directly for design of foundations.

Test Pit / Borehole Logs

Test pit / borehole log(s) presented herein are an engineering and / or geological interpretation of the subsurface conditions. Their reliability will depend to some extent on frequency of sampling and methods of excavation / drilling. Ideally, continuous undisturbed sampling or excavation / core drilling will provide the most reliable assessment but this is not always practicable, or possible to justify on economic grounds. In any case, the test pit / borehole logs represent only a very small sample of the total subsurface profile.

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

Laboratory Testing

Laboratory testing is carried out in accordance with AS 1289 Methods of Testing Soil for Engineering Purposes. Details of the test procedure used are given on the individual report forms.

Ground Water

Where ground water levels are measured in boreholes, there are several potential problems:

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

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

Test, Drill and Excavation Methods

Explanation of Terms (3 of 3)

DRILLING / EXCAVATION METHOD

HA	Hand Auger	RD	Rotary Blade or Drag Bit	NQ	Diamond Core - 47 mm
AD/V	Auger Drilling with V-bit	RT	Rotary Tricone bit	NMLC	Diamond Core – 51.9 mm
AD/T	Auger Drilling with TC-Bit	RAB	Rotary Air Blast	HQ	Diamond Core – 63.5 mm
AS	Auger Screwing	RC	Reverse Circulation	HMLC	Diamond Core – 63.5 mm
HSA	Hollow Stem Auger	CT	Cable Tool Rig	DT	Diatube Coring
S	Excavated by Hand Spade	PT	Push Tube	NDD	Non-destructive digging
BH	Tractor Mounted Backhoe	PC	Percussion	PQ	Diamond Core - 83 mm
JET	Jetting	E	Tracked Hydraulic Excavator	X	Existing Excavation

SUPPORT

Nil	No support	S	Shotcrete	RB	Rock Bolt
C	Casing	Sh	Shoring	SN	Soil Nail
WB	Wash bore with Blade or Bailer	WR	Wash bore with Roller	T	Timbering

WATER

▽ Water level at date shown	◁ Partial water loss
▷ Water inflow	◀ Complete water loss

GROUNDWATER NOT OBSERVED (NO)	The observation of groundwater, whether present or not, was not possible due to drilling water, surface seepage or cave in of the borehole/test pit.
GROUNDWATER NOT ENCOUNTERED (NX)	The borehole/test pit was dry soon after excavation. However, groundwater could be present in less permeable strata. Inflow may have been observed had the borehole/test pit been left open for a longer period.

PENETRATION / EXCAVATION RESISTANCE

L	Low resistance: Rapid penetration possible with little effort from the equipment used.
M	Medium resistance: Excavation possible at an acceptable rate with moderate effort from the equipment used.
H	High resistance: Further penetration possible at slow rate & requires significant effort equipment.
R	Refusal/ Practical Refusal. No further progress possible without risk of damage/ unacceptable wear to digging implement / machine.

These assessments are subjective and dependent on many factors, including equipment power, weight, condition of excavation or drilling tools, and operator experience.

SAMPLING

D	Small disturbed sample	W	Water Sample	C	Core sample
B	Bulk disturbed sample	G	Gas Sample	CONC	Concrete Core

U63 Thin walled tube sample - number indicates nominal undisturbed sample diameter in millimetres

TESTING

SPT	Standard Penetration Test to AS1289.6.3.1-2004
4,7,11	4,7,11 = Blows per 150mm.
N=18	'N' = Recorded blows per 300mm penetration following 150mm seating
DCP	Dynamic Cone Penetration test to AS1289.6.3.2-1997. 'n' = Recorded blows per 150mm penetration

Notes:

RW	Penetration occurred under rod weight only
HW	Penetration occurred under hammer and rod weight only
20/100mm	Where practical refusal or hammer double bouncing occurred, blows and penetration for that interval are reported (e.g. 20 blows for 100 mm penetration)

CPT	Static cone penetration test
CPTu	CPT with pore pressure (u) measurement
PP	Pocket penetrometer test expressed as instrument reading (kPa)
FP	Field permeability test over section noted
VS	Field vane shear test expressed as uncorrected shear strength (sv = peak value, sr = residual value)
PM	Pressuremeter test over section noted
PID	Photoionisation Detector reading in ppm
WPT	Water pressure tests

SOIL DESCRIPTION

Density		**Consistency**		**Moisture**	
VL	Very loose	VS	Very soft	D	Dry
L	Loose	S	Soft	M	Moist
MD	Medium dense	F	Firm	W	Wet
D	Dense	St	Stiff	Wp	Plastic limit
VD	Very dense	VSt	Very stiff	Wl	Liquid limit
		H	Hard		

ROCK DESCRIPTION

Strength		**Weathering**	
VL	Very low	EW	Extremely weathered
L	Low	HW	Highly weathered
M	Medium	MW	Moderately weathered
H	High	SW	Slightly weathered
VH	Very high	FR	Fresh
EH	Extremely high		