



GEOTECHNICAL INVESTIGATION

Proposed Vertical Retirement Village
Lot 8002, Baringa Drive, Baringa

Report for: Plantation Baringa Pty Ltd
23387-001-Rev0
15 January 2023

PLANS AND DOCUMENTS
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DEVELOPMENT APPROVAL

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Tectonic Geotechnical Pty Ltd
PO Box 899, Buderim QLD 4556
Office: 07 5478 9016
Email: admin@tectonicgeo.com.au
www.tectonicgeo.com.au
A.B.N. 83 165 727 828

tectonic
geotechnical & environmental engineers

Document Review

Document No.	Revision	Prepared By	Reviewed By	Date Issued
001 - DRAFT	0	Mitchel Stewart	Ashley Davey	12 January 2024
001	0	Mitchel Stewart	Ashley Davey	15 January 2024



Report Distribution

Revision	Method of Delivery	Issued To
0	Electronic	Mr Fred Beytell (fred@prattproperty.com.au)

Prepared By:

Mitchel Stewart BEnvMgmt
Geo/Environmental Consultant

Reviewed By:

Ashley Davey RPEQ 8159
Principal Geotechnical Engineer

Executive Summary

This report details the results of a geotechnical investigation undertaken for the proposed vertical retirement village on Lot 8002 at Baringa Drive, Baringa. The investigation was performed by Tectonic for Plantation Baringa Pty Ltd in accordance with Proposal P23633-Rev0 dated 13 October 2023. The scope of work included a desk study of available geotechnical information for the site, drilling of boreholes at eight locations and laboratory testing of soil samples. This report summarises the results of the investigation and includes recommendations regarding earthworks, footings and pavements, along with an assessment of the acid sulfate soil (ASS) hazard.

Preliminary design drawings indicate that the proposed development will comprise retirement units in two 5-storey buildings, with a separate single storey communal indoor area, swimming pool and at-grade carparking (including under the multi-level buildings). We are advised that the maximum column loads for the 5-storey buildings are expected to be in the order of 3500 kN to 4000 kN (working).

The subsurface conditions encountered in the boreholes were relatively consistent across the site. In summary the subsurface conditions encountered comprised:

- **Topsoil** – mostly loose to medium dense, silty sand from the ground surface to depths of about 0.2 m BGL;
- **Level 1 Controlled Fill** – encountered under the topsoil in boreholes BH6, BH7 and BH8 to the north, comprising very stiff to hard, sandy clay and medium dense to dense, clayey sand to depths of between 0.4 m and 0.8 m BGL; then (or underlying the topsoil in the other boreholes)
- **Natural Residual Soils** – comprising very stiff to hard, sandy clays of mostly high plasticity. The residual soils tended to very low strength sandstone from about 7.6 m BGL in borehole BH8.

Combining our assessment of the existing subsurface conditions along with laboratory test results, we estimate potential surface movements in the order of about 40 mm to 60 mm. Consequently, the site is designated **Class H1** as defined in AS2870. Due to the reactive nature of the clays across this site, planting of trees requires careful consideration near buildings.

Due to the approximate level nature of the site, bulk earthworks are expected to be minimal and should adopt conventional practices. Topsoil stripping depths are estimated to be about 200 mm on average. Excavations for the proposed communal pool up to about 2 m BGL should be achievable using toothed buckets. To minimise potential for reactive soil movements, fill across building and pavement areas should comprise imported low reactivity material such as non-descript crushed rock or more select, higher CBR-rated materials.

Strip/pad footings to support the 5-storey building walls/columns could be founded in the very stiff natural clays at about 1 m BGL and designed using an allowable bearing pressure (ABP) of 300 kPa, with resultant settlements not exceeding 25 mm. Groundwater seepage was encountered at about 3.5 m BGL, however we anticipate that there would be a low risk of seepage affecting strip/pad footing excavations say to about 1 m BGL. Nevertheless, it would be prudent to allow for placement of blinding concrete across footing excavation bases to provide protection from softening by rainfall and/or groundwater seepage.

For the communal open space structure, a slab on ground proportioned for Class H1 could be adopted with slab beams founded in stiff (or stiffer) and/or medium dense (or denser) soils (natural or Level 1 controlled fill) and designed using an ABP of 100 kPa.

Based upon the results of laboratory testing, it is recommended that design of pavements should be based upon a CBR value of 3% subject to over-excavation and replacement of the subgrade to at least 300 mm depth using compacted, select granular fill.

Based on published ASS hazard and geology mapping the proposed development would have a negligible risk of encountering ASS or affecting groundwater conditions which may impact ASS prone areas. The proposed development may therefore proceed without need for any further specific ASS management measures.

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Borehole Reports and Explanatory Notes

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Previous (2021) Tectonic Borehole Reports, Explanatory Notes and Laboratory Test Certificates

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Limitations

1.0 INTRODUCTION

This report details the results of a geotechnical investigation undertaken for the proposed vertical retirement village on Lot 8002 at Baringa Drive, Baringa. The investigation was performed by Tectonic for Plantation Baringa Pty Ltd in accordance with Proposal P23633-Rev0 dated 13 October 2023.

The scope of work included a desk study of available geotechnical information for the site, drilling of boreholes at eight locations and laboratory testing of soil samples. This report summarises the results of the investigation and includes recommendations regarding earthworks, footings and pavements, along with an assessment of the acid sulfate soil (ASS) hazard.

2.0 REFERENCED PREVIOUS GEOTECHNICAL DOCUMENTS

Previous geotechnical documents referenced as part of this report comprise:

1. Report for a proposed townhouse development undertaken for Stockland Pty Ltd.
 - Ref. 21219-001-Rev0, dated July 2021.
2. Report on earthworks supervision and testing of the bulk earthworks by Core Consultants (Core).
 - Ref. J000168-001-R-Rev0, dated February 2016.
3. Level 1 Report (AS3798) by Wagner Soil Testing (Wagner).
 - Ref. J15/69, Version 1, dated 2 February 2016.

Key information from these reports is summarised in Section 4.

3.0 DEVELOPMENT DETAILS

Preliminary design drawings prepared by O.G.E Group Architects were supplied to us (Ref. Project No. 23040, Rev P3, dated 06 October 2023) and indicate that the proposed development will comprise retirement units in two 5-storey buildings, with a separate single storey communal indoor area, swimming pool and at-grade carparking (including under the multi-level buildings). We are advised by the project structural engineers (Empire Engineering) that the maximum column loads for the 5-storey buildings are expected to be in the order of 3500 kN to 4000 kN (working). Localised excavations will be required for underground services, footings and pool construction, however, are not expected to extend beyond about 1 m to 2 m below ground level (BGL).



Text Figure 1: Extract from ground floor plan for the proposed development (courtesy of O.G.E, 2023)

4.0 BACKGROUND GEOTECHNICAL INFORMATION

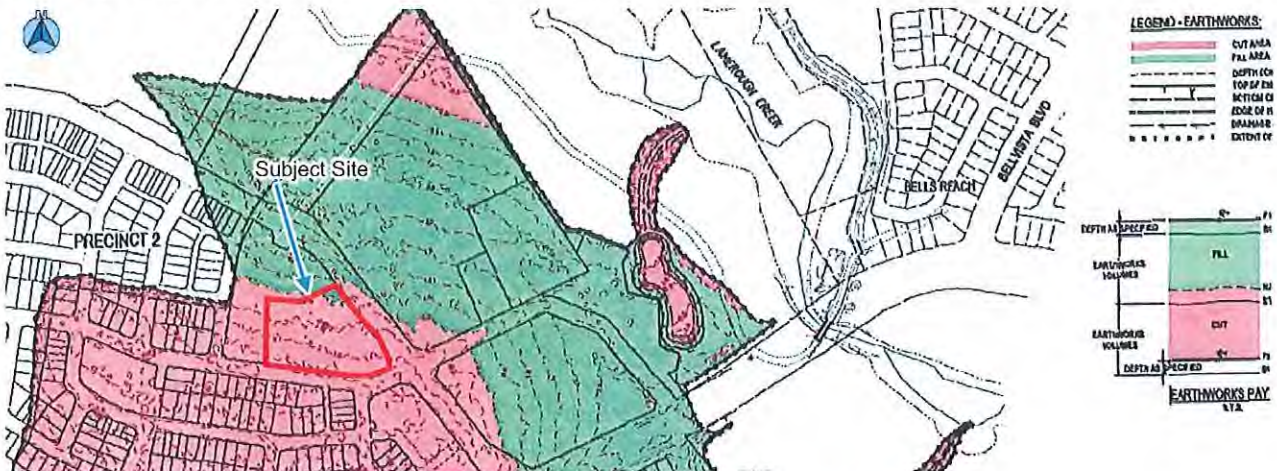
4.1 Previous Tectonic Investigation

Tectonic completed an investigation for a proposed townhouse development at the site in 2021. The investigation comprised the drilling of boreholes at ten locations to depths of 2.5 m BGL across the allotment. Ten Shrink-Swell Index (SSI) laboratory tests were also completed on undisturbed soil samples recovered from the boreholes for site classification purposes.

Reports of those boreholes and the laboratory results are presented in Appendix C. The previous borehole locations are shown in Figure 1 at the end of this report.

4.2 Geotechnical Works by Others

The Core and Wagner documents indicate that bulk earthworks in the area of the site were completed late 2015 to early 2016. It is understood that the filling was carried out in a controlled fashion with Level 1 certification of the filling, including supervision and compaction control testing, arranged by the civil contractor. As shown in Text Figure 2, bulk earthworks across the subject site mostly comprised cuts (pink shading), with filling to the north (green shading). The Core report indicated that the fill soils placed generally comprised of sandy clay / clayey sand sourced from excavation on site.



Text Figure 2: Extract from general earthworks layout plan (courtesy of Wagner, 2016)

5.0 SITE DESCRIPTION

The site is situated centrally within the suburb of Baringa with frontages to Baringa Drive to the east, Lukin Terrace to the south and Evans Lane to the west. The site was vacant, grassed and approximately level at the time of the investigation. Existing underground services were located to the fringes of the subject site, in the road reserves. Surrounding properties featured residential blocks along with a Goodstart Early Learning Centre (ELC) to the north, Baringa State Primary School and Baringa IGA to east and the Stockland Aura Display Village and Sales Centre to the south-east.

Text Figure 3 overleaf presents an aerial image of the site and the immediate surrounds, with the above noted features annotated.



Text Figure 3: November 2023 aerial image of the site and surrounds (courtesy of Nearmap)

Text Figures 4 and 5 below and overleaf illustrate site conditions at the time of the investigation.



Text Figure 4: View over site looking west



Text Figure 5: View of site looking south-east

6.0 METHOD OF INVESTIGATION

6.1 Fieldwork

The current subsurface investigation comprised the drilling of eight boreholes (designated BH1 to BH8). Borehole BH1 was drilled to 2.5 m BGL, six boreholes (BH2 to BH7) were drilled to 6 m BGL, and borehole BH8 was extended to 9 m BGL to target weathered rock. Boreholes were drilled using a mini-compact crawler rig utilising solid flight auger methods.

To enable an assessment of *in situ* soil strength, standard penetration tests (SPTs) were conducted at 1.5 m depth intervals in the 6 m deep boreholes and DCP testing was conducted adjacent to and within each of the other boreholes to depths of up to 2 m BGL. Where cohesive material was encountered during drilling pocket penetrometer (PP) testing was also completed on relatively un disturbed auger cuttings.

Reports of the current investigation boreholes, along with explanatory notes, are presented in Appendix A. Borehole locations are shown in Figure 1 at the end of this report.

6.2 Laboratory Testing

Soil samples were dispatched to a NATA accredited laboratory for geotechnical testing. Laboratory testing was undertaken in accordance with Australian Standard AS1289 *Method for Testing Soils for Engineering Purposes* and comprised two particle size distribution and Atterberg limits tests for soil characterisation purposes; and two single point CBR tests (with standard compactions) to check subgrade strength for pavement design. Laboratory test results are presented in Section 7.3 and reports are given in Appendix B.

7.0 INVESTIGATION FINDINGS

7.1 Regional Geology

The 1:100,000 scale Caloundra Surface Geology Map indicates that the site is underlain by strata of the late Triassic to Jurassic age Landsborough Sandstone formation, described as “*quartzose sandstone, feldspathic labile lithofeldspathic labile and quartzose sandstone, siltstone, shale, minor coal [with a] ferruginous oolite marker*”.

7.2 Subsurface Conditions

The subsurface conditions encountered in the boreholes drilled as part of the current investigation were relatively consistent across the site. In summary the subsurface conditions encountered comprised:

- **Topsoil** – mostly loose to medium dense, silty sand from the ground surface to depths of about 0.2 m BGL;
- **Level 1 Controlled Fill** – encountered under the topsoil in boreholes BH6, BH7 and BH8 to the north, comprising very stiff to hard, sandy clay and medium dense to dense, clayey sand to depths of between 0.4 m and 0.8 m BGL; then (or underlying the topsoil in the other boreholes)
- **Natural Residual Soils** – comprising very stiff to hard, sandy clays of mostly high plasticity. The residual soils tended to very low strength sandstone from about 7.6 m BGL in borehole BH8.

Having been supervised and tested on a Level 1 basis, the fill across the site may be classified as ‘controlled’ in accordance with the definitions given in AS 2870-2011 *Residential Slabs and Footings*.

Slight groundwater seepage was encountered at about 3.5 m BGL in all boreholes that extended past this depth. It should be noted that groundwater seepage may develop at shallower depths following periods of heavy or prolonged rainfall.

For detailed descriptions of the soil encountered in the current investigation boreholes refer to the reports and explanatory notes attached in Appendix A.

Subsurface conditions encountered during the current investigation strongly correspond with those found in the 2021 investigation boreholes.

7.3 Geotechnical Laboratory Test Results

Laboratory results from the current investigation are summarised in Tables 1 and 2 below and overleaf. Laboratory test certificates are presented in Appendix B.

Table 1: Summary of Atterberg Limits and PSD Laboratory Testing

BH No.	Depth (m)	Atterberg Limits			Particle Size Distribution		
		Liquid Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Fines Content * (%)	Sand Content ** (%)	Coarse Fraction *** (%)
BH1	0.3 – 0.5	80	56	20.5	71	29	0
BH8	1.7 – 2.0	79	58	18.5	65	34	1

Note: * Fines Content is the percentage of clay/silt fraction in the soil sample
 ** Sand Content taken as % retained on 0.075 mm sieve less % passing 2.36 mm
 *** Coarse Fraction taken as % retained on ≥ 2.36 mm sieves.

Results of laboratory testing conducted on the samples from boreholes BH1 and BH8 indicated that the materials tested were sandy clays of high plasticity, and have a high potential for reactivity subject to ‘normal’ seasonal soil moisture variations.

We note that soil samples tested as part of the 2021 investigation returned SSI values ranging from 0.5% to 6.5%, which indicated up to a high potential for soil reactivity. SSI values for the corresponding boreholes are indicated in Figure 1.

Laboratory testing conducted on sandy clay subgrade samples from boreholes BH1 and BH5 indicated CBR values of 2%, with high swell readings (measured in the mould after soaking).

8.0 ENGINEERING ASSESSMENT

8.1 Earthworks

Due to the approximate level nature of the site, bulk earthworks are expected to be minimal. Excavations will be required for underground services, footings and the communal pool, however are not expected to extend beyond about 1 m to 2 m BGL. Minor filling may be required to achieve design pad levels for buildings and pavements.

8.1.1 Site Preparation and Trafficability

Prior to construction, organic rich topsoil and any water softened materials (e.g. if ponded water collects on the surface) must be stripped and removed from the construction area. Topsoil stripping depths are estimated to be about 200 mm on average, based on the boreholes. Following stripping, the subgrade should be proof rolled and visually assessed by a civil or geotechnical RPEQ to ensure no heaving or unacceptable subgrade deflection occurs. Any identified 'soft spots' should be excavated and replaced with compacted select fill.

The existing controlled fill and natural soil would provide good trafficability for most construction plant. Placement of a working platform (e.g. 75 mm to 150 mm rock fill) nominally 150 mm thick may be required on heavily trafficked areas (e.g. site entry/driveway and laydown areas) and if construction is to occur during or after heavy or prolonged rainfall. Specific design would need to be carried out to determine working platform requirements for any heavy plant (e.g. mobile cranes or piling rigs).

The site should be graded to shed surface water runoff away from construction areas. Swale drains should be graded to discharge into a control point before release off-site.

8.1.2 Excavations and Batter Slopes

Excavations are expected to range up to 2 m BGL for underground services, footings and pool construction. Excavations to such depths should be achievable using excavators with toothed bucket attachments.

Excavations up to 2 m BGL may encounter groundwater seepage, but such seepage should be relatively slow from the mostly clayey soils. In such instances, groundwater could be managed by grading the base of trench excavations to a low point (sump) for collection and pumping out.

Unsurcharged batters may be temporarily formed no steeper than 1V:1H. Flatter temporary profiles will be required if groundwater seepage is encountered, or if batters are not protected from stormwater. Exposure of temporary batters should be minimised in order to limit potential development of instability.

Permanent batters in controlled fill materials (Ref. Section 8.1.3 for specifications) and stiff (or stiffer) natural soils should not exceed 1V:2H. Permanent batters must be protected from erosion by revegetation and/or surface treatment.

Any excavations which may be required adjacent to existing structures will need to be specifically designed to ensure that the structures are not undermined.

The above recommendations do not supersede any existing safety regulations or legislation applicable to excavations (e.g. limits on personnel entry into trenches).

8.1.3 Filling

Excluding topsoil and any over-wet soils, the existing fill and natural materials are expected to be suitable for re-use as trench backfill, subject to appropriate moisture treatment during handling and compaction. To minimise potential for reactive soil movements, fill across building and pavement areas should comprise imported low reactivity material such as non-descript crushed rock or more select, higher CBR-rated materials. It is recommended that such structural fill should comply with the following:

- Minimum CBR of 10%
- Maximum plasticity index of 15%
- Shrink-swell index $\leq 1\%$
- Maximum particle size of 100 mm

All structural fill should be compacted at moisture contents within the range of $\pm 2\%$ of OMC for Standard Compaction. Fill should be placed in 250 mm thick (loose thickness) layers and be compacted by repeated rolling to achieve a dry density ratio of at least 98% of the maximum Dry Density Ratio (DDR), or 100% DDR within 0.3 m depth of pavement subgrades, based upon the Standard Compaction method.

Confirmatory compaction testing must be carried out at regular intervals. A minimum of two tests per vertical lift is recommended where structural fill heights are to exceed 300 mm. Further details for control and testing of fill are given in Australian Standard AS 3798-2007 *Guidelines on Earthworks for Commercial and Residential Developments*. It is recommended that Level 1 geotechnical inspection and testing of any further structural filling is carried out as specified in AS3798.

8.2 Building Foundations

8.2.1 Site Classification

Site classification for residential footing design is undertaken in accordance with Section 2 of AS2870. Clause 2.5.3 (a) (ii) of AS2870 states that *"the classification of a site with controlled sand fill deeper than 0.8 m shall be the same as the natural site prior to filling. However, the presence of the sand may be used to justify by engineering principles a less severe reactive site classification. The effect of the fill on the settlement of the underlying soil shall be taken into account"*.

We have undertaken an engineering assessment of available data to classify the site area. From a geotechnical engineering viewpoint, the primary considerations for classification are:

- Confirmation that the fill is controlled and of sufficient strength to provide an allowable bearing pressure (ABP) of at least 100 kPa at founding level (i.e. close to finished surface level).
- Determination of potential characteristic surface movement (y_s) due to shrink-swell of the foundation soils caused by 'normal' seasonal moisture variations down to the depth of design soil suction change ($H_s = 1.5$ m for Baringa).
- Long-term potential settlement of the controlled fill under the future building loads.
- Long-term potential settlement of the deeper natural soil profile generated by load from the controlled fill and future building loads.

In relation to each of the above items, we comment as follows:

- Level 1 documentation prepared by Core and Wagner indicates that the existing fill across the site was placed under Level 1 inspection and testing. *In situ* strength testing indicates that the existing fill materials (predominantly sand) are of sufficient strength to provide an ABP of at least 100 kPa at founding level (i.e. close to finished surface level).
- The natural clay materials across the site were typically of high plasticity and we have calculated y_s of between about 40 mm and 60 mm (equivalent to Class H1¹).
- Settlements due to consolidation of deeper natural soils are not expected to exceed 10 mm.

¹ From AS2870, Class S (0 mm < $y_s \leq 20$ mm), Class M (20 mm < $y_s \leq 40$ mm), Class H1 (40 mm < $y_s \leq 60$ mm), Class H2 (60 mm < $y_s \leq 75$ mm), Class E ($y_s > 75$ mm)

Combining our assessment of each of the above factors, along with results from laboratory testing, we estimate potential surface movements in the order of about 40 mm to 60 mm. Consequently, the site is designated to be **Class H1** as defined in AS2870. This is subject to the following:

It should be noted that the predicted order of movement is based on the existing soil profile (i.e. no cutting or filling), and moisture content changes within soils due to normal seasonal moisture variations only. Reactive soil movements and the site classification may be impacted if additional filling is undertaken.

Design for any proposed deep landscaping must consider the effects this may have on foundation moisture variations. Irrigation of deep landscaping may cause abnormal moisture conditions to develop after construction, which would consequently increase the probability of damage to the buildings. Potential risks from deep landscaping for the development include:

- The effect of trees too close to the building footings.
- Excessive or irregular watering of gardens adjacent to the buildings.
- Failure to maintain site drainage.

Due to the reactive nature of the clays across this site, planting of trees should be avoided near the foundations of the buildings as they can cause damage by drying of the clay at substantial distances. To reduce, but not eliminate, the possibility of damage, tree planting should be restricted to a distance from the buildings as follows (as per AS2870-2011):

- 1 x the mature height of the tree.
- Where rows or groups of trees are involved, the distance from the buildings should be increased.

Installation of tree root barriers adjacent to the edges of the buildings could be considered. For a root barrier to be effective, it would need to be installed to a minimum depth of 1.5 m BGL. Such a root barrier could comprise HDPE installed within a narrow trench dug using a 'ditch witch' or similar.

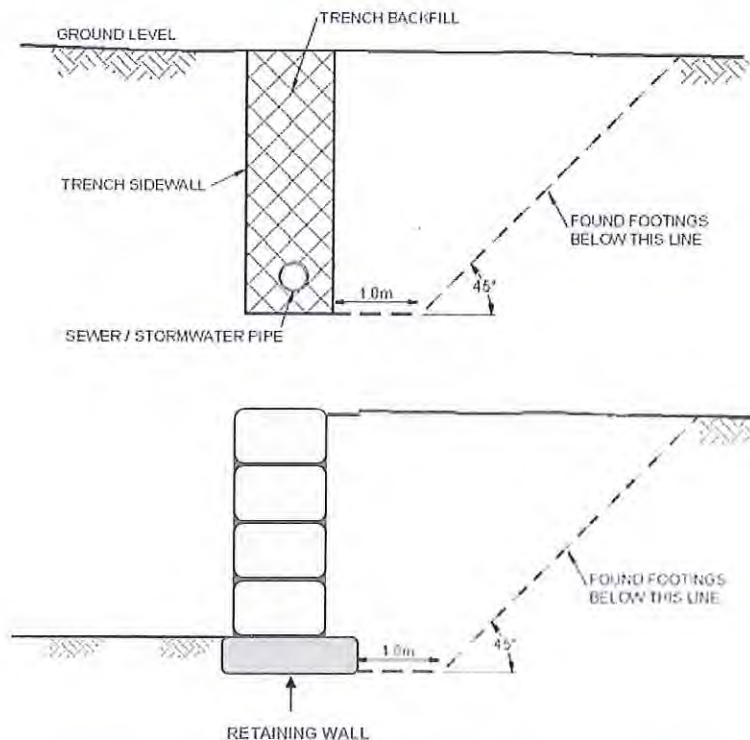
Furthermore, installation of subsurface drainage (e.g. 'aggi' pipe or 'Megaflo' type strip drainage) would be recommended across the bases of any deep landscaping areas. Any water captured by subsurface drainage would need to be piped into a controlled point of release (i.e. existing stormwater infrastructure in surrounding streets).

8.2.2 Footing Design

Strip/pad footings to support the 5-storey building walls/columns could be founded in the very stiff natural clays at about 1 m BGL and designed using an ABP of 300 kPa, with resultant settlements not exceeding 25 mm. Groundwater seepage was encountered in the boreholes at about 3.5 m BGL, however we anticipate that there would be a low risk of seepage affecting strip/pad footing excavations say to about 1 m BGL. Nevertheless, it would be prudent to allow for placement of blinding concrete across footing excavation bases to provide protection from softening by rainfall and/or groundwater seepage.

For the communal open space structure, a slab on ground proportioned for Class H1 could be adopted with slab beams founded in stiff (or stiffer) and/or medium dense (or denser) soils (natural or Level 1 controlled fill) and designed using an ABP of 100 kPa.

All footings should be founded such that they are not adversely affected by any adjacent excavations, trenches, or retaining walls that are not designed to support building loads. To minimise the potential for any adverse interaction effects, footings should be founded at least below a plane extending 1 m horizontally from the base of trenches/excavations/retaining walls, then rising up at 1V:1H. This requirement is illustrated in Text Figure 6 overleaf.



Text Figure 6: Footing depth required to minimise risk of undermining

Site drainage should be designed to readily remove surface water and to prevent ponding of water on subgrade areas during construction and also adjacent to foundations and perimeter slabs once construction is completed.

If any soil conditions encountered during construction are found to differ from those noted in the geotechnical investigation, Tectonic should be notified immediately and an inspection carried out to determine if changes to footing design are required.

For the proposed communal building in particular, your attention is drawn to further information regarding foundation maintenance and footing performance attached in Appendix D, the CSIRO document *Foundation Maintenance and Footing Performance: A Homeowner's Guide*.

8.3 Retaining Structures

Design for temporary and permanent retaining structures could be carried out using a pressure distribution applicable to the wall type and based on the parameters listed in Table 2. The values in Table 2 assume that the walls are fully drained, and no allowance is included for hydrostatic pressures, construction loading, up-slope footing loadings or the effects of sloping ground and backfill compaction stresses. Retaining structures should be engineer designed in accordance with AS4678-2002 *Earth-retaining structures*.

Table 2: Retaining Structure Design Parameters

Retained material	Unit weight (kN/m ³)	Friction angle (Degrees)	Lateral earth pressure coefficients		
			K _a (Cantilever wall)	K _o (Non-yielding wall)	K _p
Stiff (or Stiffer) Clays (Controlled Fill & Natural)	19	27	0.38	0.55	2.66

8.4 Pavements

CBR testing of natural clays from the likely subgrades returned CBR values of 2%. It is suggested that a CBR value of 3% could be adopted for design subject to over-excavation and replacement of the subgrade to at least 300 mm depth using compacted, select granular fill.

Proposed pavement subgrades must be 'proof rolled' and visually assessed by an experienced RPEQ to ensure no heaving or unacceptable subgrade deflection occurs. Should heaving or deflection occur, excavation of 'soft spots' may be required, followed by reinstatement with compacted select granular fill.

The suggested CBR value would apply to properly drained subgrades only, and must be confirmed by subgrade inspection and testing, if necessary, by an experienced RPEQ following earthworks. 'Properly drained subgrades' require open graded drains, site grades that shed water and prevent ponding, and subsurface drains adjacent to pavements.

8.5 Permanent Drainage

Adequate site drainage must be installed to ensure that stormwater runoff is directed away from building walls/footings and pavement areas.

Subsurface drainage must be installed behind any retaining walls (e.g. slotted 'aggi' pipe wrapped in filter 'sock' placed in gravel backfill). Depending on matters such as the extent of drainage installed and site-specific groundwater conditions, the designer must make an assessment of hydrostatic pressure to be accounted for in the design of the retaining structure.

All excess stormwater collected around the site (including overflow from rainwater tanks) should be directed by pipes / channels / swales into existing stormwater infrastructure in the surrounding road reserves. On-site infiltration of stormwater is not recommended due to the highly reactive nature of the clays, and the potential for adverse effects on the performance of buildings and pavements.

9.0 ACID SULFATE SOIL HAZARD ASSESSMENT

9.1 Information on Acid Sulfate Soil

ASS is common in low-lying coastal areas of Queensland, typically in Holocene to Pleistocene age alluvial sediments located below RL 5 m AHD. Such areas are often characterised by the presence of estuaries, swamps, floodplains, salt marshes and mangroves, primarily occurring in estuarine based alluvial soil.

ASS affected soils contain iron sulfides, most frequently pyrite, which, when exposed to air can oxidise to form sulfuric acid. Existing acidity attributed to the historic oxidation of iron sulfides may also be present because of previous exposure of ASS material either by human interference or by natural processes.

When these soils are maintained in their natural setting (generally anaerobic conditions below the groundwater table or sea level), the iron sulfides are unable to oxidise, therefore the ASS remains in a stable state, and in equilibrium with the surrounding environment. However, where disturbances such as civil construction or development expose ASS to aerobic conditions, the iron sulfides are able to oxidise and form sulfuric acid, resulting in the soil becoming acidic. The resulting creation of large volumes of acidity can occur rapidly, resulting in significant impacts to local waterways, sensitive terrestrial environments, or in extreme cases, public health.

9.2 Regional Acid Sulfate Soil Mapping

The Queensland Government's Maroochy-Caloundra ASS Map 2 (NR&M-SEA-I-A0 3331) indicates that the site is located well above the outer limit of Holocene/estuarine ASS (i.e. above RL 5 m AHD). The site is therefore characterised as ***"land with a low probability of acid sulfate soil occurrence"***.

9.3 Application to SCC Regulation

Development involving ASS must comply with the requirements of state and local regulations pertaining to ASS. Locally, SCC has developed the ASS Overlay Code, and its attendant guidelines, as part of the Sunshine Coast Planning Scheme (2014).

The purpose of the ASS overlay code is to ensure that the generation or release of acid and metal contaminants from disturbance of ASS does not have adverse effects on the natural environment, built environment, infrastructure or human health. This is achieved through compliance with the following development performance outcomes:

- a) *development ensures that the release of acid and associated metal contaminants into the environment is avoided by either:*
 - i. *not disturbing ASS when excavating or otherwise removing soil or sediment, extracting groundwater or filling land; or*
 - ii. *treating and, if required, undertaking ongoing management of any disturbed ASS and associated drainage waters.*

Although the site is located within ASS Overlay Code Area 2, this being defined as land located between RL 5 m and RL 20 m AHD, the proposed works will not involve disturbance of soil or groundwater at or below RL 5 m AHD and therefore do not have potential to disturb ASS. This is because the existing ground surface level is at about RL 8 m AHD and excavations up to about 2 m BGL are proposed. The proposed development is therefore deemed to meet performance outcome PO1 of the SCC's ASS Overlay Code (i.e. development does not disturb ASS).

9.4 ASS Outcome

Proposed earthworks associated with the vertical retirement village would have a negligible risk of encountering ASS or affecting groundwater conditions which may impact ASS prone areas. The proposed development may therefore proceed without need for any further specific ASS management measures. No further site assessment regarding ASS is warranted for the proposed development.

10.0 LIMITATIONS

Your attention is drawn to the document *Limitations*, which is included in Appendix E of this report. The statements presented in this document are intended to advise you of what your realistic expectations of this report should be, and to present you with recommendations on how to minimise the risks associated with the services provided by Tectonic for this project.



Notes:
Aerial Imagery courtesy of NearMap (30 November 2023)

tectonic
geotechnical & environmental engineers

Tectonic Geotechnical Pty Ltd
PO Box 899
Buderim Qld 4556
Office: 07 5478 9016
Email: admin@tectonico.com.au

PROJECT:

GEOTECHNICAL INVESTIGATION
VERTICAL RETIREMENT VILLAGE
LOT 8002, BARINGA DRIVE,
BARINGA

TITLE:

SITE PLAN

CLIENT:

PLANTATION BARINGA PTY LTD

DRAWN:

MS DATE: 06/12/2023

CHECKED:

ACD DATE: 06/12/2023

SCALE:

AS SHOWN

LEGEND:



Approx. 2023 Borehole
Locations



Approx. 2021 Borehole
Locations (renamed P-BH,
denoting previous borehole)
SSI = Shrink-Swell Index Value

PROJECT NO.:

23387-001

FIGURE:

1

REV:

0

APPENDIX A

Borehole Reports and Explanatory Notes

Engineering Log - Borehole

Project No.: 23387

Client: Plantation Baringa Pty Ltd		Commenced: 5/12/2023	
Project Name: Vertical Retirement Village		Completed: 5/12/2023	
Hole Location: Lot 8002 Baringa Drive, Barings		Logged By: BC	
Hole Position: 508029.5 m E 7034706.7 m N MGA2020 Zone 56		Checked By: ACD	

Drill Model and Mounting: Compac 018	Inclination: -90°	RL Surface: 8.00 m
Hole Diameter: 100 mm	Bearing: 360°	Datum: AHD Operator: Pacific Geotech

Drilling Information				Material Description and Observations									
Method	Penetration	Water	Samples Tests Remarks	Recovery	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description soil type; plasticity or particle characteristics, secondary and minor components, colour	Moisture Condition	Consistency Relative Density	Pocket Penetrometer UCS (kPa)	DCP TEST Blows per 100 mm
AD/T		Not Encountered	BDS 0.3-0.5m		7.0	1		CH	Silty SAND, (TOPSOIL), fine to medium grained, grey, with organics Sandy CLAY, high plasticity, red brown mottled pale grey, fine to coarse grained sand, (RESIDUAL) with fine to medium grained subangular gravel	L to MD	VSt to H	450 X 350 X	
						2			becoming pale grey mottled red brown				
					5.0	3			Hole Terminated at 2.50 m Target depth				
					4.0	4							
					3.0	5							
					2.0	6							
					1.0	7							
					0.0	8							
					-1.0	9							

Method AD/T - Auger Drilling TC Bit AD/V - Auger Drilling V Bit RT - Rotary Tri-cone Bit RD - Rotary Drilling NMLC - Rock Core HA - Hand Auger	Penetration VE - Very Easy E - Easy F - Firm H - Hard VH - Very hard	Water Level (Date) Inflow Partial Loss Complete Loss	Samples and Tests U## - Undisturbed Sample (## mm) DS - Disturbed Sample BDS - Bulk Disturbed Sample SPT - Standard Penetration Test	Moisture Condition D - Dry M - Moist W - Wet	Consistency/Relative Density VS - Very Soft S - Soft F - Firm VSt - Very Stiff H - Hard VL - Very Loose L - Loose MD - Medium Dense D - Dense VD - Very Dense Fr - Friable
Graphic Log/Core Loss Core recovered (hatching indicates material) Core loss	Classification Symbols and Soil Descriptions Based on Unified Soil Classification System	Plastic Limit < PL = PL > PL			

Engineering Log - Borehole

Project No.: 23387

Client: Plantation Baringa Pty Ltd				Commenced: 5/12/2023			
Project Name: Vertical Retirement Village				Completed: 5/12/2023			
Hole Location: Lot 8002 Baringa Drive, Barings				Logged By: BC			
Hole Position: 508075.0 m E 7034699.6 m N MGA2020 Zone 56				Checked By: ACD			
Drill Model and Mounting: Compac 018		Inclination: -90°		RL Surface: 8.00 m			
Hole Diameter: 100 mm		Bearing: 360°		Datum: AHD		Operator: Pacific Geotech	

Drilling Information				Material Description and Observations																												
Method	Penetration	Samples Tests Remarks	Recovery	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description soil type; plasticity or particle characteristics, secondary and minor components, colour	Moisture Condition	Consistency Relative Density	Pocket Penetrometer UCS (kPa)	DCP TEST Blows per 100 mm																				
											100	200	300	400	500	0	5	10	15	20	25											
AD/T	Slight seepage @ 3.5m	SPT 2,5,6 N=11		7.0	1		CH	Silty SAND, (TOPSOIL), fine to medium grained, grey, with organics	M	MD	460																					
				6.0	2			Sandy CLAY, high plasticity, red brown mottled pale grey, fine to coarse grained sand, trace fine to medium sized subrounded gravel, (RESIDUAL)					VSt to H	330	420																	
				5.0	3			with fine to medium sized subangular gravel								M	260	360														
				4.0	4			becoming pale grey mottled red brown, trace fine to medium sized subangular gravel											VSt	230	230											
				3.0	5			becoming red brown mottled pale grey														M to M	220	230								
				2.0	6			Hole Terminated at 6.00 m Target depth																								
				2.0	6																											
				1.0	7																											
				0.0	8																											
				-1.0	9																											

Method AD/T - Auger Drilling TC Bit AD/M - Auger Drilling V Bit RT - Rotary Tri-cone Bit RD - Rotary Drilling NMLC - Rock Core HA - Hand Auger	Penetration VE - Very Easy E - Easy F - Firm H - Hard VH - Very hard	Water Level (Date) Inflow Partial Loss Complete Loss	Samples and Tests U## - Undisturbed Sample (## mm) DS - Disturbed Sample BDS - Bulk Disturbed Sample SPT - Standard Penetration Test	Moisture Condition D - Dry M - Moist W - Wet Plastic Limit < PL = PL > PL	Consistency/Relative Density VS - Very Soft S - Soft F - Firm VSt - Very Stiff H - Hard VL - Very Loose L - Loose MD - Medium Dense D - Dense VD - Very Dense Fr - Friable
Graphic Log/Core Loss Core recovered (hatching indicates material) Core loss					
Classification Symbols and Soil Descriptions Based on Unified Soil Classification System					

Engineering Log - Borehole

Project No.: 23387

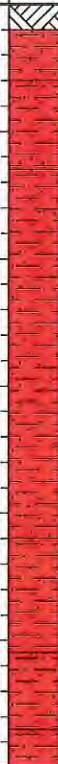
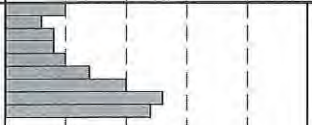
Client: Plantation Baringa Pty Ltd
Project Name: Vertical Retirement Village
Hole Location: Lot 8002 Baringa Drive, Barings
Hole Position: 508133.8 m E 7034699.1 m N MGA2020 Zone 56

Commenced: 5/12/2023
Completed: 5/12/2023
Logged By: BC
Checked By: ACD

Drill Model and Mounting: Compac 018
Hole Diameter:

Inclination: -90°
Bearing: 360°

RL Surface: 8.00 m
Datum: AHD Operator: Pacific Geotech

Drilling Information						Material Description and Observations												
Method	Penetration	Water	Samples Tests Remarks	Recovery	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description soil type: plasticity or particle characteristics, secondary and minor components, colour	Moisture Condition	Consistency	Relative Density	Pocket Penetrometer UCS (kPa)	DCP TEST Blows per 100 mm				
AD/T		Slight seepage @ 3.5m 	SPT 4,6,7 N=13		7.0	1		CH	Silty SAND, (TOPSOIL), fine to medium grained, grey, with organics	M	VSt to H		500 500 500					
								Sandy CLAY, high plasticity, orange pale grey, fine to coarse grained sand, trace fine to medium sized subrounded gravel, (RESIDUAL)										
								becoming pale grey mottled red brown, without gravel										
								2			trace fine to medium sized subangular gravel							
								3										
								4			extremely weathered seams, becoming red brown mottled pale grey, with fine to medium sized subangular gravel							
								5			becoming red brown mottled pale grey	M to W	VSt					
								6			tending to extremely weathered material, becoming orange red		H					
								7			Hole Terminated at 6.00 m Target depth							
								8										
					9													

Method	Penetration	Water	Samples and Tests	Moisture Condition	Consistency/Relative Density
AD/T- Auger Drilling TC Bit AD/V- Auger Drilling V Bit RT - Rotary Tri-cone Bit RD - Rotary Drilling NMLC - Rock Core HA - Hand Auger	 VE - Very Easy E - Easy F - Firm H - Hard VH - Very hard	 Level (Date)  Inflow  Partial Loss  Complete Loss	U## - Undisturbed Sample (## mm) DS - Disturbed Sample BDS- Bulk Disturbed Sample SPT - Standard Penetration Test	D - Dry M - Moist W - Wet	VS - Very Soft S - Soft F - Firm VSt - Very Stiff H - Hard VL - Very Loose L - Loose MD - Medium Dense D - Dense VD - Very Dense Fr - Friable
Graphic Log/Core Loss  Core recovered (hatching indicates material)  Core loss			Classification Symbols and Soil Descriptions Based on Unified Soil Classification System		
			Plastic Limit < PL = PL < PL		

TECTONIC 3.0.0.2 LIB G.L.B. Log 1 TECTONIC BOREHOLE 23387.GPJ <<DrawingFile>> 12/1/2024 11:18 10.02.00.04 Batgel Lib and In Site Tool - DGD Lib: Tectonic 3.0.2 2021-03-30 P.J.: Tectonic 3.0.2 2021-03-30

Method

AD/T - Auger Drilling TC Bit
AD/V - Auger Drilling V Bit
RT - Rotary Tri-cone Bit
RD - Rotary Drilling
NMLC - Rock Core
HA - Hand Auger

Penetration

VE - Very Easy
E - Easy
F - Firm
H - Hard
VH - Very hard

Water

Level (Date)
Inflow
Partial Loss
Complete Loss

Graphic Log/Core Loss

Core recovered (hatching indicates material)
Core loss

Samples and Tests

U## - Undisturbed Sample (## mm)
DS - Disturbed Sample
BDS - Bulk Disturbed Sample
SPT - Standard Penetration Test

Moisture Condition

D - Dry
M - Moist
W - Wet

Consistency/Relative Density

VS - Very Soft
S - Soft
F - Firm
VSt - Very Stiff
H - Hard
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense
Fr - Friable

Classification Symbols and

Soil Descriptions

Based on Unified Soil Classification System

Plastic Limit

< PL
= PL
< PL

Engineering Log - Borehole

Project No.: 23387

Client: Plantation Baringa Pty Ltd		Commenced: 5/12/2023	
Project Name: Vertical Retirement Village		Completed: 5/12/2023	
Hole Location: Lot 8002 Baringa Drive, Barings		Logged By: BC	
Hole Position: 508104.1 m E 7034716.4 m N MGA2020 Zone 56		Checked By: ACD	

Drill Model and Mounting: Compac 018	Inclination: -90°	RL Surface: 8.00 m
Hole Diameter: 100 mm	Bearing: 360°	Datum: AHD Operator: Pacific Geotech

Drilling Information				Material Description and Observations													
Method	Penetration	Water	Samples Tests Remarks	Recovery	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description soil type; plasticity or particle characteristics, secondary and minor components, colour	Moisture Condition	Consistency Relative Density	Pocket Penetrometer UCS (kPa)	DCP TEST Blows per 100 mm				
AD/T	Slight seepage @ 3.5m		SPT 4,5,6 N=11		7.0	1		CH	Silty SAND, (TOPSOIL), fine to medium grained, grey, with organics	L to MD		100	0				
					6.0	2			Sandy CLAY, high plasticity, orange red brown, fine to coarse grained sand, trace fine to medium sized subrounded gravel, (RESIDUAL)				200	5			
					5.0	3			becoming pale grey mottled red brown, trace fine to medium sized subangular gravel	M	VSt to H	300	10				
					4.0	4			extremely weathered seams	M to W	VSt	400	15				
					3.0	5						500	20				
					2.0	6			Hole Terminated at 6.00 m Target depth					500	25		
			SPT 4,7,8 N=15		6.0												
			SPT 4,5,7 N=12		5.0												
			SPT 7,7,10 N=17		4.0												
					3.0												
					2.0												
					1.0												
					0.0												
					-1.0												

Method AD/T - Auger Drilling TC Bit AD/V - Auger Drilling V Bit RT - Rotary Tri-cone Bit RD - Rotary Drilling NMLC - Rock Core HA - Hand Auger	Penetration VE - Very Easy E - Easy F - Firm H - Hard VH - Very hard Graphic Log/Core Loss Core recovered (hatching indicates material) Core loss	Water Level (Date) Inflow Partial Loss Complete Loss	Samples and Tests U## - Undisturbed Sample (## mm) DS - Disturbed Sample BDS - Bulk Disturbed Sample SPT - Standard Penetration Test	Moisture Condition D - Dry M - Moist W - Wet Plastic Limit < PL = PL > PL	Consistency/Relative Density VS - Very Soft S - Soft F - Firm VSt - Very Stiff H - Hard VL - Very Loose L - Loose MD - Medium Dense D - Dense VD - Very Dense Fr - Friable
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Based on Unified Soil Classification System

Engineering Log - Borehole

Project No.: 23387

Client:	Plantation Baringa Pty Ltd	Commenced:	5/12/2023
Project Name:	Vertical Retirement Village	Completed:	5/12/2023
Hole Location:	Lot 8002 Baringa Drive, Barings	Logged By:	BC
Hole Position:	508068.4 m E 7034724.0 m N MGA2020 Zone 56	Checked By:	ACD

Drill Model and Mounting:	Compac 018	Inclination:	-90°	RL Surface:	8.00 m		
Hole Diameter:	100 mm	Bearing:	360°	Datum:	AHD	Operator:	Pacific Geotech

Drilling Information						Material Description and Observations																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
Method	Penetration	Water	Samples Tests Remarks	Recovery	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description soil type: plasticity or particle characteristics, secondary and minor components, colour	Moisture Condition	Consistency Relative Density	Pocket Penetrometer UCS (kPa)	DCP TEST Blows per 100 mm																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
AD/T		Slight seepage @ 3.5m	BDS 0.3-0.5m					CH	Silty SAND, (TOPSOIL), fine to medium grained, grey, with organics	M	L to MD																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													

Method AD/T - Auger Drilling TC Bit AD/V - Auger Drilling V Bit RT - Rotary Tri-cone Bit RD - Rotary Drilling NMLC - Rock Core HA - Hand Auger	Penetration VE - Very Easy E - Easy F - Firm H - Hard VH - Very hard	Water Level (Date) Inflow Partial Loss Complete Loss	Samples and Tests U## - Undisturbed Sample (## mm) DS - Disturbed Sample BDS - Bulk Disturbed Sample SPT - Standard Penetration Test	Moisture Condition D - Dry M - Moist W - Wet	Consistency/Relative Density VS - Very Soft S - Soft F - Firm VSt - Very Stiff H - Hard VL - Very Loose L - Loose MD - Medium Dense D - Dense VD - Very Dense Fr - Friable
Graphic Log/Core Loss Core recovered (hatching indicates material) Core loss	Classification Symbols and Soil Descriptions Based on Unified Soil Classification System	Plastic Limit < PL = PL > PL			

Engineering Log - Borehole

Project No.: 23387

Client: Plantation Baringa Pty Ltd		Commenced: 5/12/2023	
Project Name: Vertical Retirement Village		Completed: 5/12/2023	
Hole Location: Lot 8002 Baringa Drive, Barings		Logged By: BC	
Hole Position: 508023.1 m E 7034731.1 m N MGA2020 Zone 56		Checked By: ACD	
Drill Model and Mounting: Compac 018		Inclination: -90°	RL Surface: 8.00 m
Hole Diameter: 100 mm		Bearing: 360°	Datum: AHD Operator: Pacific Geotech

Drilling Information					Material Description and Observations								
Method	Penetration	Water	Samples Tests Remarks	Recovery	Depth (m)	Graphic Log	Classification Symbol	Material Description soil type; plasticity or particle characteristics, secondary and minor components, colour	Moisture Condition	Consistency Relative Density	Pocket Penetrometer UCS (kPa)	DCP TEST Blows per 100 mm	
AD/T	Slight seepage @ 3.5m	SPT 4,6,7 N=13	7.0	1	Silty SAND, (TOPSOIL), fine to medium grained, grey, with organics	CH	Sandy CLAY, (FILL), high plasticity, red brown, fine to coarse grained sand	D to VD	M	320 150	400	10 15 20 25	
													Sandy CLAY, high plasticity, red mottled pale grey, fine to coarse grained sand, trace fine to medium sized subangular gravel
													with fine to medium sized subangular gravel
													becoming pale grey mottled red brown, without gravel
													tending to extremely weathered material, becoming red brown mottled pale grey
													becoming red brown
		SPT 5,8,9 N=17	6.0	2									
		SPT 5,11,13 N=24	5.0	3									
		SPT 9,13,13 N=26	4.0	4									
			3.0	5									
			2.0	6									
			1.0	7									
			0.0	8									
			-1.0	9									
Hole Terminated at 6.00 m Target depth													

Method
AD/T - Auger Drilling TC Bit
AD/V - Auger Drilling V Bit
RT - Rotary Tri-cone Bit
RD - Rotary Drilling
NMLC - Rock Core
HA - Hand Auger

Penetration
VE - Very Easy
E - Easy
F - Firm
H - Hard
VH - Very hard

Water
Level (Date)
Inflow
Partial Loss
Complete Loss

Graphic Log/Core Loss
Core recovered (hatching)
Indicates material
Core loss

Samples and Tests
U## - Undisturbed Sample (## mm)
DS - Disturbed Sample
BDS - Bulk Disturbed Sample
SPT - Standard Penetration Test

Moisture Condition
D - Dry
M - Moist
W - Wet

Consistency/Relative Density
VS - Very Soft
S - Soft
F - Firm
VSt - Very Stiff
H - Hard
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense
Fr - Friable

Classification Symbols and Soil Descriptions
Based on Unified Soil Classification System

Plastic Limit
< PL
= PL
< PL

Engineering Log - Borehole

Project No.: 23387

Client:		Plantation Baringa Pty Ltd		Commenced:		5/12/2023												
Project Name:		Vertical Retirement Village		Completed:		5/12/2023												
Hole Location:		Lot 8002 Baringa Drive, Barings		Logged By:		BC												
Hole Position:		508050.1 m E 7034753.5 m N MGA2020 Zone 56		Checked By:		ACD												
Drill Model and Mounting:		Compac 018		Inclination:		-90°												
Hole Diameter:		100 mm		RL Surface:		8.00 m												
				Bearing:		360°												
				Datum:		AHD												
				Operator:		Pacific Geotech												
Drilling Information						Material Description and Observations												
Method	Penetration	Water	Samples Tests Remarks	Recovery	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description soil type: plasticity or particle characteristics, secondary and minor components, colour	Moisture Condition	Consistency Relative Density	Pocket Penetrometer UCS (kPa)	DCP TEST Blows per 100 mm					
AD/T		Slight seepage @ 3.5m	SPT 2,4,5 N=9		7.0	1		CH	Silty SAND, (TOPSOIL), fine to medium grained, grey, with organics	M	L MD to D VSt to H	450 380 420 280 350 200 370						
									Clayey SAND, (FILL), fine to coarse grained, orange									
									Sandy CLAY, high plasticity, red brown mottled pale grey, fine to coarse grained sand, trace fine to medium sized subangular gravel, (RESIDUAL)									
			SPT 4,7,11 N=18		6.0	2			becoming pale grey mottled red brown, without gravel									
			SPT 4,6,8 N=14		5.0	3			tending to extremely weathered material, becoming red brown mottled pale grey, with fine to medium sized subangular gravel									
			SPT 7,8,13 N=21		4.0	4												
					3.0	5												
					2.0	6			Hole Terminated at 6.00 m Target depth									
					1.0	7												
					0.0	8												
					-1.0	9												
Method AD/T - Auger Drilling TC Bit AD/V - Auger Drilling V Bit RT - Rotary Tri-cone Bit RD - Rotary Drilling NMLC - Rock Core HA - Hand Auger Penetration VE - Very Easy E - Easy F - Firm H - Hard VH - Very hard Water Level (Date) Inflow Partial Loss Complete Loss Samples and Tests U## - Undisturbed Sample (## mm) DS - Disturbed Sample BDS - Bulk Disturbed Sample SPT - Standard Penetration Test Moisture Condition D - Dry M - Moist W - Wet Consistency/Relative Density VS - Very Soft S - Soft F - Firm VSt - Very Stiff H - Hard VL - Very Loose L - Loose MD - Medium Dense D - Dense VD - Very Dense Fr - Friable Plastic Limit < PL = PL > PL Graphic Log/Core Loss Core recovered (hatching indicates material) Core loss Classification Symbols and Soil Descriptions Based on Unified Soil Classification System																		

Engineering Log - Borehole

Project No.: 23387

Client: Plantation Baringa Pty Ltd		Commenced: 5/12/2023	
Project Name: Vertical Retirement Village		Completed: 5/12/2023	
Hole Location: Lot 8002 Baringa Drive, Barings		Logged By: BC	
Hole Position: 508102.0 m E 7034740.8 m N MGA2020 Zone 56		Checked By: ACD	

Drill Model and Mounting: Compac 018	Inclination: -90°	RL Surface: 8.00 m
Hole Diameter: 100 mm	Bearing: 360°	Datum: AHD Operator: Pacific Geotech

Drilling Information				Material Description and Observations											
Method	Penetration	Water	Samples Tests Remarks	Recovery	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description soil type; plasticity or particle characteristics, secondary and minor components, colour	Moisture Condition	Consistency	Relative Density	Pocket Penetrometer UCS (kPa)	DCP TEST Blows per 100 mm	
AD/T	Slight Seepage @ 3.5m	DS 1.7-2.0m			7.0	1			Silty SAND, (TOPSOIL), fine to medium grained, grey, with organics	MD					
							Clayey SAND, (FILL), fine to coarse grained, orange, (ALLUVIAL)								
						2		CH	Sandy CLAY, high plasticity, red brown, fine to coarse grained sand, trace fine to medium sized subrounded gravel	M	VSt to H				
							becoming red brown mottled pale grey								
						3			becoming pale grey mottled red brown, without gravel	M to W	VSt				
						4		becoming pale grey mottled orange							
						5		becoming orange mottled pale grey							
						6		tending to very low strength rock							
						7									
8															
9															
Hole Terminated at 9.00 m Target depth															

Method AD/T - Auger Drilling TC Bit AD/V - Auger Drilling V Bit RT - Rotary Tri-cone Bit RD - Rotary Drilling NMLC - Rock Core HA - Hand Auger	Penetration VE - Very Easy E - Easy F - Firm H - Hard VH - Very hard	Water Level (Date) Inflow Partial Loss Complete Loss	Samples and Tests U## - Undisturbed Sample (## mm) DS - Disturbed Sample BDS - Bulk Disturbed Sample SPT - Standard Penetration Test	Moisture Condition D - Dry M - Moist W - Wet	Consistency/Relative Density VS - Very Soft S - Soft F - Firm VSt - Very Stiff H - Hard VL - Very Loose L - Loose MD - Medium Dense D - Dense VD - Very Dense Fr - Friable
Graphic Log/Core Loss Core recovered (hatching) Indicates material Core loss			Classification Symbols and Soil Descriptions Based on Unified Soil Classification System		

DRILLING/EXCAVATION METHOD

AD*	Auger Drilling	RA	Rotary Air	BH	Tractor Mounted Backhoe
ADH	Hollow Auger	RD	Rotary Blade or Drag bit	EX	Tracked Hydraulic Excavator
HA	Hand Auger	RT	Rotary Tri-cone bit	HMLC	Core – 63mm
*T	TC-Bit			HQ	Core – 63mm
*V	V-Bit			NMLC	Core – 47mm
				NQ	Core – 52mm
				R	Ripper
				RH	Rock Hammer

WATER

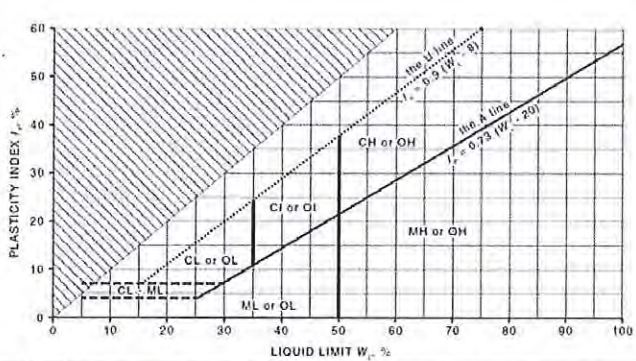
GROUNDWATER NOT OBSERVED	The observation of groundwater, whether present or not, was not possible due to drilling water, surface seepage or cave in of the borehole/test pit.
GROUNDWATER NOT ENCOUNTERED	The borehole/test pit was dry soon after excavation. However, groundwater could be present in less permeable strata. Inflow may have been observed had the borehole/test pit been left open for a longer period.

SAMPLING AND TESTING

SPT	Standard Penetration Test to AS1289.6.3.1-2004
5,4,10 N=14	5,4,10 = Blows per 150mm. N = Blows per 300mm penetration following 150mm seating
30/65mm	Where practical refusal occurs, the blows and penetration for that interval are reported
RW	Penetration occurred under the rod weight only
HW	Penetration occurred under the hammer and rod weight only
HB	Hammer double bouncing on anvil
DS	Disturbed sample
BDS	Bulk disturbed sample
SV	Field shear vane test expressed as uncorrected shear strength (s_v = peak value, s_r = residual value)
PP	Pocket penetrometer test expressed as instrument reading in kPa
U50	Thin walled tube sample - number indicates nominal sample diameter in millimetres
DCP	Dynamic cone penetration test
CPT	Electronic cone penetration test
CPTu	Electronic cone penetration test with pore pressure (u) measurement

CLASSIFICATION AND INFERRED STRATIGRAPHY

Soil is classified and described in borehole and test pit logs using the preferred method given in AS1726 – 2017. The material properties are assessed in the field by visual/tactile methods.

Particle Size			Plasticity Properties
Major Division	Sub Division	Particle Size	
BOULDERS		> 200 mm	
COBBLES		63 to 200 mm	
GRAVEL	Coarse	19 to 63 mm	
	Medium	6.7 to 19 mm	
	Fine	2.36 to 6.7 mm	
SAND	Coarse	0.6 to 2.36 mm	
	Medium	0.21 to 0.6 mm	
	Fine	0.075 to 0.21	
SILT		0.002 to 0.075	
CLAY		< 0.002 mm	

NOTE: The U line is an approximate upper bound for most materials. Data which plot above the U line may represent unusual/problem soil behavior, or unreliable data and should be considered carefully.

MOISTURE CONDITION

AS1726 - 2017

Symbol	Term	Description
D	Dry	Sands and gravels are free flowing. Clays & Silts may be brittle or friable and powdery.
M	Moist	Soils are darker than in the dry condition & may feel cool. Sands and gravels tend to cohere.
W	Wet	Soils exude free water. Sands and gravels tend to cohere.

CONSISTENCY AND DENSITY

AS1726 - 2017

Symbol	Term	Undrained Shear Strength	Symbol	Term	Density Index %	SPT "N" #
VS	Very Soft	0 to 12 kPa	VL	Very Loose	Less than 15	0 to 4
S	Soft	12 to 25 kPa	L	Loose	15 to 35	4 to 10
F	Firm	25 to 50 kPa	MD	Medium Dense	35 to 65	10 to 30
St	Stiff	50 to 100 kPa	D	Dense	65 to 85	30 to 50
VSt	Very Stiff	100 to 200 kPa	VD	Very Dense	Above 85	Above 50
H	Hard	Above 200 kPa				

In the absence of test results, consistency and density may be assessed from correlations with the observed behaviour of the material.

SPT correlations are not stated in AS1726 – 2017, and may be subject to corrections for overburden pressure and equipment type.

METHOD OF ROCK DESCRIPTION USED ON LOGS

CLASSIFICATION AND INFERRED STRATIGRAPHY

Rock is classified and described in borehole and test pit logs using the preferred method given in AS1726 – 2017. The material properties are assessed in the field by visual/tactile methods.

STRENGTH

Symbol	Term	Point Load Index, $I_s(50)$ (MPa)	Field Guide
VL	Very Low	0.03 to 0.1	Material crumbles under firm blows with sharp end of pick; can be peeled with knife; too hard to cut a triaxial sample by hand. Pieces up to 30 mm can be broken by finger pressure.
L	Low	0.1 to 0.3	Easily scored with a knife; indentations 1 mm to 3 mm show in the specimen with firm blows of pick point; has dull sound under hammer. A piece of core 150 mm long by 50 mm diameter may be broken by hand. Sharp edges of core may be friable and break during handling.
M	Medium	0.3 to 1	Readily scored with a knife; a piece of core 150 mm long by 50 mm diameter can be broken by hand with difficulty.
H	High	1 to 3	A piece of core 150 mm long by 50 mm diameter cannot be broken by hand but can be broken with pick with a single firm blow; rock rings under hammer.
VH	Very High	3 to 10	Hand specimen breaks with pick after more than one blow; rock rings under hammer.
EH	Extremely High	>10	Specimen requires many blows with geological pick to break through intact material; rock rings under hammer.

Relationship between $I_s(50)$ and UCS (unconfined compressive strength) will vary with rock type and strength, and should be determined on a site-specific basis. UCS is typically 10 to 30 x $I_s(50)$, but can be as low as 5.

ROCK MATERIAL WEATHERING

Symbol	Term	Field Guide
RS	Residual Soil	Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a large change in volume but the soil has not been significantly transported.
EW	Extremely Weathered	Rock is weathered to such an extent that it has soil properties - i.e. it either disintegrates or can be remoulded, in water.
HW	DW Highly Weathered Distinctly Weathered	Whole of rock is discoloured, usually by iron staining or bleaching to the extent that the colour of the original rock is not recognizable. Rock strength is significantly changed by weathering. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores.
MW		Whole of rock is discoloured, usually by iron staining or bleaching to the extent that the colour of the original rock is not recognizable; but shows little or no change of strength from fresh rock.
SW	Slightly Weathered	Rock is slightly discoloured but shows little or no change of strength relative to fresh rock.
FR	Fresh	Rock shows no sign of decomposition or staining.

ABBREVIATIONS FOR DEFECT TYPES AND DESCRIPTIONS

Defect Type	Coating or Infilling	Roughness
CS/CZ Crushed seam/zone (Fault)	Ca Calcite	Po Polished
DB Drilling break	Clay Clay	Sm Smooth
EW Extremely weathered seam	Cn Clean	Sl Slickensided
HB Handling break	Co Coating ($\geq 1\text{mm}$)	Ro Rough
IS/IZ Infilled seam/zone	Fe Iron oxide	VRo Very rough
J Joint	Op Open	
Pt Parting	Qz Quartz	
SS/SZ Sheared seam/zone (Fault)	St Stain	
Vn Vein	Vn Veneer ($<1\text{mm}$)	
	X Carbonaceous	
		Planarity
		Cu Curved
		Dis Discontinuous
		Ir Irregular
		Pl Planar
		St Stepped
		Un Undulating

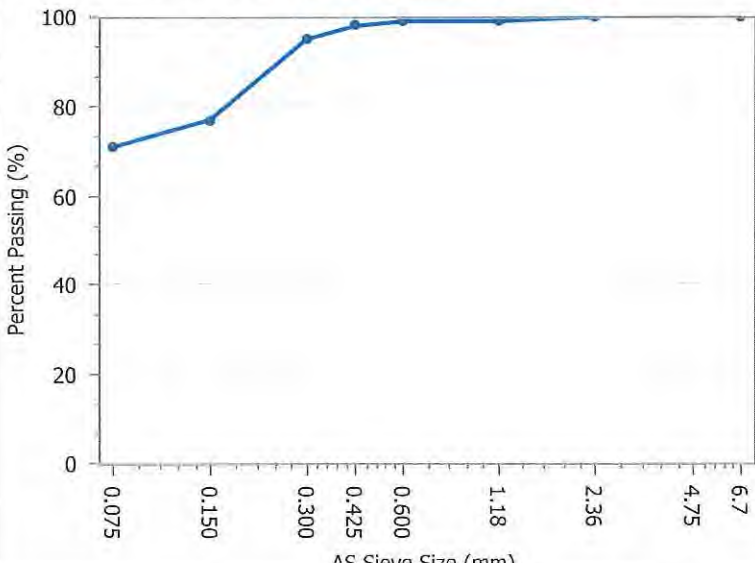
APPENDIX B

Laboratory Test Certificates

QUALITY OF MATERIALS REPORT

Client:	Tectonic Geotechnical Pty Ltd	Report Number:	3740/R/63311-1
Client Address:	924 David Low Way, Marcoola	Project Number:	3740/P/2437
Project:	Lot 8002 Baringa Drive, Baringa	Lot Number:	
Location:	Various	Internal Test Request:	3740/T/47797
Supplied To:	Tectonic Geotechnical Pty Ltd	Client Reference/s:	O/N 23387
Area Description:		Report Date / Page:	8/01/2024 Page 1 of 2

Test Procedures	AS1289.3.6.1, AS1289.3.1.2, AS1289.3.2.1, AS1289.3.4.1, AS1289.2.1.1, AS 1289.3.3.1		
Sample Number	3740/S/250002	Borehole name	BH1
Sampling Method	Tested As Received	Start Sample Depth (m)	0.3
Date Sampled	5/12/2023	End Sample Depth (m)	0.5
Sampled By	Client Sampled	(m)	
Date Tested	12/12/2023	Material Source	Insitu
PSD Preparation	Washed	Material Type	-
Atterberg Preparation	Dry Sieved / Oven Dried	Prep Material > 53.0mm (%)	

Material Description		CH Clay, high plasticity, with sand					
AS Sieve (mm)	Specification Minimum (%)	Percent Passing (%)	Specification Maximum (%)	PARTICLE SIZE DISTRIBUTION GRAPH			
6.7		100					
2.36		100					
1.18		99					
0.600		99					
0.425		98					
0.300		95					
0.150		77					
0.075		71					
Test Result	Specification Minimum (%)	Result	Specification Maximum (%)	Test Result	Specification Minimum (%)	Result	Specification Maximum (%)
Liquid Limit (%)		80		0.075/0.425 Fines Ratio		0.72	
Plastic Limit (%)		24		PI x 0.425 Ratio (%)		5510.4	
Plastic Index (%)		56		LS x 0.425 Ratio (%)		2017.2	
Linear Shrinkage (%)		20.5		Shrinkage Observations		-	

Remarks

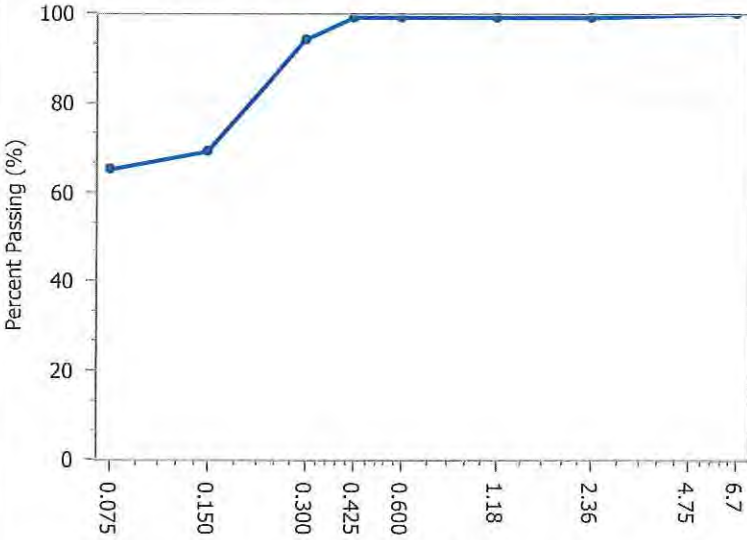
		Accredited for compliance with ISO/IEC 17025 – Testing			
Accreditation Number:	1986	Corporate Site Number:	3740		
				Approved Signatory: Thomas Hewitt	
				Form ID: W85Rep Rev 3	

QUALITY OF MATERIALS REPORT

Client:	Tectonic Geotechnical Pty Ltd	Report Number:	3740/R/63311-1
Client Address:	924 David Low Way, Marcoola	Project Number:	3740/P/2437
Project:	Lot 8002 Baringa Drive, Baringa	Lot Number:	
Location:	Various	Internal Test Request:	3740/T/47797
Supplied To:	Tectonic Geotechnical Pty Ltd	Client Reference/s:	O/N 23387
Area Description:		Report Date / Page:	8/01/2024 Page 2 of 2

Test Procedures	AS1289.3.6.1, AS1289.3.1.2, AS1289.3.2.1, AS1289.3.4.1, AS1289.2.1.1, AS 1289.3.3.1		
Sample Number	3740/S/250004	Borehole name	BH8
Sampling Method	Tested As Received	Start Sample Depth (m)	1.7
Date Sampled	5/12/2023	End Sample Depth (m)	2.0
Sampled By	Client Sampled	(m)	
Date Tested	12/12/2023	Material Source	Insitu
PSD Preparation	Washed	Material Type	-
Atterberg Preparation	Dry Sieved / Air Dried	Prep Material > 53.0mm (%)	

Material Description	CH Sandy Clay, high plasticity, trace of gravel		
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AS Sieve (mm)	Specification Minimum (%)	Percent Passing (%)	Specification Maximum (%)	PARTICLE SIZE DISTRIBUTION GRAPH 
6.7		100		
2.36		99		
1.18		99		
0.600		99		
0.425		99		
0.300		94		
0.150		69		
0.075		65		

Test Result	Specification Minimum (%)	Result	Specification Maximum (%)	Test Result	Specification Minimum (%)	Result	Specification Maximum (%)
Liquid Limit (%)		79		0.075/0.425 Fines Ratio		0.66	
Plastic Limit (%)		21		PI x 0.425 Ratio (%)		5718.8	
Plastic Index (%)		58		LS x 0.425 Ratio (%)		1824.1	
Linear Shrinkage (%)		18.5		Shrinkage Observations		-	

Remarks

		Accredited for compliance with ISO/IEC 17025 – Testing	
Accreditation Number:	1986		
Corporate Site Number:	3740		
Approved Signatory: Thomas Hewitt Form ID: W85Rep Rev 3			



CALIFORNIA BEARING RATIO REPORT

Client:	Tectonic Geotechnical Pty Ltd	Report Number:	3740/R/63467-2
Client Address:	924 David Low Way, Marcoola	Project Number:	3740/P/2437
Project:	Lot 8002 Baringa Drive, Baringa	Lot Number:	
Location:	Various	Internal Test Request:	3740/T/47797
Supplied To:	Tectonic Geotechnical Pty Ltd	Client Reference/s:	O/N 23387
Area Description:		Report Date / Page:	15/01/2024

Page 1 of 2

Test Procedures	AS1289.6.1.1, AS1289.5.1.1, AS1289.2.1.1		
Sample Number	3740/S/250002	Borehole name	BH1
Sampling Method	Tested As Received	Start Sample Depth (m)	0.3
Date Sampled	5/12/2023	End Sample Depth (m)	0.5
Sampled By	Client Sampled		(m)
Date Tested	12/01/2024	Prep Material > 53mm (%)	-
Material Source	Insitu	Material Limit Start	-
Material Type	-	Material Limit End	-
Client Reference	-	Compactive Effort	Standard

Material Description CH Clay, high plasticity, with sand

Maximum Dry Density (t/m³):	1.60	CBR PENETRATION PLOT <table><caption>CBR Penetration Plot Data Points (Estimated)</caption><tr><th>Penetration (mm)</th><th>Load (N)</th></tr><tr><td>0.5</td><td>50</td></tr><tr><td>1.5</td><td>150</td></tr><tr><td>2.5</td><td>250</td></tr><tr><td>3.5</td><td>350</td></tr><tr><td>4.5</td><td>420</td></tr><tr><td>5.5</td><td>480</td></tr><tr><td>6.5</td><td>530</td></tr><tr><td>7.5</td><td>580</td></tr><tr><td>8.5</td><td>620</td></tr><tr><td>9.5</td><td>650</td></tr><tr><td>10.5</td><td>670</td></tr><tr><td>11.5</td><td>680</td></tr><tr><td>12.5</td><td>680</td></tr></table>	Penetration (mm)	Load (N)	0.5	50	1.5	150	2.5	250	3.5	350	4.5	420	5.5	480	6.5	530	7.5	580	8.5	620	9.5	650	10.5	670	11.5	680	12.5	680
Penetration (mm)	Load (N)																													
0.5	50																													
1.5	150																													
2.5	250																													
3.5	350																													
4.5	420																													
5.5	480																													
6.5	530																													
7.5	580																													
8.5	620																													
9.5	650																													
10.5	670																													
11.5	680																													
12.5	680																													
Optimum Moisture Content (%):	23.5																													
Field Moisture Content (%):	22.8																													
Sample Percent Oversize (%)	0.0																													
Oversize Included / Excluded	Excluded																													
Target Density Ratio (%):	98																													
Target Moisture Ratio (%):	100																													
Placement Dry Density (t/m³):	1.58																													
Placement Dry Density Ratio (%):	99.0																													
Placement Moisture Content (%):	23.7																													
Placement Moisture Ratio (%):	100.0																													
Test Condition / Soaking Period:	Soaked / 4 Days																													
CBR Surcharge (kg)	4.5																													
Dry Density After Soak (t/m³):	1.51																													
Total Curing Time (hrs)	168																													
Liquid Limit Method	Estimation																													
Moisture (top 30mm) After Soak (%)	31.3																													
Moisture (remainder) After Soak (%)	25.6																													
CBR Swell (%):	4.5																													
Minimum CBR Specification (%):	-																													
CBR Value @ 5.0mm (%):	2.0																													

Remarks	Re-Issued Report Replaces Report No 3740/R/63467-1 (reason: Incorrect swell reported in S/250003)
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	Accredited for compliance with ISO/IEC 17025 – Testing		
	Accreditation Number:	1986	
	Corporate Site Number:	3740	
			Approved Signatory: Thomas Hewitt
			Form ID: W2ASRep Rev 3

CALIFORNIA BEARING RATIO REPORT

Client:	Tectonic Geotechnical Pty Ltd	Report Number:	3740/R/63467-2
Client Address:	924 David Low Way, Marcoola	Project Number:	3740/P/2437
Project:	Lot 8002 Baringa Drive, Baringa	Lot Number:	
Location:	Various	Internal Test Request:	3740/T/47797
Supplied To:	Tectonic Geotechnical Pty Ltd	Client Reference/s:	O/N 23387
Area Description:		Report Date / Page:	15/01/2024

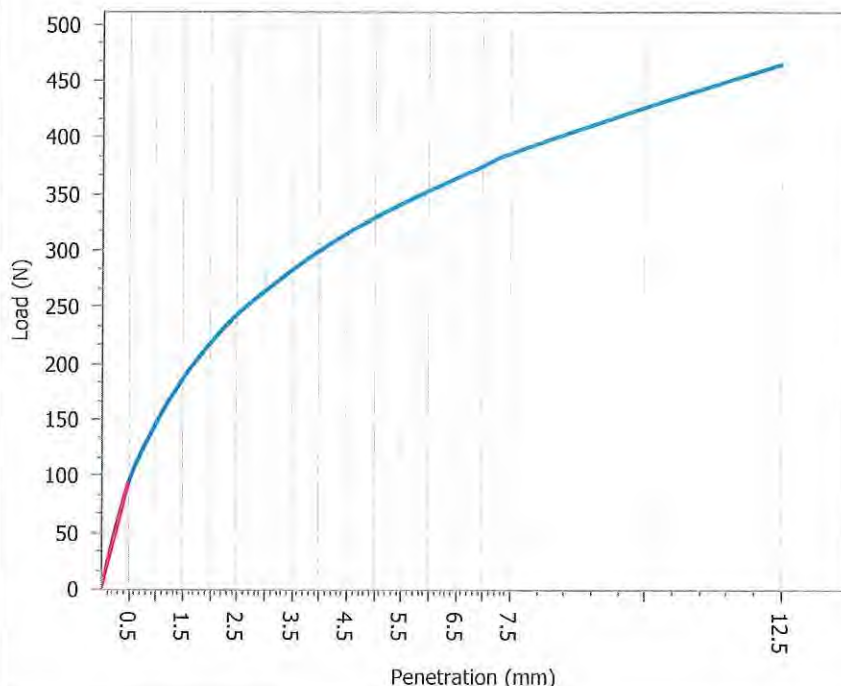
Page 2 of 2

Test Procedures	AS1289.6.1.1, AS1289.5.1.1, AS1289.2.1.1		
Sample Number	3740/S/250003	Borehole name	BH5
Sampling Method	Tested As Received	Start Sample Depth (m)	0.3
Date Sampled	5/12/2023	End Sample Depth (m)	0.5
Sampled By	Client Sampled		(m)
Date Tested	12/01/2024	Prep Material > 53mm (%)	-
Material Source	Insitu	Material Limit Start	-
Material Type	-	Material Limit End	-
Client Reference	-	Compactive Effort	Standard

Material Description Sandy clay, with gravel

Maximum Dry Density (t/m³):	1.09
Optimum Moisture Content (%):	27.0
Field Moisture Content (%):	19.8
Sample Percent Oversize (%)	0.0
Oversize Included / Excluded	Excluded
Target Density Ratio (%):	98
Target Moisture Ratio (%):	100
Placement Dry Density (t/m³):	1.08
Placement Dry Density Ratio (%):	98.5
Placement Moisture Content (%):	27.3
Placement Moisture Ratio (%):	101.5
Test Condition / Soaking Period:	Soaked / 4 Days
CBR Surcharge (kg)	4.5
Dry Density After Soak (t/m³):	1.00
Total Curing Time (hrs)	168
Liquid Limit Method	Estimation
Moisture (top 30mm) After Soak (%)	27.7
Moisture (remainder) After Soak (%)	26.4
CBR Swell (%):	7.0
Minimum CBR Specification (%):	-
CBR Value @ 2.5mm (%):	2.0

CBR PENETRATION PLOT



Remarks Re-issued Report Replaces Report No 3740/R/63467-1 (reason: Incorrect swell reported in S/250003)



Accredited for compliance with ISO/IEC 17025 – Testing

Accreditation Number: 1986
Corporate Site Number: 3740

Approved Signatory: Thomas Hewitt
Form ID: W2ASRep Rev 3

APPENDIX C

Previous (2021) Tectonic Investigation Borehole Reports and Laboratory Test Certificates

Engineering Log - Borehole

Project No.: 21219

Client: Stockland Development Pty Ltd		Commenced: 10/6/2021	
Project Name: Baringa Terraces (MD) Stage 3		Completed: 10/6/2021	
Hole Location: MD3 (Lot 8002), Baringa		Logged By: BNH	
Hole Position: 508034.0 m E 7034756.0 m N MGA2020 Zone 56		Checked By: ACD	

Drill Model and Mounting: 4WD Auger	Inclination: -90°	RL Surface: No survey
Hole Diameter: 100 mm	Bearing: 360°	Datum: AHD Operator: Tectonic

Drilling Information					Material Description and Observations									
Method	Penetration	Water	Samples Tests Remarks	Recovery	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description soil type; plasticity or particle characteristics, secondary and minor components, colour	Moisture Condition	Consistency	Relative Density	Pocket Penetrometer UCS (kPa)	DCP TEST (AS 1289.6.3.2-1997) Blows per 100 mm
AD/T	Not Encountered	U50 0.93-1.18m				0.5		SM	Silty SAND (TOPSOIL), fine to medium grained, grey, trace of rootlets	D				
						1.0		CH	Sandy CLAY, high plasticity, red mottled pale grey, fine to medium grained sand (RESIDUAL)	St to VSt				
						1.5								
						2.0			becoming pale grey mottled red orange	M				
						2.5								
						2.5			Hole Terminated at 2.50 m Target depth					20/95mm
						3.0								Refusal

Method

AD/T - Auger Drilling TC Bit

AD/V - Auger Drilling V Bit

RT - Rotary Tri-cone Bit

RD - Rotary Drilling

NMLC - Rock Core

HA - Hand Auger

Penetration

VE - Very Easy

E - Easy

F - Firm

H - Hard

VH - Very hard

Water

Level (Date)

Inflow

Partial Loss

Complete Loss

Samples and Tests

U## - Undisturbed Sample (## mm)

DS - Disturbed Sample

BDS - Bulk Disturbed Sample

SPT - Standard Penetration Test

Moisture Condition

D - Dry

M - Moist

W - Wet

Consistency/Relative Density

VS - Very Soft

S - Soft

F - Firm

VSt - Very Stiff

H - Hard

VL - Very Loose

L - Loose

MD - Medium Dense

D - Dense

VD - Very Dense

Fr - Friable

Graphic Log/Core Loss

Core recovered (hatching indicates material)

Core loss

Classification Symbols and Soil Descriptions

Based on Unified Soil Classification System

Plastic Limit

< PL

= PL

> PL

Engineering Log - Borehole

Project No.: 21219

Client: Stockland Development Pty Ltd			Commenced: 10/6/2021																	
Project Name: Baringa Terraces (MD) Stage 3			Completed: 10/6/2021																	
Hole Location: MD3 (Lot 8002), Baringa			Logged By: BNH																	
Hole Position: 508026.0 m E 7034756.0 m N MGA2020 Zone 56			Checked By: ACD																	
Drill Model and Mounting: 4WD Auger		Inclination: -90°		RL Surface: No survey																
Hole Diameter: 100 mm		Bearing: 360°		Datum: AHD Operator: Tectonic																
Drilling Information						Material Description and Observations														
Method	Penetration	Water	Samples Tests Remarks	Recovery	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description soil type: plasticity or particle characteristics, secondary and minor components, colour	Moisture Condition	Consistency	Relative Density	Pocket Penetrometer UCS (kPa)	DCP TEST (AS 1289.6.3.2-1997) Blows per 100 mm						
AD/T	Not Encountered		DS 0.5-1.0m U50 0.5-0.74m			0.5		SM	Silty SAND (TOPSOIL), fine to medium grained, brown, trace of rootlets	M	MD			350 330 340 350 360 370 380 390 400 410 420 430 440 450 460 470 480 490 500	0	5	10	15	20	25
						1.0		CH	Sandy CLAY, high plasticity, pale grey and red orange (RESIDUAL)											
						1.5			becoming pale grey mottled red and orange											
						2.0			becoming pale grey mottled red											
						2.5			Hole Terminated at 2.50 m Target depth											
						3.0														
						3.5														
						4.0														
						4.5														
						5.0														
Method			Penetration			Water			Samples and Tests			Moisture Condition			Consistency/Relative Density					
AD/T - Auger Drilling TC Bit AD/V - Auger Drilling V Bit RT - Rotary Tri-cone Bit RD - Rotary Drilling NMLC - Rock Core HA - Hand Auger			 VE - Very Easy E - Easy F - Firm H - Hard VH - Very hard			 Level (Date) Inflow Partial Loss Complete Loss			U## - Undisturbed Sample (## mm) DS - Disturbed Sample BDS - Bulk Disturbed Sample SPT - Standard Penetration Test			D - Dry M - Moist W - Wet			VS - Very Soft S - Soft F - Firm VSt - Very Stiff H - Hard VL - Very Loose L - Loose MD - Medium Dense D - Dense VD - Very Dense Fr - Friable					
Graphic Log/Core Loss			Classification Symbols and Soil Descriptions			Plastic Limit			Based on Unified Soil Classification System											
 Core recovered (hatching indicates material) Core loss			 < PL = PL > PL																	

Engineering Log - Borehole

Project No.: 21219

Client:		Stockland Development Pty Ltd			Commenced:		10/6/2021																																																																																		
Project Name:		Baringa Terraces (MD) Stage 3			Completed:		10/6/2021																																																																																		
Hole Location:		MD3 (Lot 8002), Baringa			Logged By:		BNH																																																																																		
Hole Position:		508059.0 m E 7034745.0 m N MGA2020 Zone 56			Checked By:		ACD																																																																																		
Drill Model and Mounting:		4WD Auger			Inclination:		-90°		RL Surface:		No survey																																																																														
Hole Diameter:		100 mm			Bearing:		360°		Datum:		AHD Operator: Tectonic																																																																														
Drilling Information					Material Description and Observations																																																																																				
Method	Penetration	Water	Samples Tests Remarks	Recovery	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description soil type: plasticity or particle characteristics, secondary and minor components, colour	Moisture Condition	Consistency	Relative Density	Pocket Penetrometer UCS (kPa)	DCP TEST (AS 1289.6.3.2-1997) Blows per 100 mm																																																																											
AD/T		Not Encountered	DS 0.1-0.4m			0.5		SM SC CI CH	Silty SAND (TOPSOIL), fine to medium grained, grey, trace of rootlets Clayey SAND, fine to medium grained, pale yellow, occasionally tending to sandy clay becoming pale grey yellow red Sandy CLAY, medium plasticity, red mottled pale grey and orange, fine to medium grained sand (RESIDUAL) Sandy CLAY, high plasticity, pale grey mottled orange red, fine to medium grained sand becoming pale grey mottled pale red	MD D M VSt			100 200 300 400 500																																																																												
						2.5			Hole Terminated at 2.50 m Target depth																																																																																
						3.0																																																																																			
Method AD/T - Auger Drilling TC Bit AD/V - Auger Drilling V Bit RT - Rotary Tri-cone Bit RD - Rotary Drilling NMLC - Rock Core HA - Hand Auger															Penetration VE - Very Easy E - Easy F - Firm H - Hard VH - Very hard															Water Level (Date) Inflow Partial Loss Complete Loss															Samples and Tests U## - Undisturbed Sample (## mm) DS - Disturbed Sample BDS - Bulk Disturbed Sample SPT - Standard Penetration Test															Moisture Condition D - Dry M - Moist W - Wet															Consistency/Relative Density VS - Very Soft S - Soft F - Firm VSt - Very Stiff H - Hard VL - Very Loose L - Loose MD - Medium Dense D - Dense VD - Very Dense Fr - Friable														
Graphic Log/Core Loss Core recovered (hatching indicates material) Core loss															Classification Symbols and Soil Descriptions Based on Unified Soil Classification System															Plastic Limit < PL = PL < PL																																																											

Engineering Log - Borehole

Project No.: 21219

Client: Stockland Development Pty Ltd			Commenced: 10/6/2021																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
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Hole Location: MD3 (Lot 8002), Baringa			Logged By: BNH																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
Hole Position: 508058.0 m E 7034713.0 m N MGA2020 Zone 56			Checked By: ACD																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
Drill Model and Mounting: 4WD Auger		Inclination: -90°		RL Surface: No survey																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
Hole Diameter: 100 mm		Bearing: 360°		Datum: AHD Operator: Tectonic																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
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Method	Penetration	Water	Samples Tests Remarks	Recovery	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description soil type; plasticity or particle characteristics, secondary and minor components, colour	Moisture Condition	Consistency	Relative Density	Pocket Penetrometer UCS (kPa)	DCP TEST (AS 1289.6.3.2-1997) Blows per 100 mm																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
AD/T	Not Encountered		DS 0.2-0.5m			0.5		SM	Silty SAND (TOPSOIL), fine to medium grained, grey, trace of rootlets	MD																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												

TECTONIC 3.03.2 US G.L.B. Log 1 TECTONIC BOREHOLE 21219.CPJ <DrawingFile> 25/6/2021 12:48 10.02.00.04 Dargal Lab and in Sil. Tool - DGD | Lib: Tectonic 3.03.2 2021-03-30 Proj: Tectonic 3.03.2 2021-03-30

Method

AD/T - Auger Drilling TC Bit
AD/V - Auger Drilling V Bit
RT - Rotary Tri-cone Bit
RD - Rotary Drilling
NMLC - Rock Core
HA - Hand Auger

Penetration

VE - Very Easy
E - Easy
F - Firm
H - Hard
VH - Very hard

Water

Level (Date)
Inflow
Partial Loss
Complete Loss

Graphic Log/Core Loss

Core recovered (hatching indicates material)
Core loss

Samples and Tests

U## - Undisturbed Sample (## mm)
DS - Disturbed Sample
BDS - Bulk Disturbed Sample
SPT - Standard Penetration Test

Moisture Condition

D - Dry
M - Moist
W - Wet

Consistency/Relative Density

VS - Very Soft
S - Soft
F - Firm
VSt - Very Stiff
H - Hard
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense
Fr - Friable

Classification Symbols and

Soil Descriptions

Based on Unified Soil Classification System

Plastic Limit

< PL
= PL
> PL

Engineering Log - Borehole

Project No.: 21219

Client: Stockland Development Pty Ltd		Commenced: 10/6/2021	
Project Name: Baringa Terraces (MD) Stage 3		Completed: 10/6/2021	
Hole Location: MD3 (Lot 8002), Baringa		Logged By: BNH	
Hole Position: 508081.0 m E 7034757.0 m N MGA2020 Zone 56		Checked By: ACD	
Drill Model and Mounting: 4WD Auger		Inclination: -90°	RL Surface: No survey
Hole Diameter: 100 mm		Bearing: 360°	Datum: AHD Operator: Tectonic

Drilling Information						Material Description and Observations													
Method	Penetration	Water	Samples Tests Remarks	Recovery	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description soil type: plasticity or particle characteristics, secondary and minor components, colour	Moisture Condition	Consistency	Relative Density	Pocket Penetrometer UCS (kPa)	DCP TEST (AS 1289.6.3.2-1997) Blows per 100 mm					
AD/T	Not Encountered		DS 0.2-1.0m U50 0.81-1.0m DS 1.0-1.5m			0.0		SM	Silty SAND (TOPSOIL), fine to medium grained, grey, trace of rootlets	M	MD								
						0.2		CI	Silty SAND (FILL), fine to medium grained, grey		St								
						0.5			Sandy CLAY, medium plasticity, red brown orange, occasionally tending to clayey sand, fine to medium grained sand (RESIDUAL)										
						1.0		CH	Sandy CLAY, high plasticity, pale grey mottled, red and grey, fine to medium grained sand (RESIDUAL)		St to VSt								
						1.5			becoming pale grey mottled pale red										
						2.0					VSt to H								
						2.5					H								
						2.5													
						3.0													
													2.5						
Hole Terminated at 2.50 m Target depth																			

Method

AD/T- Auger Drilling TC Bit
AD/V- Auger Drilling V Bit
RT - Rotary Tri-cone Bit
RD - Rotary Drilling
NMLC - Rock Core
HA - Hand Auger

Penetration

VE - Very Easy
E - Easy
F - Firm
H - Hard
VH - Very hard

Water

Level (Date)
 Inflow
 Partial Loss
 Complete Loss

Graphic Log/Core Loss

Core recovered (hatching indicates material)
 Core loss

Classification Symbols and Soil Descriptions

Based on Unified Soil Classification System

Samples and Tests

U## - Undisturbed Sample (## mm)
DS - Disturbed Sample
BDS - Bulk Disturbed Sample
SPT - Standard Penetration Test

Moisture Condition

D - Dry
M - Moist
W - Wet

Consistency/Relative Density

VS - Very Soft
S - Soft
F - Firm
VSt - Very Stiff
H - Hard
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense
Fr - Friable

Plastic Limit

< PL
= PL
> PL

Engineering Log - Borehole

Project No.: 21219

[illegible]

Engineering Log - Borehole

Project No.: 21219

Client:		Stockland Development Pty Ltd			Commenced:		10/6/2021							
Project Name:		Baringa Terraces (MD) Stage 3			Completed:		10/6/2021							
Hole Location:		MD3 (Lot 8002), Baringa			Logged By:		BNH							
Hole Position:		508100.0 m E 7034755.0 m N MGA2020 Zone 56			Checked By:		ACD							
Drill Model and Mounting:		4WD Auger		Inclination:		-90°		RL Surface:		No survey				
Hole Diameter:		100 mm		Bearing:		360°		Datum:		AHD Operator: Tectonic				
Drilling Information						Material Description and Observations								
Method	Penetration	Water	Samples Tests Remarks	Recovery	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description soil type: plasticity or particle characteristics, secondary and minor components, colour	Moisture Condition	Consistency	Relative Density	Pocket Penetrometer UCS (kPa)	DCP TEST (AS 1289.6.3.2-1997) Blows per 100 mm
AD/T	Not Encountered		DS 0.5-1.0m			0.5		SM	Silty SAND (TOPSOIL), fine to medium grained, grey, trace of rootlets	M	MD			Augered to 0.5m
									Silty SAND (FILL), fine to medium grained, grey		D			
									Clayey SAND (FILL), fine to medium grained, yellow					
									occasionally tending to sandy clay					
						1.0					L to MD			
									becoming red		MD			
								CH	Sandy CLAY, high plasticity, red occasionally mottled red yellow orange (RESIDUAL)		VSt			
						1.5			becoming pale grey mottled pale red					
											VSt to H			
						2.0					H			
			DS 1.3-1.5m											
			DS 1.5-2.0m											
						2.5			Hole Terminated at 2.50 m Target depth					
						3.0								

Method

AD/T - Auger Drilling TC Bit
AD/V - Auger Drilling V Bit
RT - Rotary Tri-cone Bit
RD - Rotary Drilling
NMLC - Rock Core
HA - Hand Auger

Penetration

VE - Very Easy
E - Easy
F - Firm
H - Hard
VH - Very hard

Water

Level (Date)
Inflow
Partial Loss
Complete Loss

Graphic Log/Core Loss

Core recovered (hatching indicates material)
Core loss

Samples and Tests

U## - Undisturbed Sample (## mm)
DS - Disturbed Sample
BDS - Bulk Disturbed Sample
SPT - Standard Penetration Test

Classification Symbols and Soil Descriptions

Based on Unified Soil Classification System

Moisture Condition

D - Dry
M - Moist
W - Wet

Plastic Limit

< PL
= PL
> PL

Consistency/Relative Density

VS - Very Soft
S - Soft
F - Firm
VSt - Very Stiff
H - Hard
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense
Fr - Friable

Engineering Log - Borehole

Project No.: 21219

Client: Stockland Development Pty Ltd				Commenced: 10/6/2021										
Project Name: Baringa Terraces (MD) Stage 3				Completed: 10/6/2021										
Hole Location: MD3 (Lot 8002), Baringa				Logged By: BNH										
Hole Position: 508115.0 m E 7034732.0 m N MGA2020 Zone 56				Checked By: ACD										
Drill Model and Mounting: 4WD Auger		Inclination: -90°		RL Surface: No survey										
Hole Diameter: 100 mm		Bearing: 360°		Datum: AHD		Operator: Tectonic								
Drilling Information						Material Description and Observations								
Method	Penetration	Water	Samples Tests Remarks	Recovery	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description soil type; plasticity or particle characteristics, secondary and minor components, colour	Moisture Condition	Consistency	Relative Density	Pocket Penetrometer UCS (kPa)	DCP TEST (AS 1289.6.3.2-1997) Blows per 100 mm
AD/T	Not Encountered		DS 0.15-0.5m			0.0		SM	Silty SAND (TOPSOIL), fine to medium grained, grey, trace of rootlets	M	MD			
								CI	Silty SAND (FILL), fine to medium grained, grey					
									Sandy CLAY, medium plasticity, brown orange red, occasionally tending to clayey sand, fine to medium grained sand, trace of gravel (RESIDUAL)					
									with fine to medium sized sub-angular to sub-rounded gravel					
						0.5				St to VSt		230 250		
						1.0		CH	Sandy CLAY, high plasticity, pale grey mottled orange red, fine to medium grained sand				200 450	
						1.5			becoming pale grey mottled pale orange				340 450	
						2.0							300 340	
						2.5							460 460	
						2.5			Hole Terminated at 2.50 m Target depth				420 520	
						3.0								
Method AD/T- Auger Drilling TC Bit AD/V- Auger Drilling V Bit RT - Rotary Tri-cone Bit RD - Rotary Drilling NMLC -Rock Core HA - Hand Auger				Penetration  VE - Very Easy E - Easy F - Firm H - Hard VH - Very hard		Water  Level (Date)  Inflow  Partial Loss  Complete Loss		Samples and Tests U## - Undisturbed Sample (## mm) DS - Disturbed Sample BDS - Bulk Disturbed Sample SPT - Standard Penetration Test		Moisture Condition D - Dry M - Moist W - Wet		Consistency/Relative Density VS - Very Soft S - Soft F - Firm VSt - Very Stiff H - Hard VL - Very Loose L - Loose MD - Medium Dense D - Dense VD - Very Dense Fr - Friable		
Graphic Log/Core Loss  Core recovered (hatching indicates material)  Core loss								Classification Symbols and Soil Descriptions Based on Unified Soil Classification System		Plastic Limit < PL = PL < PL				

Engineering Log - Borehole

Project No.: 21219

Client:		Stockland Development Pty Ltd		Commenced:		10/6/2021												
Project Name:		Baringa Terraces (MD) Stage 3		Completed:		10/6/2021												
Hole Location:		MD3 (Lot 8002), Baringa		Logged By:		BNH												
Hole Position:		508114.0 m E 7034701.0 m N MGA2020 Zone 56		Checked By:		ACD												
Drill Model and Mounting:		4WD Auger		Inclination:		-90°												
Hole Diameter:		100 mm		Bearing:		360°												
				RL Surface:		No survey												
				Datum:		AHD												
				Operator:		Tectonic												
Drilling Information				Material Description and Observations														
Method	Penetration	Water	Samples Tests Remarks	Recovery	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description soil type: plasticity or particle characteristics, secondary and minor components, colour	Moisture Condition	Consistency	Relative Density	Pocket Penetrometer UCS (kPa)	DCP TEST (AS 1289.6.3.2-1997) Blows per 100 mm				
AD/T	Not Encountered		U50 0.46-0.69m DS 0.5-1.0m			0.0		SM	Silty SAND (TOPSOIL), fine to medium grained, grey, trace of rootlets	M	MD							
						0.1		CH	Silty SAND (FILL), fine to medium grained, grey									
						0.2			Sandy CLAY, high plasticity, orange red and pale grey, fine to medium grained sand (RESIDUAL)									
						0.3			becoming red purple orange									
						0.4												
						0.5												
						0.6												
						0.7												
						0.8												
						0.9												
1.0							becoming pale grey mottled orange and red		VSt to H									
1.1																		
1.2																		
1.3																		
1.4																		
1.5																		
1.6																		
1.7																		
1.8																		
1.9																		
2.0									becoming pale grey mottled red and orange, trace of gravel		D to M	VSt						
2.1																		
2.2																		
2.3																		
2.4																		
2.5									Hole Terminated at 2.50 m Target depth									
2.6																		
2.7																		
2.8																		
2.9																		
3.0																		
Method AD/T - Auger Drilling TC Bit AD/V - Auger Drilling V Bit RT - Rotary Tri-cone Bit RD - Rotary Drilling NMLC - Rock Core HA - Hand Auger																		
Penetration VE - Very Easy E - Easy F - Firm H - Hard VH - Very hard																		
Water Level (Date) Inflow Partial Loss Complete Loss																		
Samples and Tests U## - Undisturbed Sample (## mm) DS - Disturbed Sample BDS - Bulk Disturbed Sample SPT - Standard Penetration Test																		
Moisture Condition D - Dry M - Moist W - Wet																		
Consistency/Relative Density VS - Very Soft S - Soft F - Firm VSt - Very Stiff H - Hard VL - Very Loose L - Loose MD - Medium Dense D - Dense VD - Very Dense Fr - Friable																		
Plastic Limit < PL = PL > PL																		
Graphic Log/Core Loss Core recovered (hatching) Indicates material Core loss																		
Classification Symbols and Soil Descriptions Based on Unified Soil Classification System																		

Engineering Log - Borehole

Project No.: 21219

Client:	Stockland Development Pty Ltd	Commenced:	10/6/2021
Project Name:	Baringa Terraces (MD) Stage 3	Completed:	10/6/2021
Hole Location:	MD3 (Lot 8002), Baringa	Logged By:	BNH
Hole Position:	508129.0 m E 7034717.0 m N MGA2020 Zone 56	Checked By:	ACD

Drill Model and Mounting:	4WD Auger	Inclination:	-90°	RL Surface:	No survey
Hole Diameter:	100 mm	Bearing:	360°	Datum:	AHD
				Operator:	Tectonic

Drilling Information						Material Description and Observations																																																																																																																																											
Method	Penetration	Water	Samples Tests Remarks	Recovery	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description soil type: plasticity or particle characteristics, secondary and minor components, colour	Moisture Condition	Consistency	Relative Density	Pocket Penetrometer UCS (kPa)	DCP TEST (AS 1289.6.3.2-1997) Blows per 100 mm																																																																																																																																			
AD/T		Not Encountered	U50 0.5-0.61m			0.0		SM	Silty SAND (TOPSOIL), fine to medium grained, grey, trace of rootlets	M	MD																																																																																																																																						

Material Test Report

Report Number: ML21/150-1
Issue Number: 1
Date Issued: 01/07/2021
Client: TECTONIC GEOTECHNICAL PTY LTD
 PO BOX 899, BUDERIM QLD
Contact: Carissa Bruggemann
Project Number: ML21/150
Project Name: Geotechnical Investigation - MD3 (Lot 8002)
Project Location: MD3, Lot 8002, Baringa
Client Reference: 21219
Work Request: 3813
Dates Tested: 17/06/2021 - 30/06/2021
Location: Baringa



**MORRISON
GEOTECHNIC**

Brisbane | Gold Coast | Sunshine Coast

Morrison Geotechnic Pty Ltd

ABN: 51 009 878 899

Maroochydore Laboratory

Unit 4 / 81 Wises Road Maroochydore QLD 4558

Phone: (07) 5443 9522

Email: gflett@mgeo.com.au



Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Gina Flett

Lab Manager

NATA Accredited Laboratory Number: 1169

Shrink Swell Index AS 1289 7.1.1 & 2.1.1

Sample Number	M21-3813A	M21-3813B	M21-3813C	M21-3813D	M21-3813E
Date Sampled	10/06/2021	10/06/2021	10/06/2021	10/06/2021	10/06/2021
Date Tested	25/06/2021	25/06/2021	25/06/2021	29/06/2021	29/06/2021
Material Source	**	**	**	**	**
Sample Location	BH1 (0.93 - 0.18m)	BH2 (0.56 - 0.74m)	BH3 (1.04 - 1.15m)	BH4 (0.62 - 0.8m)	BH5 (0.81 - 1.0m)
Inert Material Estimate (%)	**	**	**	**	**
Pocket Penetrometer before (kPa)	<335	<355	<345	<340	<480
Pocket Penetrometer after (kPa)	<380	<300	<320	<290	<385
Shrinkage Moisture Content (%)	14.8	24.6	21.6	23.9	16.1
Shrinkage (%)	0.9	2.3	2.7	2.1	0.9
Swell Moisture Content Before (%)	16.4	26.6	14.3	23.2	22.4
Swell Moisture Content After (%)	16.7	27.2	15.4	26.5	24.6
Swell (%)	0.0	1.6	0.1	1.4	0.6
Shrink Swell Index Iss (%)	0.5	1.7	1.5	1.5	0.7
Visual Description	**	**	**	**	**
Cracking	SC	SC	SC	MC	SC
Crumbling	**	**	**	**	**
Remarks	**	**	**	**	**

Shrink Swell Index (Iss) reported as the percentage vertical strain per pF change in suction.

Cracking Terminology: UC Uncracked, SC Slightly Cracked, MC Moderately Cracked, HC Highly Cracked, FR Fragmented.

NATA Accreditation does not cover the performance of pocket penetrometer readings.

Material Test Report

Report Number: ML21/150-1
Issue Number: 1
Date Issued: 01/07/2021
Client: TECTONIC GEOTECHNICAL PTY LTD
 PO BOX 899, BUDERIM QLD
Contact: Carissa Bruggemann
Project Number: ML21/150
Project Name: Geotechnical Investigation - MD3 (Lot 8002)
Project Location: MD3, Lot 8002, Baringa
Client Reference: 21219
Work Request: 3813
Dates Tested: 17/06/2021 - 30/06/2021
Location: Baringa



Brisbane | Gold Coast | Sunshine Coast
 Morrison Geotechnic Pty Ltd
 ABN: 51 009 878 899
 Maroochydore Laboratory
 Unit 4 / 81 Wises Road Maroochydore QLD 4558
 Phone: (07) 5443 9522
 Email: gflett@mgeo.com.au



Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Gina Flett

Lab Manager

NATA Accredited Laboratory Number: 1169

Shrink Swell Index AS 1289 7.1.1 & 2.1.1					
Sample Number	M21-3813F	M21-3813G	M21-3813H	M21-3813I	M21-3813J
Date Sampled	10/06/2021	10/06/2021	10/06/2021	10/06/2021	10/06/2021
Date Tested	29/06/2021	29/06/2021	29/06/2021	29/06/2021	30/06/2021
Material Source	**	**	**	**	**
Sample Location	BH6 (0.5 - 0.72m)	BH7 (0.85 - 1.1m)	BH8 (0.92 - 1.12m)	BH9 (0.46 - 0.69m)	BH10 (0.5 - 0.66m)
Inert Material Estimate (%)	**	**	**	**	**
Pocket Penetrometer before (kPa)	<350	<320	<270	<365	<325
Pocket Penetrometer after (kPa)	<295	<250	<260	<275	<305
Shrinkage Moisture Content (%)	22.8	17.2	23.6	27.0	19.6
Shrinkage (%)	11.2	1.6	0.6	2.5	7.7
Swell Moisture Content Before (%)	25.2	15.7	23.8	23.1	20.1
Swell Moisture Content After (%)	28.2	19.7	25.4	28.2	23.7
Swell (%)	1.0	0.0	1.2	0.6	0.2
Shrink Swell Index Iss (%)	6.5	0.9	0.7	1.6	4.3
Visual Description	**	**	**	**	**
Cracking	SC	SC	MC	MC	SC
Crumbling	**	**	**	**	**
Remarks	**	**	**	**	**

Shrink Swell Index (Iss) reported as the percentage vertical strain per pF change in suction.

Cracking Terminology: UC Uncracked, SC Slightly Cracked, MC Moderately Cracked, HC Highly Cracked, FR Fragmented.

NATA Accreditation does not cover the performance of pocket penetrometer readings.

APPENDIX D

Foundation Maintenance and Footing Performance: A Homeowner's Guide

Foundation Maintenance and Footing Performance: A Homeowner's Guide



BTF 18
replaces
Information
Sheet 10/91

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

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

Soil Types

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

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

Causes of Movement

Settlement due to construction

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

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

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

Erosion

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

Saturation

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

Seasonal swelling and shrinkage of soil

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

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

Shear failure

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

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

GENERAL DEFINITIONS OF SITE CLASSES

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

Tree root growth

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

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

Unevenness of Movement

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

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

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

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

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

Effects of Uneven Soil Movement on Structures

Erosion and saturation

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

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

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

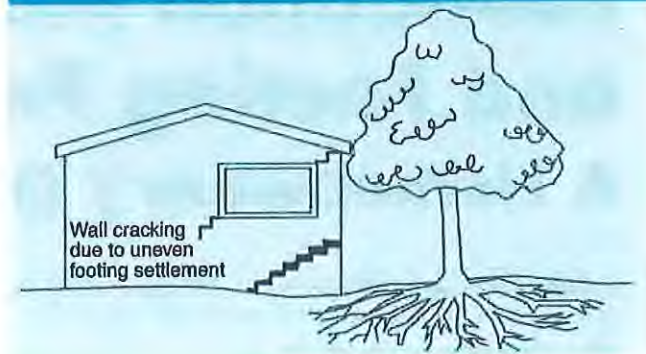
Seasonal swelling/shrinkage in clay

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

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

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

Trees can cause shrinkage and damage



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

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

Movement caused by tree roots

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

Complications caused by the structure itself

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

Effects on full masonry structures

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

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

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

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

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

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

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

Effects on framed structures

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

Effects on brick veneer structures

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

Water Service and Drainage

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

Pipe leakage and trench water flows also encourage tree and shrub roots to the source of water, complicating and exacerbating the problem.

Poor roof plumbing can result in large volumes of rainwater being concentrated in a small area of soil:

- Incorrect falls in roof guttering may result in overflows, as may gutters blocked with leaves etc.

- Corroded guttering or downpipes can spill water to ground.
- Downpipes not positively connected to a proper stormwater collection system will direct a concentration of water to soil that is directly adjacent to footings, sometimes causing large-scale problems such as erosion, saturation and migration of water under the building.

Seriousness of Cracking

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

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

Prevention/Cure

Plumbing

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

Ground drainage

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

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

Protection of the building perimeter

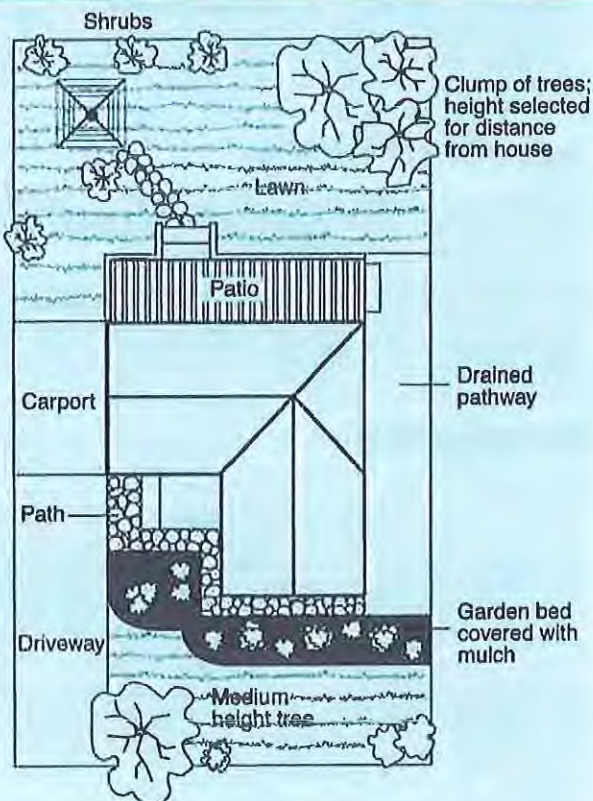
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

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

Gardens for a reactive site



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

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

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

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

Condensation

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

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

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

The garden

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

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

Existing trees

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

Information on trees, plants and shrubs

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

Excavation

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

Remediation

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

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

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

The information in this and other issues in the series was derived from various sources and was believed to be correct when published.

The information is advisory. It is provided in good faith and not claimed to be an exhaustive treatment of the relevant subject.

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APPENDIX E

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