Terara Shoalhaven Sand
C/- Ernest Panucci

martens consulting engineers

# Land Resource Assessment:

# Proposed Expansion of Sand Dredging Operations at Terara Shoalhaven Sand, Terara, NSW

ENVIRONMENTAL

WATER

WASTEWATER

GEOTECHNICAL

CIVIL

PROJECT MANAGEMENT

P1806743JR07V01
March 2019

**Limitations Statement**

The sole purpose of this report and the associated services performed by Martens & Associates Pty Ltd is to complete a land resource assessment, in accordance with the scope of services set out in the contract / quotation between Martens & Associates Pty Ltd and Terara Shoalhaven Sand c/- Ernest Panucci (hereafter known as the Client). That scope of works and services were defined by the requests of the Client, by the time and budgetary constraints imposed by the Client, and by the availability of access to the site.

Martens & Associates Pty Ltd derived the data in this report primarily from a number of sources which may include for example site inspections, correspondence regarding the proposal, examination of records in the public domain, interviews with individuals with information about the site or the project, and field explorations conducted on the dates indicated. The passage of time, manifestation of latent conditions or impacts of future events may require further examination / exploration of the site and subsequent data analyses, together with a re-evaluation of the findings, observations and conclusions expressed in this report.

In preparing this report, Martens & Associates Pty Ltd may have relied upon and presumed accurate certain information (or absence thereof) relative to the site. Except as otherwise stated in the report, Martens & Associates Pty Ltd has not attempted to verify the accuracy of completeness of any such information (including for example survey data supplied by others).

The findings, observations and conclusions expressed by Martens & Associates Pty Ltd in this report are not, and should not be considered an opinion concerning the completeness and accuracy of information supplied by others. No warranty or guarantee, whether express or implied, is made with respect to the data reported or to the findings, observations and conclusions expressed in this report. Further, such data, findings and conclusions are based solely upon site conditions, information and drawings supplied by the Client *etc*. in existence at the time of the investigation.

This report has been prepared on behalf of and for the exclusive use of the Client, and is subject to and issued in connection with the provisions of the agreement between Martens & Associates Pty Ltd and the Client. Martens & Associates Pty Ltd accepts no liability or responsibility whatsoever for or in respect of any use of or reliance upon this report by any third party.

**Head Office**
Suite 201, 20 George Street
Hornsby, NSW 2077, Australia
ACN 070 240 890 ABN 85 070 240 890
**Phone: +61-2-9476-8777**
Fax: +61-2-9476-18767
Email: mail@martens.com.au
Web: www.martens.com.au

**Document and Distribution Status**

| Author(s) | Reviewer(s) | Project Manager | Signature |
|---|---|---|---|
| Mr Andrew Mesthos<br>Mr Dan Irwin | Mr Jeff Fulton<br>Dr Daniel Martens | Mr Jeff Fulton | |

| Revision No. | Description | Status | Release Date | Document Location | | | |
|---|---|---|---|---|---|---|---|
| | | | | File Copy | Terara Shoalhaven Sand Pty Ltd | Ernest Panucci | |
| 1 | Land Resource Assessment | Draft | 08.03.2019 | 1P, 1H | 1P | 1P | |
| 1 | Land Resource Assessment | Final | 20.03.2019 | 1P, 1H | 1P | 1P | |
| | | | | | | | |

Distribution Types: F = Fax, H = hard copy, P = PDF document, E = Other electronic format. Digits indicate number of document copies.

**All enquiries regarding this project are to be directed to the Project Manager.**

# Executive Summary

### Overview

This report, prepared by Martens and Associates (MA), documents the findings of a land resource assessment to satisfy the Secretaries Environmental Assessment Requirements (SEARs 1234, Attachment A) outlined by the NSW Department of Planning & Environment (DPE) for the proposed expansion of the current Terara Shoalhaven Sand extraction area at the western point of Burruga Island, Terara, NSW ('the site').

### Geological Profile

The proposed extraction expansion zone is situated in the western and north western portion of a mid-channel accretion bar known as Burruga Island, within the Shoalhaven River, NSW. Site soils comprise Shoalhaven alluvial material, a sequence of medium and coarse quartzose and lithic sands with varying proportions of fine sands, interlaid by silts, clays and carbonaceous matter that were deposited after periods of flooding. Subsurface investigation by vibrocore to a maximum of 3.7 meters below ground level (surface level of -3.9 mAHD), across 5 borehole locations, identified the following unit:

> Unit 1: Sand, medium and coarse grained, with varying portions of fine grained sand, brown-grey to dark grey in colour.

### Resource Characteristics

Resource characteristics and suitability for use in concrete were assessed by petrographic and particle size distribution analysis. A total of 6 samples were analysed, three for petrographic analysis by Geochempet against Australian and international standards (ASTM C295, AS2758.1 – 2014, AS1141 and HB79-15) and three to Resource Laboratories Pty Ltd, a NATA accredited laboratory, for particle size distribution analysis. Results indicated the resource comprises poorly graded medium and medium to fine quartzose and lithic sand, with free silica content between 53 % - 76 %. All samples returned values for 'potential for mild or slow deleterious alkali-silica reactivity in concrete' and were considered suitable for use in concrete. Encountered minor lenses (< 0.5 m thick) of clays, silts and carbonaceous matter, deposited after periods of river flooding, will likely require separation by screening and hydraulic methods from the bulk sand resource prior to retail.

### Resource Quantity

Resource volumes were calculated from proposed extraction area (JPS, 2018) that was defined to include a 25 m buffer between mapped seagrass beds. Two volumes were calculated, a tested resource based on 2018 field investigation termination depths and a likely resource based on current and historic dredging operations coupled with river water levels. A land resource quantity of 1,140,000 $m^3$, weighing approximately 1,940,000 tonnes, is calculated for resource feasibility purposes.

**Resource Extraction, Processing and Mine Life Expectancy**

Resource extraction within the proposed expansion zone will be by dredge and is to utilise existing equipment and infrastructure (i.e. dredge, pipeline, trenches and processing plant). The proposed extraction rate of up to 100,000 tonnes per annum will allow an extraction life expectancy of 19 years, possibly longer if proposed extraction rates are not realised year on year.

**Conclusions**

The proposed sand extraction expansion at the western and north-western portion of Burruga Island will allow for up to 1,940,000 tonnes of high quality construction sand to be available for use over a 19 year lifespan.

# Contents

## i. Abbreviations

AHD – Australian Height Datum

DCP – Dynamic Cone Penetrometer

DPE - Department of Planning & Environment (NSW)

DPWI – Department of Primary Industries Water

EIS – Environmental Impact Statement

LGA – Local government area

MA – Martens and Associates Pty Ltd

MBGL – Metres below ground level

NATA – National Association of Testing Authorities

NSW – New South Wales

PSD – Particle size distribution

QLD - Queensland

SCC – Shoalhaven City Council

SEARs - Secretaries Environmental Assessment Requirements

VC – Vibrocore

# 1 Introduction

## 1.1 Overview

This report, prepared by Martens and Associates (MA), documents the findings of a land resource assessment to satisfy the Secretaries Environmental Assessment Requirements (SEARs 1234, Attachment A) outlined by the NSW Department of Planning & Environment (DPE) and accompany an Environmental Impact Statement (EIS) for a proposed expansion of sand extraction area in the vicinity of Burruga Island in the lower Shoalhaven River, NSW (the site).

## 1.2 Scope of Report

Project scope and objectives have been tailored to address required land resource state and local statutory and regulatory requirements for the proposed development (refer Section 2 for more details). They include:

1. Assess volume and quality of sand deposits at the site.
2. Provide geological site summary including land capability and potential contamination.
3. Justify the proposed expansion.

## 1.3 Proposed Development Overview

The proposal includes the extension of the existing dredging footprint around the western and north western portion of the Shoalhaven River mid-channel bar known as Burruga Island. The proposed dredging expansion will allow for the extraction of up to 100,000 tonnes of river sand per annum, over a 19 year period. Refer to drawing PS02-AZ00, Attachment A for the location of proposed sand dredging operations.

## 1.4 Summary of Field Works Undertaken

Field works were devised to identify the potential quality and extent of the sand resource within the proposed extraction area. A summary of field works undertaken on the 18th September, 2018, for the land resource assessment is presented below. Further details are provided in Section 4.

- Inspection of the site via barge to assess existing site conditions, river morphology and geology.

- Four Dynamic Cone Penetrometer (DCP) tests up to 5.0 metres below ground level (mbgl).
- Drilling of five vibrocore boreholes (VC301, VC302A, VC302B, VC303, VC304A and VC304B) to termination depths between 1.6 m and 3.7 mbgl (-1.5 mAHD to -3.7 mAHD).
- Collection of soil samples for laboratory testing and future reference.

# 2 Statutory and Regulatory Requirements

The Secretary of the NSW Department of Planning and Environment (DP&E) has consulted with relevant government agencies and has provided environmental requirements for the project (EAR1234, 2018). They are summarised in Table 1.

**Table 1**: Secretary of the NSW Department of Planning and Environment Environmental Assessment Requirements (SEARs) as relates to this assessment.

| Rehabilitation Management Plan Requirements | | Section of Report |
|---|---|---|
| **Department of Planning & Environment SEARs (General Requirements)** | | |
| The EIS must include a comprehensive description of the development, including: | | |
| o | A detailed site description and history of any previous quarrying on the site, including a current survey plan. | **Section 3** |
| o | Identification of the resource, including the amount, type and composition. | **4.2**, **5** & **6** |
| o | The layout of the proposed works and components (including any existing infrastructure that would be used for the development). | **6.2** |
| A conclusion justifying why the development should be approved, taking into consideration: | | |
| o | Alternatives. | **7 & 8** |
| o | The suitability of the site. | **7 & 8** |
| **Department of Planning & Environment SEARs (Key Issues)** | | |
| Land Resource including an assessment of: | | |
| o | Potential impacts on soils and land capability (including potential erosion and land contamination) and the proposed mitigation, management and remedial measures. | **Refer to River Stability Assessment and Contamination Reports** |
| o | The compatibility of the development with other land uses in the vicinity of the development, in accordance with the requirements of Clause 12 of *State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007*. | **Refer to Planning Assessment** |

# 3 Site Description

A summary of general site details is provided in Table 2. Site location is shown in drawing PS06-A000, PS06-A050 and PS06-JZ00, Attachment A.

**Table 2:** General site information.

| Item | Description / Detail |
|---|---|
| Site address | Shoalhaven River, Bed of the Shoalhaven River, Nowra, NSW. |
| Legal identifier | Lot 1-4 DP 1184790 |
| Approximate area | Sand extraction extension: 0.26 $km^2$ (JPS, 2018) |
| Local Government Area | Shoalhaven City Council (SCC) |
| Current zoning | Burruga Island is currently zoned RU1 – Primary Production.<br>The proposed dredging location is currently zoned W2 – Recreational Waterways. |
| Site description and proposed use | The existing sand extraction area is located at the south and south western portion of Burruga Island. The proposal includes the extension of the existing dredging footprint along the western and north western portion of Burruga Island and involves the extraction of sand via dredge of up to 100,000 tonnes per annum over 19 years. |
| Surrounding land uses | The northern bank of the Shoalhaven River is occupied by industrial properties including Manildra Group, Shoalhaven Starches Pty Ltd, Argyle Meat and Venus Shell Systems with rural residential properties and agricultural land.<br>The river bank to the south contains a mixture of residential properties, agricultural land and commercial properties including, Shoalhaven Caravan Village, Terara Shoalhaven Sand Pty Ltd and Terara Riverside Retreat. |
| Topography | The sand flats for the proposed dredging area are slightly undulating, with site slopes < 2%. The site is located on sand flats in the tidal portion of Shoalhaven River at the western portion of Burruga Island. The southeast portion of the proposed dredging area (closest to the western end of Burruga Island) has an elevation of 0.2 mAHD, - 0.3 mAHD in the northern, - 1.1 mAHD in the eastern and - 2.7 mAHD in the western portion. |
| Expected geology | The *Wollongong 1:250,000 Geological Series Sheet S1 56.9 (1966)* describes site geology as alluvium, gravel, swamp deposits and sand dunes.<br>The NSW Environment and Heritage eSPADE website identifies the site as having Shoalhaven soil landscapes consisting of alluvium – gravel, sand, silt and clay derived mainly from sandstone and shale overlying buried estuarine sediments. |

## 3.1 Geological Setting

### *3.1.1 Surrounding Landscapes*

Neighbouring sediments of the Shoalhaven River are part of the Shoalhaven fluvial soil landscape and consist of alluvium gravel, sand, silt and clay derived from sandstone and shale of the Shoalhaven Group (eSPADE, 2018). Primary deposition on river banks and floodplains occur during floods, where the river transports high concentrations of suspended silts and clays and has created an extensive floodplain (approximately 120 $km^2$) through lateral accretion.

### *3.1.2 Shoalhaven River Geomorphology*

The Shoalhaven River is the largest river on the south coast of NSW and represents a tectonically stable, high-energy and wave-dominated river delta (Wright et al, 1980) that is classified as a 'barrier estuary' (Umwelt Australia, 2006). Historic, current and proposed extraction zones are located on the western side of a main mid-channel bar, located 10 km from the river mouth, proximal to the Nowra Bridge, known as Burruga Island. River bedload sediments are dominated by fine to coarse, relatively poor sorted, angular sands comprised of quartz, feldspar and lithic fragments.

### *3.1.3 Burruga Island*

The shape of Burruga Island can be attributed to the migration of sediment downstream, which has resulted in 2 distinct accretion points: a subaqueous portion where alluvial deposition has led to formation of extensive sand and mudflat areas which are partially exposed during low tide; and a subaerial portion, where aeolian deposits have built up the Island via processes similar to dune formation.

The island represents the mid extent of tidal influences within the Shoalhaven River, where vertical mixing with marine reworked sediments (well rounded quartz grains) occurs causing vertical homogeneity within the coarse sediments (Wright et al, 1980).

Sediments east of Burruga Island towards the Shoalhaven River delta become increasing dominated by marine sands, whereas the proportion of lithic sediments increase to the west (Figure 1, Attachment B). Lenses of carbonaceous matter, silts and clays can become trapped and buried in cross-bedded sequences and ripples during periods of low stage river conditions.

## 3.2 Previous Sand Dredging Activity

Sand has been extracted by dredging operations from the Shoalhaven River on a permissive occupancy lease since 1968, with all land based activities (processing, stockpiling and dispatch) currently situated at Lots 1 and 2 DP 787495 (123 and 125 Terara Road, Terara, NSW).

Historic dredging has been allocated to the southern and south-western portion of Burruga Island where sand has been extracted to typically between 4 mbgl to 6 mbgl. The current owners of Terara Shoalhaven Sands Pty Ltd, purchased the extraction lease in 1988 and have since extracted between approximately 20,000 tonnes to 65,000 tonnes per annum (private correspondence, 2018).

## 3.3 Site Contamination

Refer to MA03 (2018) for information related to site contamination.

# 4 Field Investigation Findings

## 4.1 Subsurface Investigation Methodology

Subsurface investigation for the land resource assessment was undertaken by vibrocore drilling with attached aluminium casing. Cores were removed by block and tackle, cut by angle-grinder to investigation termination depth, PVC capped and then secured with duct-tape to maintain *in-situ* characteristics and limit sample disturbance during transport.

Drilling works were supported by barge and undertaken during neap tidal conditions. Vibrocore locations were marked by handheld GPS with logging of recovered cores conducted post field works by a MA geologist. Two vibcrocore locations were twinned (2 m spacing) to determine immediate horizontal continuity of sediments.

Samples for internal reference were placed in sandwich bags with bulk samples for resource characterisation placed in polyethylene bags, weighing approximately 500 g to 1 kg. Petrographic samples were dispatched to Geochempet Services in Clontarf, QLD and particle size density bulk samples sent to Resource Laboratories, Seven Hills, NSW.

## 4.2 Subsurface Conditions

Intrusive investigations identified one general soil unit within the proposed extraction extension zone.

Unit 1: Sand, medium and coarse grained, with varying portions of fine grained sand, brown-grey to dark grey in colour.

Lenses of silty sand and sandy silt with clay and organic matter, typically wood fragments, were encountered up to 0.5 m thick, with vibrocore termination often occurring on or within these lenses. Encountered lenses are likely to be relatively thin (< 0.5 m), but may extend laterally across the site. The lenses may be due to fine sediment and / or organic matter becoming trapped and subsequently buried in ripple hollows or crossbeded sequences after sediment settlement following periods of high river conditions (i.e. flooding).

Encountered conditions are described in more detail on the borehole logs in Attachment C, representative photos in Attachment D, and associated explanatory notes in Attachment I.

# 5 Resource Characteristics

## 5.1 Overview

To assess sand characteristics, 3 soil samples were submitted to Geochempet Services for petrographic analysis and 3 soils samples were submitted to Resource Laboratories for particle size distribution (PSD) analysis.

Samples were selected to characterise resource grading and suitability of the resource across the encountered depths. No samples were selected from the sandy silt or silty sand lenses with organic matter due to limited quantity of recovered sample. Laboratory analysis reports are provided in Attachment E.

## 5.2 Particle Size Distribution Results

PSD results and calculations are summarised in Table 4.

**Table 4:** Summary of PSD results and calculations.

| Location ID | Depth (m) | Grading (%) | | | | | Calculation [1] | | Grading Result [2] |
|---|---|---|---|---|---|---|---|---|---|
| | | Silt / Clay | F. Sand | M. Sand | C. Sand | Gravel | Cu | Cc | |
| **VC302A** | 1.5 – 2.1 | < 1 | 19 | 60 | 20 | < 1 | 1.08 | 2.29 | Poor |
| **VC303** | 2.1 – 2.5 | < 2 | 4 | 40 | 51 | 3 | 1.16 | 2.17 | Poor |
| **VC304A** | 1.1 – 1.6 | < 3 | 23 | 66 | 7 | < 1 | 0.93 | 2.13 | Poor |

**Notes:**
[1] Cc = Coefficient of curvature; Cu = Coefficient of uniformity.
[2] Well graded sands = Cu ≥ 6 and 1 < Cc < 3; results outside this range indicate poorly graded sands.

PSD results indicate the resource is poorly graded and consists of predominately medium and coarse sand, with varying proportion of fine sand and trace gravels and silt or clay.

## 5.3 Petrographic Analysis Results

### *5.3.1 Grading and Composition*

Laboratory petrographic analysis reports are provided in Attachment E. The petrographic laboratory reports identify the composition of the resource sands as poorly graded, medium to fine and medium quartzose and lithic sand containing between 53 % - 76 % free silica.

### 5.3.2 *Alkali – Silica Reactivity in Concrete Results*

Alkali – silica reactivity in concrete was reported within the petrographic reports. All samples returned values for '*potential for mild or slow deleterious alkali-silica reactivity in concrete*'.

### 5.3.3 *Sand Suitability for use in Concrete*

The three samples petrographically examined for suitability for use in concrete were assessed against the following Australian and international standards:

- ASTM C295 Standard Guide for *Petrographic Assessment of Aggregates for Concrete*.
- AS2758.1 – 2014 *Aggregates and rock for engineering purposes part 1; Concrete aggregates (Appendix B.)*
- AS1141 Standard Guide for the *Method for sampling and testing aggregates,* of the content of the 2015 joint publication of Cement and Concrete Association of Australia.
- HB 79-2015 *Alkali Aggregate Reaction – Guidelines on Minimising the Risk of Damage to Concrete Structures in Australia*.

All samples were classified as suitable for use in concrete, provided the appropriate precautions are taken with regards to mix and engineering design related to the perceived potential for mild or slow deleterious alkaline – silica reactivity.

## 5.4 Conclusion

Laboratory analysis indicates the bulk portion of the resource consists of poorly sorted, medium and coarse grained sand, with varying proportion of fine grained sand, containing trace silt and / or clay and fine subangular to subrounded gravels. The tested resource is considered suitable for use in concrete, subject to engineering design precautions noted in Section 5.3.3. Encountered zones containing increased fine sediment and carbonaceous content may be removed from the bulk resource by screening and hydraulic processes.

# 6 Resource Assessment

## 6.1 Unit Volumes, Weights and Cut Depth

Resource volumes were based on a proposed expansion area of 260,000 $m^2$ (JPS, 2018). The proposed area was defined to include a 25 m buffer to mapped seagrass beds.

Two resource volumes were calculated based on tested resource depths encountered in 2018 field investigations and likely depths based on current and historic dredging levels. A bulk density factor of 1.7 was applied to the resource estimates to calculate resource weight. Refer to Table 5 for a summary of tested and likely resource volumes, weights and extraction depths.

**Table 5:** Resource volumes, weights and extraction depths.

| Resource Calculation | Extraction Depth (mAHD) | Calculated Total Unit Volume ($m^3$) [1] | Bulk Density ($g/cm^3$) [2] | Calculated Total Weight (t) [3] |
|---|---|---|---|---|
| Tested [4] | -3.7 | 962,000 | 1.7 | 1,635,000 |
| Likely [5] | -6.7 | 1,140,000 | | 1,940,000 |

**Notes:**
[1] Calculated to the nearest 1,000 $m^3$ from 2018 survey data (JPS, 2018). Alterations to topography conducted / occurring after September 2018 may impact calculated volumes.
[2] Estimated bulk density.
[3] Calculated to the nearest 10,000 t.
[4] Tested values based on 2018 field investigation termination depths, assuming average resource surface level of -0.2 mAHD.
[5] Likely values based on dredging from low tide river levels (refer MA02, 2018), using a 6 m dredge arm (current site dredging practices) and an average resource surface level of -0.2 mAHD.

Based on available information presented within this report, a tested resource volume of 962,000 $m^3$, weighing approximately 1,635,000 tonnes is considered for the proposed extraction extension with a likely resource volume of 1,140,000 $m^3$, weighing approximately 1,940,000 tonnes is considered for feasibility assessment purposes.

## 6.2 Resource Extraction and Processing

Based on a feasibility resource of approximately 1,940,000 tonnes with an extraction license of 100,000 tonnes per annum, the lease life of the resource is expected to last for 19 years, longer if noted extraction rates are not realised. The methodology for extracting and processing the extracted material is summarised below. Figure 2, Attachment B identifies various aspects of the operations. All listed equipment and infrastructure below is currently in operation within the existing extraction lease.

1. A dredge is used to extract sand from the river bed. The 'cutter head' rotates slowly to dislodge bed sediments while a 300mm suction line removes disturbed sediment. Generally, the cutter arm operates in an arch shape and cuts to a maximum depth of 6 m below river water level (unless refused prior on bands of clay).

2. Sediment and water slurry is pumped via a pipeline across the river to the processing plant, located on the southern bank.

3. Course fractions (>3 mm) are screened out from the sediment and water slurry using a 3mm screen.

4. Sand fractions are then separated from the water and fines by means of a centrifuge cyclone system.

5. Sand fractions are stockpiled for distribution.

Residual water and fines are pumped back across the river to the existing fines processing facility located on the southern side of Burruga Island. A trench on the island serves as a sediment and erosion control device allowing groundwater seepage to occur and fines to settle out of suspension. The trench is cleaned out as required in accordance with the previous DA (RA12/1011).

# 7 Justification of Proposed Development

## 7.1 Suitability of Proposed Development

The proposed sand extraction development is justifiable due to the quality of material, successful history of sand extraction at Burruga Island and commercial demand for sand in the area.

Subsurface investigations identified one major subsurface unit of medium and coarse grained, poorly graded sand that is generally suitable for use for in concrete, subject to removal of thin lenses of silts, clays and carbonaceous matter.

Terara Shoalhaven Sand Pty Ltd have been trading for over 25 years, supplying washed river sand to industry in the South Coast and Sydney regions. Dredging has previously and successfully taken place in the riverbed to the south of Burruga Island.

The supply of suitable construction sand is in demand, driven by population growth and associated infrastructure projects / developments.

## 7.2 Alternatives of Proposed Development

If the proposed development is not able to proceed, industry, commercial and landscaping demand for the resource is unlikely to be met.

# 8 Resource Conclusions and Recommendations

## 8.1 Resource Lithology and Suitability

Subsurface investigations identified one major subsurface unit of medium and coarse grained, poorly graded sand that is generally suitable for use in concrete, subject to removal of thin lenses of silts, clays and carbonaceous matter.

Sand may also be used for a variety of soft landscaping purposes, where we identified is the predominant existing market for Terara Shoalhaven Sands.

## 8.2 Resource Quantity

Calculated volumes indicate a possible resource volume of 1,140,000 $m^3$, weighing approximately 1,940,000 tonnes, to a maximum resource extraction depth of -6.7 mAHD.

The calculated volume of resource is to be extracted and processed with current neighbouring sand extraction operation equipment and facilities. The current extraction licence allows a total of 100,000 tonnes of sand to be extracted annually, giving a mine life expectancy of approximately 19 years. Previously, in any one year, the maximum quantity of sand extracted has been 70,000 tonnes, whilst the minimum has been 40,000 tonnes. Based on actual extraction figures, we expect a mine life of between approximately 30 - 40 years.

## 8.3 Development Application Resource Justification

The proposed sand extraction extension development application is justifiable in terms of its location and resource. It will ensure the continued availability of on-going support to the South Coast construction market. These markets are currently experiencing a shortfall of available, local and suitable construction and landscaping sand. This shortfall of suitable construction sand is projected to worsen, leading to increased costs of the raw material, in lieu of major infrastructure projects and developments resulting from population growth.

# 9 Limitations

Martens and Associates (MA) operates in the business of providing civil, geotechnical and environmental consulting services. MA is not a financial advisor, forecaster or accountant and therefore does not make any representations or promises and cannot give any guarantee, warranty or undertaking as to any profit projection, revenue or performance of your business.

For the purpose of this report, MA has assumed all relevant material information and documents have been provided by the Client.

Except to the extent that liability under the law cannot be disclaimed, MA does not accept any liability, whether in contract, tort or otherwise whatsoever, whether or not it has been negligent, for any loss or damage including, without limitation, loss of profit and profit projection, which may arise directly or indirectly from use or reliance of any opinion, advice, recommendation, representation or information expressively or impliedly published in or in relation to this report, notwithstanding any error or omission.

MA reserves the right to make any changes or improvements to this report at any time.

Occasionally sub-surface soil conditions in areas of the site not investigated may be found to be different from those expected. Should, during site works, soil conditions be found to be significantly different to those detailed in this report, works shall cease immediately and the new conditions should be addressed by Martens & Associates to determine implications before recommencement.

# 10 References


Martens and Associates (2019) *River Stability Assessment: Proposed Expansion of Sand Dredging Operations at Terara Shoalhaven Sand, Terara, NSW,* document reference *P1806743JR01V01* (MA01, 2019).

Martens and Associates (2019) *Acid Sulfate Soils Assessment: Proposed Expansion of Sand Dredging Operations at Terara Shoalhaven Sand, Terara, NSW,* document reference *P1806743JR02V01* (MA02, 2019).

Martens and Associates (2019) *Contamination Assessment: Proposed Expansion of Sand Dredging Operations at Terara Shoalhaven Sand, Terara, NSW,* document reference *P1806743JR03V01* (MA03, 2019).

Martens and Associates (2019) *Flood Assessment: Proposed Expansion of Sand Dredging Operations at Terara Shoalhaven Sand, Terara, NSW,* document reference *P1806743JR04V01* (MA04, 2019).

Martens and Associates (2019) *Surface Water Monitoring Plan: Proposed Expansion of Sand Dredging Operations at Terara Shoalhaven Sand, Terara, NSW,* document reference *P1806743JR05V01* (MA05, 2019).

Martens and Associates (2019) *Estuarine Water Quality Impact Assessment: Proposed Expansion of Sand Dredging Operations at Terara Shoalhaven Sand, Terara, NSW,* document reference *P1806743JR06V01* (MA06, 2019).

Martens and Associates (2019) *Rehabilitation Management Plan: Proposed Expansion of Sand Dredging Operations at Terara Shoalhaven Sand, Terara, NSW,* document reference *P1806743JR08V01* (MA08, 2019).

Nearmap (2018), accessed November, 2018.

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

NSW Department of Planning and Environment (2018), *Secretary Environmental Assessment Requirements Terara Shoalhaven Sands (EAR1234)*, dated 7 March 2018.

NSW Department of Primary Industries Water (DPIW) real time groundwater bore database.

NSW Government Soil Conservation Service (2018), https://www.scs.nsw.gov.au/, viewed October, 2018.

# 11 Attachment A – Testing Locations


| REV | DESCRIPTION | DATE | DRAWN | DESIGNED | CHECKED | APPRVD |
|---|---|---|---|---|---|---|
| B | **MINOR AMENDMENTS** | **05/03/2019** | **PB** | **DI** | | |
| A | INITIAL REVISION | 20/12/2018 | PB | DOS | | |

SCALE
0 20 40 60 80 100 120 140 160 180 200 METRES
A1 (A3) 1:2,000 (1:4,000)

| GRID | DATUM | PROJECT MANAGER |
|---|---|---|
| MGA | mAHD | JF |



CLIENT
TERARA SHOALHAVEN SAND

PROJECT NAME/PLANSET TITLE
EXPANSION OF SAND EXTRACTION
A.S.S. ASSESSMENT
125 TERARA ROAD, TERARA, NSW 2541

martens & Associates Pty Ltd
Consulting Engineers
Environment
Water
Geotechnical
Civil
Suite 201, 20 George St, Hornsby, NSW 2077 Australia Phone: (02) 9476 9999 Fax: (02) 9476 8767
Email: mail@martens.com.au Internet: www.martens.com.au

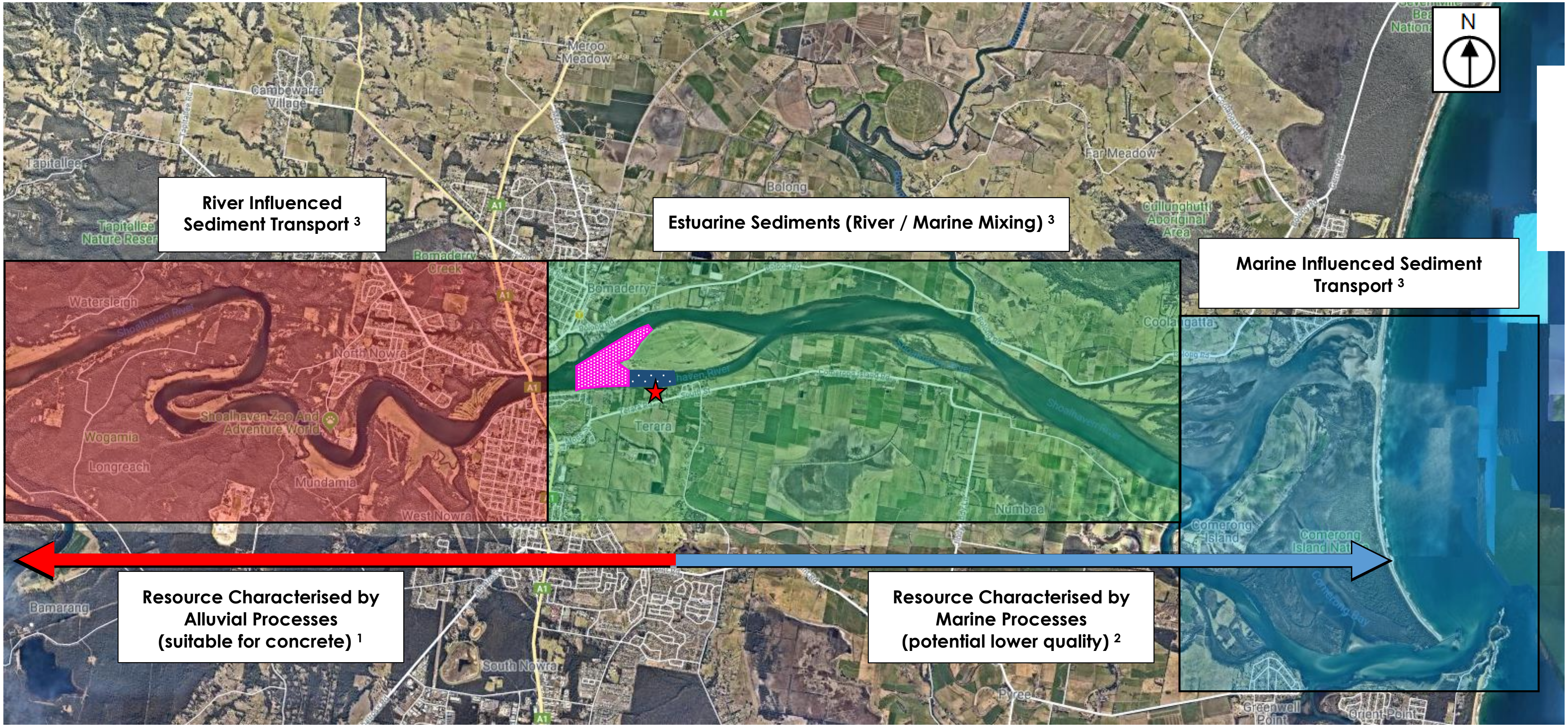
DRAWING TITLE
EXTENT OF SAND DREDGING OPERATIONS
& SITE TESTING PLAN

| PROJECT NO. | PLANSET NO. | RELEASE NO. | DRAWING NO. | REVISION |
|---|---|---|---|---|
| P1806743 | PS02 | R02 | PS02-AZ00 | B |

DRAWING ID: P1806743-PS02-R02-AZ00

PRINTED: 10.10.2018 - USER: VHUANG
A1 / A3 LANDSCAPE (A1LC_v02.0.01)

# 12 Attachment B – Figures




## Legend

| | |
|---|---|
| (pink dotted area) | Indicative proposed extraction extension zone |
| (dark dotted area) | Indicative current and historic extraction (1998 – 2018) |
| ★ | Indicative location of land processing activities. |

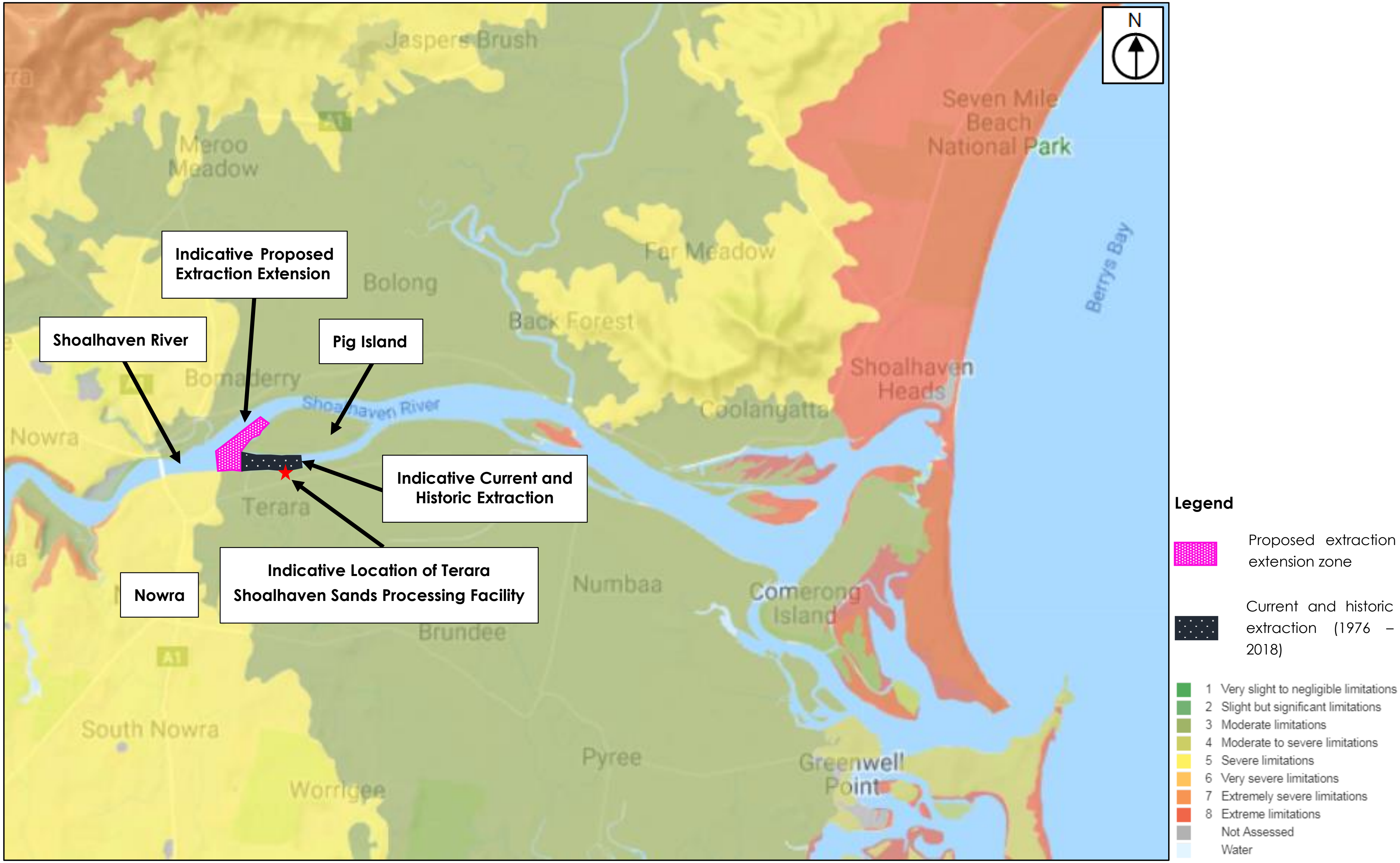
## Notes

[1] Based on resource testing within proposed extraction extension zone.

[2] Potential different geological resource characteristics towards sub-rounded to rounded marine sediments, which may impact quality of resource.

[3] Wright et al, 1980.

| **Martens & Associates Pty Ltd** ABN 85 070 240 890 | | **Environment \| Water \| Wastewater \| Geotechnical \| Civil \| Management** | |
|---|---|---|---|
| Drawn: | AM | **Shoalhaven River Resource Dominant Influences**<br>Source: Nearmap (2018). | Drawing: **FIGURE 1** |
| Approved: | SN | | |
| Date: | 20.11.2018 | | |
| Scale: | NA | | Project: P1806743JR07V01 |




**Martens & Associates Pty Ltd** ABN 85 070 240 890

**Environment | Water | Wastewater | Geotechnical | Civil | Management**

| | |
|---|---|
| Drawn: | AM |
| Approved: | SN |
| Date: | 20.11.2018 |
| Scale: | NA |

**Land and Soil Capability Map with Proposed Extraction Location and Historic Mining**

Source: NSW Government, eSPADE (2018).

Drawing: **FIGURE 1**

Project: P1806743JR07V01

# 13 Attachment C - Borehole Logs

| | | | | | | |
|---|---|---|---|---|---|---|
| CLIENT | Terara Shoalhaven Sand Pty Ltd | COMMENCED | 18/09/2018 | COMPLETED | 18/09/2018 | **REF VC301** |
| PROJECT | Land Resource and Contamination Assessment | LOGGED | AM | CHECKED | BM | Sheet 1 OF 1 |
| SITE | Shoalhaven River (Pig Island), NSW | GEOLOGY | Quaternary Deposits | VEGETATION | N/A | PROJECT NO. P1806743 |
| EQUIPMENT | Vibrocore | EASTING | | RL SURFACE | -0.3 m | DATUM AHD |
| EXCAVATION DIMENSIONS | Ø80 mm x 3.10 m depth | NORTHING | | ASPECT | West | SLOPE <2% |

| **Drilling** | | | | | **Sampling** | | **Field Material Description** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| METHOD | PENETRATION RESISTANCE | WATER | DEPTH (metres) | DEPTH RL | SAMPLE OR FIELD TEST | RECOVERED | GRAPHIC LOG | USCS / ASCS CLASSIFICATION | SOIL/ROCK MATERIAL DESCRIPTION | MOISTURE CONDITION | CONSISTENCY DENSITY | STRUCTURE AND ADDITIONAL OBSERVATIONS |
| VC | L | Drilled Over Water | 0.0 | -0.30 | 6743/VC301/0.0-0.5/S/1 D 0.00 m<br>6743/VC301/0.1-0.4/S/1 D 0.10 m<br>6743/VC301/0.2-1.0/S/1 D 0.20 m | | | SP | SAND, medium grained; brown-grey; trace wood. | | | ALLUVIUM |
| | | | 1.3 | | 6743/VC301/1.3-1.5/S/1 D 1.30 m | | | | | W | | |
| | M | | | *1.80*<br>-2.10 | 6743/VC301/1.8-2.0/S/1 D 1.80 m<br>6743/VC301/1.9-2.2/S/1 D 1.90 m | | | | Medium to coarse grained; grey; trace clay and wood fragments. | | | |
| | H | | | *2.70*<br>-3.00 | 6743/VC301/2.7-3.0/S/1 D 2.70 m<br>6743/VC301/2.7-3.1/S/1 D 2.70 m | | | SM | Silty SAND; medium to coarse grained; dark grey; with clay and wood. | | | 2.70: to 3.1m; Partial core recovery. |
| | | | | *3.10* | | | | | Hole Terminated at 3.10 m | | | 3.10: Terminated due to high penetration resistance from wood fragments. |

Depth scale (metres): 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5

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



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

***Engineering Log - TEST***

| CLIENT | Terara Shoalhaven Sand Pty Ltd | COMMENCED | 18/09/2018 | COMPLETED | 18/09/2018 | REF VC302A |
|---|---|---|---|---|---|---|
| PROJECT | Land Resource and Contamination Assessment | LOGGED | AM | CHECKED | BM | Sheet 1 OF 1 |
| SITE | Shoalhaven River (Pig Island), NSW | GEOLOGY | Quaternary Deposits | VEGETATION | N/A | PROJECT NO. P1806743 |
| EQUIPMENT | Vibrocore | EASTING | | RL SURFACE | 0.1 m | DATUM AHD |
| EXCAVATION DIMENSIONS | Ø80 mm x 1.60 m depth | NORTHING | | ASPECT | West | SLOPE <2% |

| Drilling | | | | | Sampling | | Field Material Description | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| METHOD | PENETRATION RESISTANCE | WATER | DEPTH (metres) | DEPTH RL | SAMPLE OR FIELD TEST | RECOVERED | GRAPHIC LOG | USCS / ASCS CLASSIFICATION | SOIL/ROCK MATERIAL DESCRIPTION | MOISTURE CONDITION | CONSISTENCY DENSITY | STRUCTURE AND ADDITIONAL OBSERVATIONS |
| VC | L-M | Drilled Over Water | | 0.10 | 6743/VC302A/0.0-0.4/S/1 D 0.00 m<br>6743/VC302A/0.0-0.5/S/1 D 0.00 m | | | SP | SAND; medium grained; brown-grey. | | | ALLUVIUM |
| | | | 0.5 | | 6743/VC302A/0.6-0.9/S/1 D 0.60 m | | | | | W | | |
| | | | 1.0 | 0.90<br>-0.80 | 6743/VC302A/0.9-1.2/S/1 D 0.90 m<br>6743/VC302A/1.1-1.6/S/1 D 1.10 m<br>6743/VC302A/1.2-1.6/S/1 D 1.20 m | | | | Grey. | | | |
| | H | | 1.5 | 1.60 | | | | | | | | |
| | | | | | | | | | Hole Terminated at 1.60 m | | | 1.60: Terminated due to high penetration resistance from wood fragments. |
| | | | 2.0 | | | | | | | | | |
| | | | 2.5 | | | | | | | | | |
| | | | 3.0 | | | | | | | | | |
| | | | 3.5 | | | | | | | | | |
| | | | 4.0 | | | | | | | | | |
| | | | 4.5 | | | | | | | | | |

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

martens



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

**Engineering Log - TEST**

| CLIENT | Terara Shoalhaven Sand Pty Ltd | COMMENCED | 18/09/2018 | COMPLETED | 18/09/2018 | REF VC302B |
|---|---|---|---|---|---|---|
| PROJECT | Land Resource and Contamination Assessment | LOGGED | AM | CHECKED | BM | Sheet 1 OF 1 |
| SITE | Shoalhaven River (Pig Island), NSW | GEOLOGY | Quaternary Deposits | VEGETATION | N/A | PROJECT NO. P1806743 |
| EQUIPMENT | Vibrocore | EASTING | | RL SURFACE | 0.1 m | DATUM AHD |
| EXCAVATION DIMENSIONS | Ø80 mm x 3.40 m depth | NORTHING | | ASPECT | West | SLOPE <2% |

| METHOD | PENETRATION RESISTANCE | WATER | DEPTH (metres) | DEPTH RL | SAMPLE OR FIELD TEST | RECOVERED | GRAPHIC LOG | USCS / ASCS CLASSIFICATION | SOIL/ROCK MATERIAL DESCRIPTION | MOISTURE CONDITION | CONSISTENCY DENSITY | STRUCTURE AND ADDITIONAL OBSERVATIONS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VC | L-M | Drilled Over Water | | 0.10 | 6743/VC302B/0.0-0.3/S/1 D 0.00 m | | | SP | SAND; medium grained; brown-grey. | W | | ALLUVIUM |
| | | | 0.5 | | 6743/VC302B/0.6-0.9/S/1 D 0.60 m | | | | | | | |
| | | | 1.0 | | 6743/VC302B/1.2-1.6/S/1 D 1.20 m | | | | | | | |
| | M | | 1.5 | 1.60 -1.50 | 6743/VC302B/1.6-2.0/S/1 D 1.60 m | | | | From 1.6-1.8m: wood. | | | |
| | | | 2.0 | | 6743/VC302B/2.0-2.4/S/1 D 2.00 m | | | | | | | |
| | H | | 2.5 / 3.0 | | 6743/VC302B/2.8-3.0/S/1 D 2.80 m 6743/VC302B/2.8-3.4/S/1 D 2.80 m | | | | | | | |
| | | | | 3.40 | | | | | Hole Terminated at 3.40 m | | | 3.40: Terminated due to high penetration resistance. |
| | | | 3.5 / 4.0 / 4.5 | | | | | | | | | |

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

martens



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

**Engineering Log - TEST**

| CLIENT | Terara Shoalhaven Sand Pty Ltd | COMMENCED | 18/09/2018 | COMPLETED | 18/09/2018 | **REF VC303** |
|---|---|---|---|---|---|---|
| PROJECT | Land Resource and Contamination Assessment | LOGGED | AM | CHECKED | BM | Sheet 1 OF 1 |
| SITE | Shoalhaven River (Pig Island), NSW | GEOLOGY | Quaternary Deposits | VEGETATION | N/A | PROJECT NO. P1806743 |
| EQUIPMENT | Vibrocore | EASTING | | RL SURFACE | -0.7 m | DATUM: AHD |
| EXCAVATION DIMENSIONS | Ø80 mm x 3.00 m depth | NORTHING | | ASPECT | West | SLOPE: <2% |

| Drilling | | | | | Sampling | | Field Material Description | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| METHOD | PENETRATION RESISTANCE | WATER | DEPTH (metres) | DEPTH RL | SAMPLE OR FIELD TEST | RECOVERED | GRAPHIC LOG | USCS / ASCS CLASSIFICATION | SOIL/ROCK MATERIAL DESCRIPTION | MOISTURE CONDITION | CONSISTENCY DENSITY | STRUCTURE AND ADDITIONAL OBSERVATIONS |
| VC | L | Drilled Over Water | | -0.70 | 6743/VC303/0.0-0.5/S/1 D 0.00 m<br>6743/VC303/0.0-0.5/S/2 D 0.00 m | | | SP | SAND; fine to medium grained; brown-grey. | W | | ALLUVIUM |
| | | | 0.5 | 0.50 / -1.20 | 6743/VC303/0.5-0.8/S/1 D 0.50 m<br>6743/VC303/0.5-0.8/S/2 D 0.50 m | | | ML | Clayey SILT; low plasticity; dark grey. | | | |
| | | | 1.0 | 0.80 / -1.50 | 6743/VC303/0.9-1.3/S/1 D 0.90 m<br>6743/VC303/0.9-1.3/S/2 D 0.90 m | | | SP | SAND; medium to coarse grained; brown-grey. | | | |
| | | | 1.5 | | 6743/VC303/1.5-2.1/S/1 D 1.50 m | | | | | | | |
| | M-H | | 2.0 / 2.5 | 2.00 / -2.70 | | | | | Trace subangular, fine grained, lithic gravel. | | | |
| | H | | | | 6743/VC303/2.7-3.0/S/1 D 2.70 m<br>6743/VC303/2.7-3.0/S/2 D 2.70 m | | | | | | | |
| | | | 3.0 | 3.00 | | | | | Hole Terminated at 3.00 m | | | 3.00: Terminated due to high penetration resistance. |
| | | | 3.5 | | | | | | | | | |
| | | | 4.0 | | | | | | | | | |
| | | | 4.5 | | | | | | | | | |

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



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

**Engineering Log - TEST**

MARTENS 2.00 LIB.GLB Log MARTENS BOREHOLE P1806743BHVC301,VC302A,VC302B,VC303,VC304A,VC304B.GPJ <<DrawingFile>> 05/03/2019 13:25 8.30.004 Datgel Lab and In Situ Tool - DGD | Lib: Martens 2.00 2016-11-13 Prj: Martens 2.00 2016-11-13

| CLIENT | Terara Shoalhaven Sand Pty Ltd | COMMENCED | 18/09/2018 | COMPLETED | 18/09/2018 | REF VC304A |
|---|---|---|---|---|---|---|
| PROJECT | Land Resource and Contamination Assessment | LOGGED | AM | CHECKED | BM | Sheet 1 OF 1 |
| SITE | Shoalhaven River (Pig Island), NSW | GEOLOGY | Quaternary Deposits | VEGETATION | N/A | PROJECT NO. P1806743 |
| EQUIPMENT | Vibrocore | EASTING | | RL SURFACE | -0.2 m | DATUM: AHD |
| EXCAVATION DIMENSIONS | Ø80 mm x 3.40 m depth | NORTHING | | ASPECT | West | SLOPE: <2% |

| METHOD | PENETRATION RESISTANCE | WATER | DEPTH (metres) | DEPTH / RL | SAMPLE OR FIELD TEST | RECOVERED | USCS / ASCS CLASSIFICATION | SOIL/ROCK MATERIAL DESCRIPTION | MOISTURE CONDITION | CONSISTENCY DENSITY | STRUCTURE AND ADDITIONAL OBSERVATIONS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| VC | L | Drilled Over Water | | -0.20 | 6743/VC304A/0.0-0.2/S/1 D 0.00 m; 6743/VC304A/0.0-0.2/S/2 D 0.00 m | | SP | SAND; fine to medium grained; brown-grey; trace silt. | W | | ALLUVIUM |
| | | | | 0.20 / -0.40 | | | SP | SAND; fine to medium grained, brown-grey. | | | |
| | | | 0.5 | | 6743/VC304A/0.4-0.6/S/1 D 0.40 m; 6743/VC304A/0.4-0.6/S/2 D 0.40 m | | | | | | |
| | | | | 0.90 / -1.10 | | | | Trace wood. | | | |
| | L-M | | 1.0 | | 6743/VC304A/1.0-1.2/S/1 D 1.00 m | | | | | | |
| | | | 1.5 | | 6743/VC304A/1.8-2.0/S/1 D 1.80 m | | | | | | |
| | M | | 2.0 | | 6743/VC304A/2.1-2.5/S/1 D 2.10 m | | | | | | |
| | | | 2.5 | | 6743/VC304A/2.5-2.7/S/1 D 2.50 m | | | | | | |
| | H | | 3.0 | 2.90 / -3.10 | 6743/VC304A/3.0-3.2/S/1 D 3.00 m; 6743/VC304A/3.2-3.4/S/1 D 3.20 m | | ML | Sandy SILT; low plasticity; dark grey; with wood. | | | |
| | | | 3.5 | 3.40 | | | | Hole Terminated at 3.40 m | | | 3.40: Terminated due to high penetration resistance from wood fragments. |
| | | | 4.0 | | | | | | | | |
| | | | 4.5 | | | | | | | | |

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

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



**Engineering Log - TEST**

| | | | | | | |
|---|---|---|---|---|---|---|
| CLIENT | Terara Shoalhaven Sand Pty Ltd | COMMENCED | 18/09/2018 | COMPLETED | 18/09/2018 | **REF VC304B** |
| PROJECT | Land Resource and Contamination Assessment | LOGGED | AM | CHECKED | BM | Sheet 1 OF 1 |
| SITE | Shoalhaven River (Pig Island), NSW | GEOLOGY | Quaternary Deposits | VEGETATION | N/A | PROJECT NO. P1806743 |
| EQUIPMENT | Vibrocore | EASTING | | RL SURFACE | -0.2 m | DATUM: AHD |
| EXCAVATION DIMENSIONS | Ø80 mm x 3.70 m depth | NORTHING | | ASPECT | West | SLOPE: <2% |

| METHOD | PENETRATION RESISTANCE | WATER | DEPTH (metres) | DEPTH / RL | SAMPLE OR FIELD TEST | RECOVERED | GRAPHIC LOG | USCS / ASCS CLASSIFICATION | SOIL/ROCK MATERIAL DESCRIPTION | MOISTURE CONDITION | CONSISTENCY DENSITY | STRUCTURE AND ADDITIONAL OBSERVATIONS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VC | L-M | Drilled Over Water | | -0.20 | 6743/VC304B/0.0-0.3/S/1 D 0.00 m | | | SP | SAND, fine to medium grained; brown-grey. | W | | ALLUVIUM |
| | | | 0.5 | 0.50 / -0.70 | | | | | Trace wood. | | | |
| | | | | | 6743/VC304B/0.7-1.0/S/1 D 0.70 m | | | | | | | |
| | | | 1.0 | | 6743/VC304B/1.0-1.5/S/1 D 1.00 m | | | | | | | |
| | | | 1.5 | | 6743/VC304B/1.5-1.7/S/1 D 1.50 m | | | | | | | |
| | M | | 2.0 | | 6743/VC304B/2.2-2.5/S/1 D 2.20 m | | | | | | | |
| | | | 2.5 | | | | | | | | | |
| | | | 3.0 | | | | | | | | | |
| | H | | | 3.20 / -3.40 | 6743/VC304B/3..2-3.4/S/1 D 3.20 m<br>6743/VC304B/3.2-3.7/S/1 D 3.20 m<br>6743/VC304B/3.4-3.7/S/1 D 3.40 m | | | SM | Silty SAND; fine to medium grained; brown-grey. | | | 3.20: to 3.7m: Partial core loss. |
| | | | 3.5 | 3.70 | | | | | | | | |
| | | | | | | | | | Hole Terminated at 3.70 m | | | 3.70: Terminated due to high penetration resistance. |
| | | | 4.0 | | | | | | | | | |
| | | | 4.5 | | | | | | | | | |

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

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



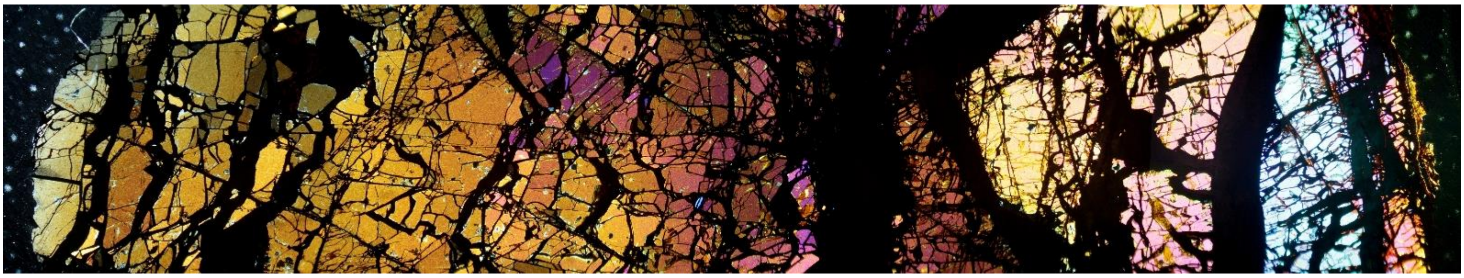
**Engineering Log - TEST**

MARTENS 2.00 LIB.GLB Log MARTENS BOREHOLE P1806743BHVC301,VC302A,VC302B,VC303,VC304A,VC304B.GPJ <<DrawingFile>> 05/03/2019 13:25 8.30.004 Datgel Lab and In Situ Tool - DGD | Lib: Martens 2.00 2016-11-13 Prj: Martens 2.00 2016-11-13

# 14 Attachment D – Representative Soil Unit Photos

Figure 3: Representative soil unit photos

# 15 Attachment E – Laboratory Reports



# Geochempet Services

**ABN 980 6945 3445**
**PETROLOGICAL and GEOCHEMICAL CONSULTANTS**
**Principals: K.E. Spring B.Sc.(Hons), MAppSc and H.M. Spring B.Sc.**

**5/14 Redcliffe Gardens Drive**
**Clontarf, QLD 4019**

**Telephone: (07) 3284 0020**

**Email: info@geochempet.com**
**www.geochempet.com**

## PETROGRAPHIC REPORT ON A SAND SAMPLE (6743/VC301/0.2-1.0m) FROM SHOALHAVEN RIVER

prepared for

**MARTENS & ASSOCIATES**
**HORNSBY, NSW**

Purchase Order: P1806743COC05V01

Invoice Number: 00008411

Client Ref: Andrew Mesthos

Issued by

C. A. Nix BAppSc MEngSc
15 October 2018

| | | | |
|---|---|---|---|
| **Sample Label**: | 6743/VC301/0.2-1.0m | **Date Sampled**: | 18/09/2018 |
| **Product**: | Sand | **Date Supplied**: | 27/09/2018 |
| **Sample Source**: | Shoalhaven River | **Date Received**: | 02/10/2018 |

**Work Requested** Petrographic analysis in relation to suitability for use as concrete sand;

**Methods** Account taken of ASTM C295 Standard Guide for *Petrographic Assessment of Aggregates for Concrete*, the AS2758.1 – 2014 *Aggregates and rock for engineering purposes part 1; Concrete aggregates (Appendix B)*, the AS1141 Standard Guide for the *Method for sampling and testing aggregates*, of the content of the 2015 joint publication of the Cement and Concrete Association of Australia and Standards Australia, (HB 79-2015) entitled *Alkali Aggregate Reaction - Guidelines on Minimising the Risk of Damage to Concrete Structures in Australia*

**Identification** Quartzose and lithic medium sand

**Description**

The sample consisted of about 2 kg of dark grey brown, coarse sand, dominated by variously coloured lithic fragments and free quartz grains.


**Figure 1:** Digital image of sub-sample from the supplied sand sample.

In a crude sieve test of a small dry subsample the following results were recorded,

| Sieve Size | Wt % of sample |
|---|---|
| Coarse (>1.18mm) | 14.5% |
| Medium (>0.3mm) | 71.5% |
| Fine (>0.075mm) | 13.4% |
| Silt (<0.075mm) | 0.6% |

The clasts are variously sub-angular to sub-rounded. The coarse and medium fraction contain minor plant matter. No deleterious grain coatings were detected using low-power binocular microscopy.

When a subsample was swirled in water it generated a persistent pale brown turbidity which with some argillaceous scum in a fashion consistent with a minor silt and clay present in the sample.

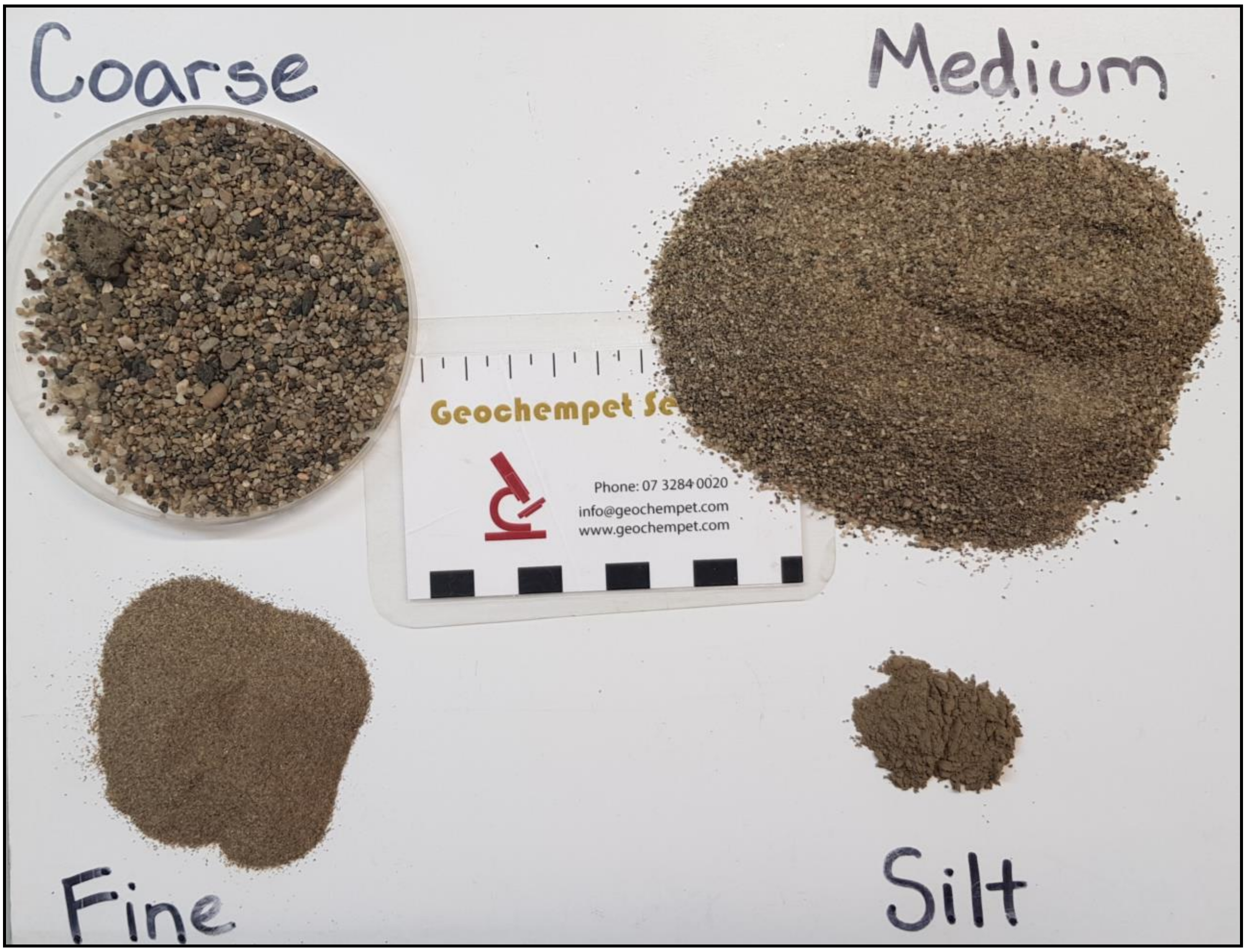



**Figure 2:** Digital image of sieve fractions recorded above.

**Figure 3:** Image of coarse sieve fraction showing common quartz and lithic clasts

A thin section was prepared for microscopic examination in transmitted polarized light. A count of 100 widely spaced points falling within sectioned sand clasts gave the following composition:

| | |
|---|---|
| 35% | quartz as unstrained or mildly strained free grains (29%) and as simple polycrystalline composites (6%) of quartz |
| 10% | moderately strained quartz as free grains |
| 2% | siliceous lithic clasts of cherty style |
| 7% | lithic clasts of quartzite (3% moderately strained) |
| 1% | lithic clasts of vein quartz (highly strained) |
| | |
| 2% | feldspar grains (K-feldspar and plagioclase) |
| 1% | free mica (muscovite and biotite) |
| | |
| 18% | lithic clasts of meta-arenite (12% quartz of which 4% is moderately strained) |
| 9% | lithic clasts of granite (7% quartz of which 3% is moderately strained) |
| 7% | lithic clasts of quartz-mica schist (2% quartz) |
| 1% | lithic clasts of intermediate volcanic rock |
| 1% | lithic clasts of acid volcanic/tuffaceous rock |
| | |
| 2% | ferruginous fragments |
| 2% | sericitized clasts |
| 1% | argillized clasts |
| 1% | charcoal / plant matter |

Free grains of unstrained or mildly strained quartz amount to about 29% and polycrystalline composite quartz fragments of similarly unstrained or more commonly mildly strained quartz amount to another 6%. Moderately strained quartz amounts to 10%: many such fragments mainly resemble vein fragments and many carry small amounts of other minerals interlocked with the quartz. Other richly siliceous clasts, amounting to 2%, are of impure cherty style (dominated by finely microcrystalline quartz), 7% quartzite and 1% highly strained vein quartz.

Free grains of feldspar amount to 2%, comprising of orthoclase and plagioclase. Free mica grains amount to about 1%.

Lithic clasts comprise acid volcanic/tuffaceous rock (1%), granite (9%), intermediate volcanics (1%), meta-arenite (18%) and quartz-mica schist (7%). Ferruginous fragments are also observed amounting to about 2%, along with sericitized clasts (2%) and argillized clasts (1%).

Plant matter and charcoal is present amounting to about 1%.

## Comments and Interpretations

The supplied Shoalhaven River sand sample (labelled 6743/VC301/0.2-1.0m) is considered to consist of quartzose and lithic sand, which may be regarded as essentially medium grained for engineering purposes. It appears to consist of water-worn river sand. The most abundant clasts in the coarse sand product are sand-sized free quartz grains and rock fragments.

The total free silica content (or quartz plus chert content) of the sand is estimated to be about **76%**, about 45% being free quartz or dominantly quartzose fragments, about 29% being quartz locked within lithic clasts and about 2% being cherty or finely microcrystalline quartz (in lithic clasts of chert and acid volcanic/tuffaceous rock).

Being composed of variously water-worn, sand-sized fragments of durable rock types and mineral grains, the coarse sand product is interpreted to be **physically suitable for use in concrete**.

Some mica is present, variously as free flakes (1%) and as 2% sericitized fragments (most likely after feldspars), which may slightly detract from the quality of the sand. Mica flakes are considered to be undesirable in concrete sand because they represent weak, flexible, cleavable and water absorbent minerals, and because the experience with natural sands is that they may segregate by floating during placement or working of concrete to weaken joints or finished surfaces. For natural sands it is commonly expected that liberated mica flakes should amount to less than about 2% in good quality concrete sand.

Specific components in the sand which are perceived to have potential for alkali-silica reaction in concrete comprise about 2% chert clasts (composed mainly of finely microcrystalline, potentially mildly reactive quartz), 20% moderately strained quartz (a mildly reactive form of quartz) and 1% highly strained quartz. Thus, the sand as a whole is predicted to have **potential for mild or slow deleterious alkali-silica reactivity in concrete.**

Thus, the supplied sand is interpreted to be **suitable for use in concrete**, provided that appropriate precautions are taken in mix and engineering design to take account of its perceived potential for mild or slow deleterious alkali-silica reactivity.

Guidance on appropriate precautions can be obtained from the 2015 joint publication of the *Cement and Concrete Association of Australia and Standards Australia*, entitled *Alkali Aggregate Reaction - Guidelines on Minimising the Risk of Damage to Concrete Structures in Australia*.

## Free Silica Content

The free silica content of the supplied product is about 76%.

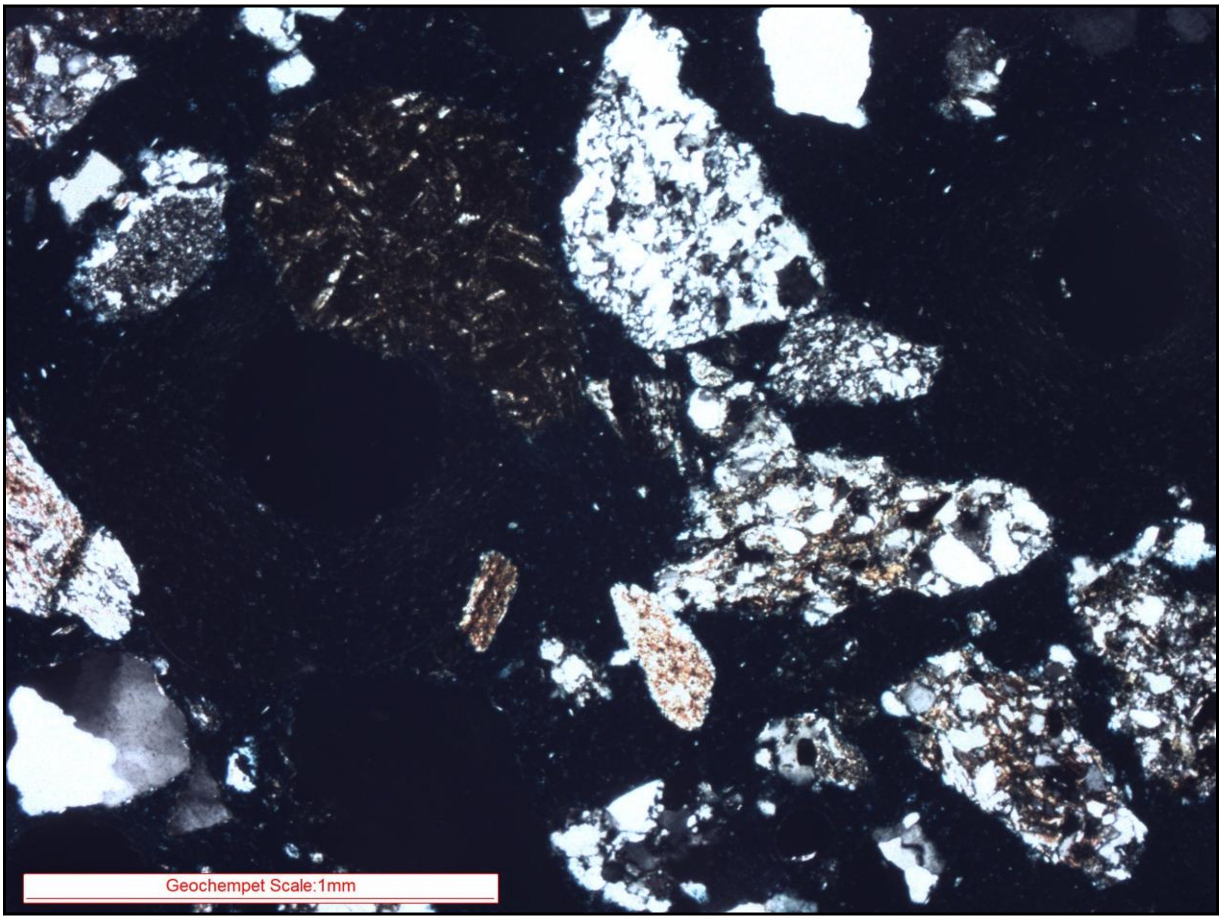
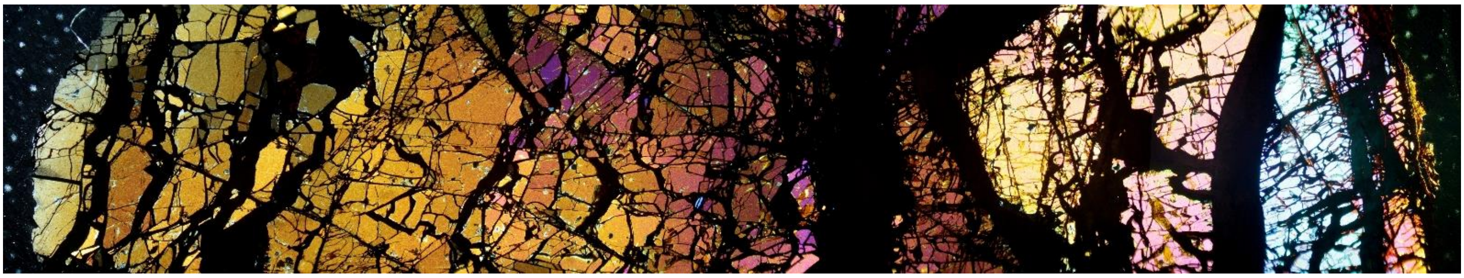



**Figure 4:** Micrograph of supplied sand sample, taken at low magnification with transmitted cross polarised light. Image shows free grains of quartz and numerous lithic clasts.



# Geochempet Services


**ABN 980 6945 3445**

**PETROLOGICAL and GEOCHEMICAL CONSULTANTS**

**Principals: K.E. Spring B.Sc.(Hons), MAppSc and H.M. Spring B.Sc.**

**5/14 Redcliffe Gardens Drive**
**Clontarf, QLD 4019**

**Telephone: (07) 3284 0020**

**Email: info@geochempet.com**
**www.geochempet.com**


## PETROGRAPHIC REPORT
## ON A SAND SAMPLE (6743/VC302B/2.8-3.4m)
## FROM SHOALHAVEN RIVER

prepared for

**MARTENS & ASSOCIATES**
**HORNSBY, NSW**

Purchase Order: P1806743COC05V01

Invoice Number: 00008411

Client Ref: Andrew Mesthos

Issued by

C. A. Nix BAppSc MEngSc
15 October 2018

**Sample Label**: 6743/VC302B/2.8-3.4m **Date Sampled**: 18/09/2018

**Product**: Sand **Date Supplied**: 27/09/2018

**Sample Source**: Shoalhaven River **Date Received**: 02/10/2018

**Work Requested** Petrographic analysis in relation to suitability for use as concrete sand;

**Methods** Account taken of ASTM C 295 Standard Guide for *Petrographic Assessment of Aggregates for Concrete*, the AS2758.1 – 2014 *Aggregates and rock for engineering purposes part 1; Concrete aggregates (Appendix B)*, the AS1141 Standard Guide for the *Method for sampling and testing aggregates*, of the content of the 2015 joint publication of the Cement and Concrete Association of Australia and Standards Australia, (HB 79-2015) entitled *Alkali Aggregate Reaction - Guidelines on Minimising the Risk of Damage to Concrete Structures in Australia*

**Identification** Quartzose and lithic medium sand

**Description**

The sample consisted of about 2 kg of dark grey brown, coarse sand, dominated by variously coloured lithic fragments and free quartz grains.


**Figure 1:** Digital image of sub-sample from the supplied sand sample.

In a crude sieve test of a small dry subsample the following results were recorded,

| Sieve Size | Wt % of sample |
|---|---|
| Coarse (>1.18mm) | 15.6% |
| Medium (>0.3mm) | 66.5% |
| Fine (>0.075mm) | 17.2% |
| Silt (<0.075mm) | 0.7% |

The clasts are variously sub-angular to sub-rounded. The coarse and medium fraction contain very minor plant matter. No deleterious grain coatings were detected using low-power binocular microscopy.

When a subsample was swirled in water it generated a persistent pale brown turbidity which with some argillaceous scum in a fashion consistent with a minor silt and clay present in the sample.

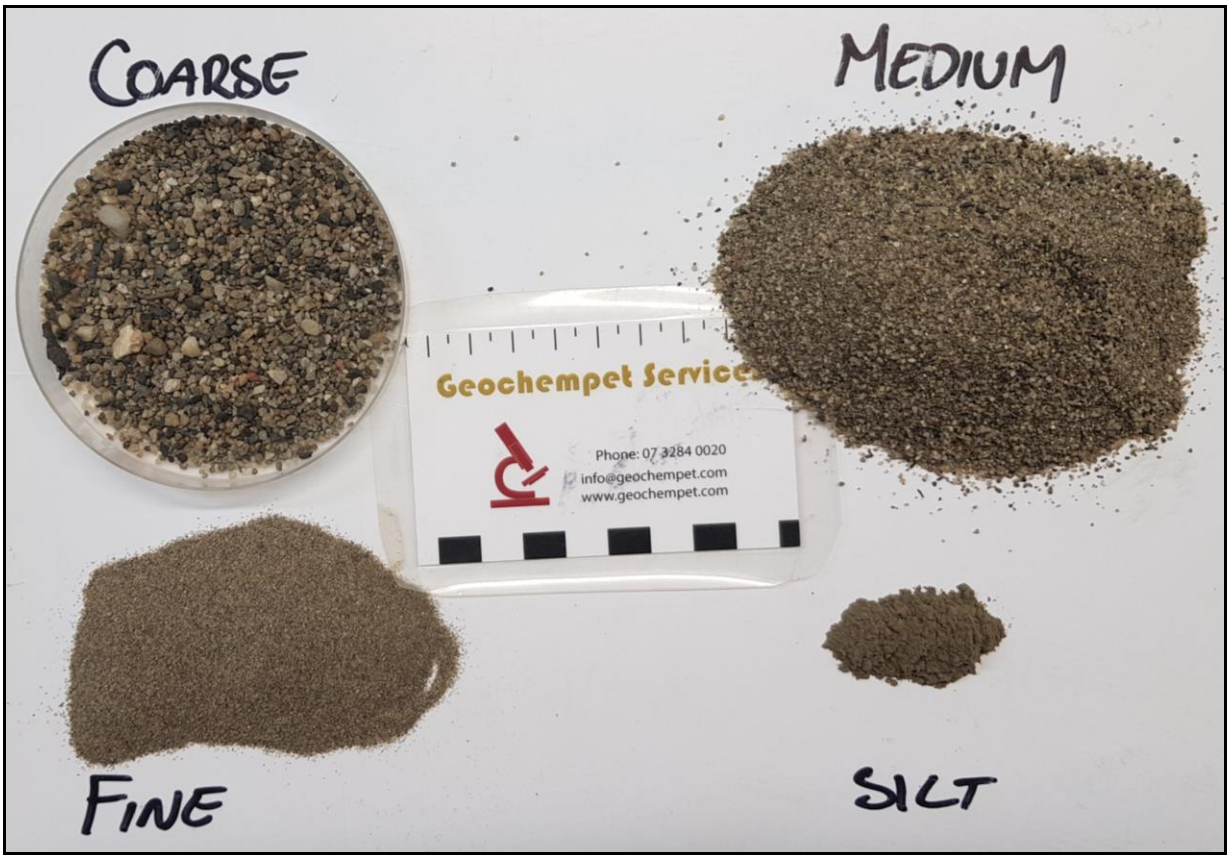



**Figure 2:** Digital image of sieve fractions recorded above.

**Figure 3:** Image of coarse sieve fraction showing abundance of quartz grains and lithic clasts.

A thin section was prepared for microscopic examination in transmitted polarized light. A count of 100 widely spaced points falling within sectioned sand clasts gave the following composition:

| | |
|---|---|
| 35% | quartz as unstrained or mildly strained free grains (30%) and as simple polycrystalline composites (5%) of quartz |
| 9% | moderately strained quartz as free grains |
| 2% | siliceous lithic clasts of cherty style |
| 10% | lithic clasts of quartzite (4% moderately strained) |
| 1% | lithic clasts of vein quartz (highly strained) |
| | |
| 3% | feldspar grains (K-feldspar and plagioclase) |
| 1% | free mica (muscovite and biotite) |
| | |
| 19% | lithic clasts of meta-arenite (12% quartz of which 3% is moderately strained) |
| 3% | lithic clasts of granite (1% quartz) |
| 6% | lithic clasts of quartz-mica schist (2% quartz) |
| 3% | lithic clasts of intermediate volcanic rock |
| 1% | lithic clasts of acid volcanic/tuffaceous rock |
| | |
| 2% | ferruginous fragments |
| 3% | sericitized clasts |
| 2% | argillized clasts |
| <1% | charcoal / plant matter |

Free grains of unstrained or mildly strained quartz amount to about 30% and polycrystalline composite quartz fragments of similarly unstrained or more commonly mildly strained quartz amount to another 5%. Moderately strained quartz amounts to 9%: many such fragments mainly resemble vein fragments and many carry small amounts of other minerals interlocked with the quartz. Other richly siliceous clasts, amounting to 2%, are of impure cherty style (dominated by finely microcrystalline quartz), 10% quartzite and 1% highly strained vein quartz.

Free grains of feldspar amount to 3%, comprising of orthoclase and plagioclase. Free mica grains amount to about 1%.

Lithic clasts comprise acid volcanic/tuffaceous rock (1%), granite (3%), intermediate volcanics (3%), meta-arenite (19%) and quartz-mica schist (6%). Ferruginous fragments are also observed amounting to about 2%, along with sericitized clasts (3%) and argillized clasts (2%).

Plant matter and charcoal is present amounting to less than 1%.

**Comments and Interpretations**

The supplied Shoalhaven River sand sample (labelled 6743/VC302B/2.8-3.4m) is considered to consist of quartzose and lithic sand, which may be regarded as essentially medium grained for engineering purposes. It appears to consist of water-worn river sand. The most abundant clasts in the coarse sand product are sand-sized free quartz grains and rock fragments.

The total free silica content (or quartz plus chert content) of the sand is estimated to be about **72%**, about 44% being free quartz or dominantly quartzose fragments, about 26% being quartz locked within lithic clasts and about 2% being cherty or finely microcrystalline quartz (in lithic clasts of chert and acid volcanic/tuffaceous rock).

Being composed of variously water-worn, sand-sized fragments of durable rock types and mineral grains, the coarse sand product is interpreted to be **physically suitable for use in concrete**.

Some mica is present, variously as free flakes (1%) and as 3% sericitized fragments (most likely after feldspars), which may slightly detract from the quality of the sand. Mica flakes are considered to be undesirable in concrete sand because they represent weak, flexible, cleavable and water absorbent minerals, and because the experience with natural sands is that they may segregate by floating during placement or working of concrete to weaken joints or finished surfaces. For natural sands it is commonly expected that liberated mica flakes should amount to less than about 2% in good quality concrete sand.

Specific components in the sand which are perceived to have potential for alkali-silica reaction in concrete comprise about 2% chert clasts (composed mainly of finely microcrystalline, potentially mildly reactive quartz), 16% moderately strained quartz (a mildly reactive form of quartz) and 1% highly strained quartz. Thus, the sand as a whole is predicted to have **potential for mild or slow deleterious alkali-silica reactivity in concrete.**

Thus, the supplied sand is interpreted to be **suitable for use in concrete**, provided that appropriate precautions are taken in mix and engineering design to take account of its perceived potential for mild or slow deleterious alkali-silica reactivity.

Guidance on appropriate precautions can be obtained from the 2015 joint publication of the *Cement and Concrete Association of Australia and Standards Australia*, entitled *Alkali Aggregate Reaction - Guidelines on Minimising the Risk of Damage to Concrete Structures in Australia*.

## Free Silica Content

The free silica content of the supplied product is about 72%.

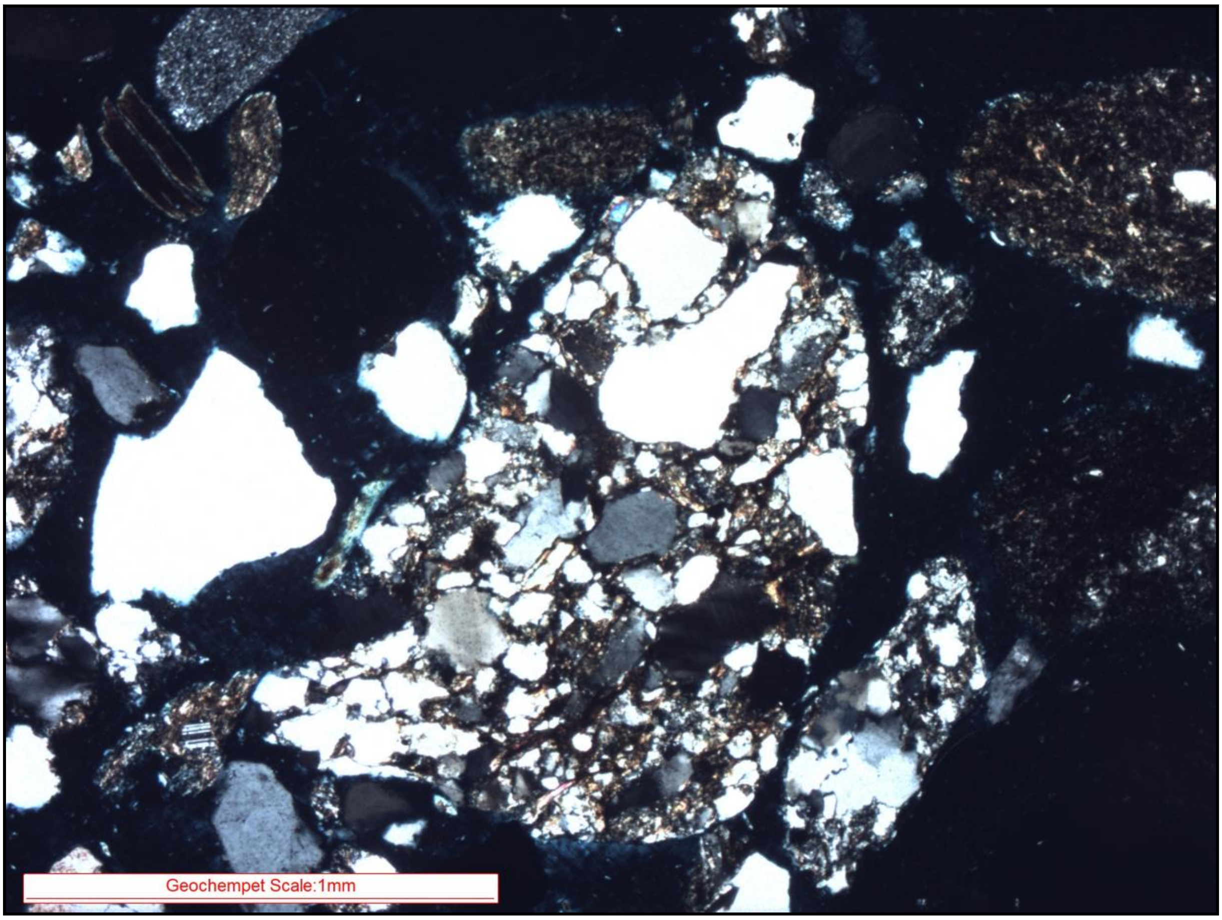
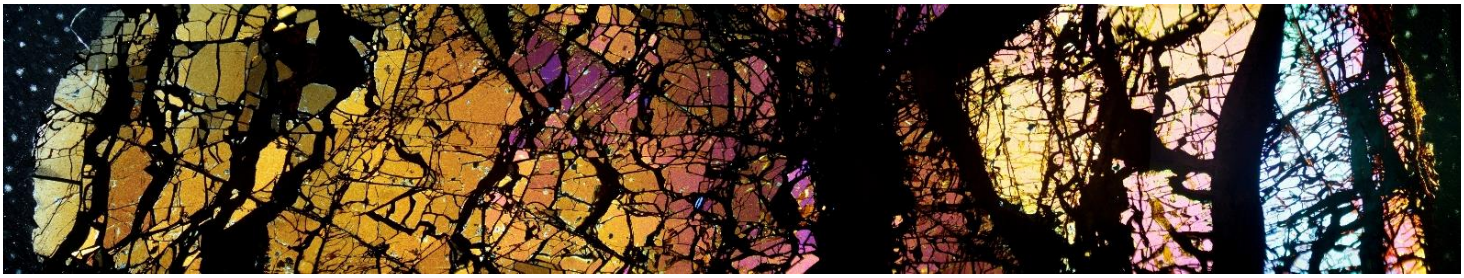



**Figure 4:** Micrograph of supplied sand sample, taken at low magnification with transmitted cross polarised light. Image shows free grains of quartz and numerous lithic clasts.



# Geochempet Services


**ABN 980 6945 3445**

**PETROLOGICAL and GEOCHEMICAL CONSULTANTS**

**Principals: K.E. Spring B.Sc.(Hons), MAppSc and H.M. Spring B.Sc.**

**5/14 Redcliffe Gardens Drive**
**Clontarf, QLD 4019**

**Telephone: (07) 3284 0020**

**Email: info@geochempet.com**
**www.geochempet.com**


## PETROGRAPHIC REPORT
## ON A SAND SAMPLE (6743/VC304B/1.0-1.5m)
## FROM SHOALHAVEN RIVER

prepared for

**MARTENS & ASSOCIATES**
**HORNSBY, NSW**

Purchase Order: P1806743COC05V01

Invoice Number: 00008411

Client Ref: Andrew Mesthos

Issued by

C. A. Nix BAppSc MEngSc
15 October 2018

| | | | |
|---|---|---|---|
| **Sample Label**: | 6743/VC304B/1.0-1.5m | **Date Sampled**: | 18/09/2018 |
| **Product**: | Sand | **Date Supplied**: | 27/09/2018 |
| **Sample Source**: | Shoalhaven River | **Date Received**: | 02/10/2018 |

**Work Requested** Petrographic analysis in relation to suitability for use as concrete sand;

**Methods** Account taken of ASTM C295 Standard Guide for *Petrographic Assessment of Aggregates for Concrete*, the AS2758.1 – 2014 *Aggregates and rock for engineering purposes part 1; Concrete aggregates (Appendix B)*, the AS1141 Standard Guide for the *Method for sampling and testing aggregates*, of the content of the 2015 joint publication of the Cement and Concrete Association of Australia and Standards Australia, (HB 79-2015) entitled *Alkali Aggregate Reaction - Guidelines on Minimising the Risk of Damage to Concrete Structures in Australia*

**Identification** Quartzose and lithic medium to fine sand

**Description**

The sample consisted of about 2 kg of dark grey brown, coarse sand, dominated by variously coloured lithic fragments and free quartz grains.


**Figure 1:** Digital image of sub-sample from the supplied sand sample.

In a crude sieve test of a small dry subsample the following results were recorded,

| Sieve Size | Wt % of sample |
|---|---|
| Coarse (>1.18mm) | 1.1% |
| Medium (>0.3mm) | 72.7% |
| Fine (>0.075mm) | 25.7% |
| Silt (<0.075mm) | 0.5% |

The clasts are variously sub-angular to sub-rounded. The minor coarse fraction contains common plant matter. No deleterious grain coatings were detected using low-power binocular microscopy.

When a subsample was swirled in water it generated a persistent pale brown turbidity which with some argillaceous scum in a fashion consistent with a minor silt and clay present in the sample.

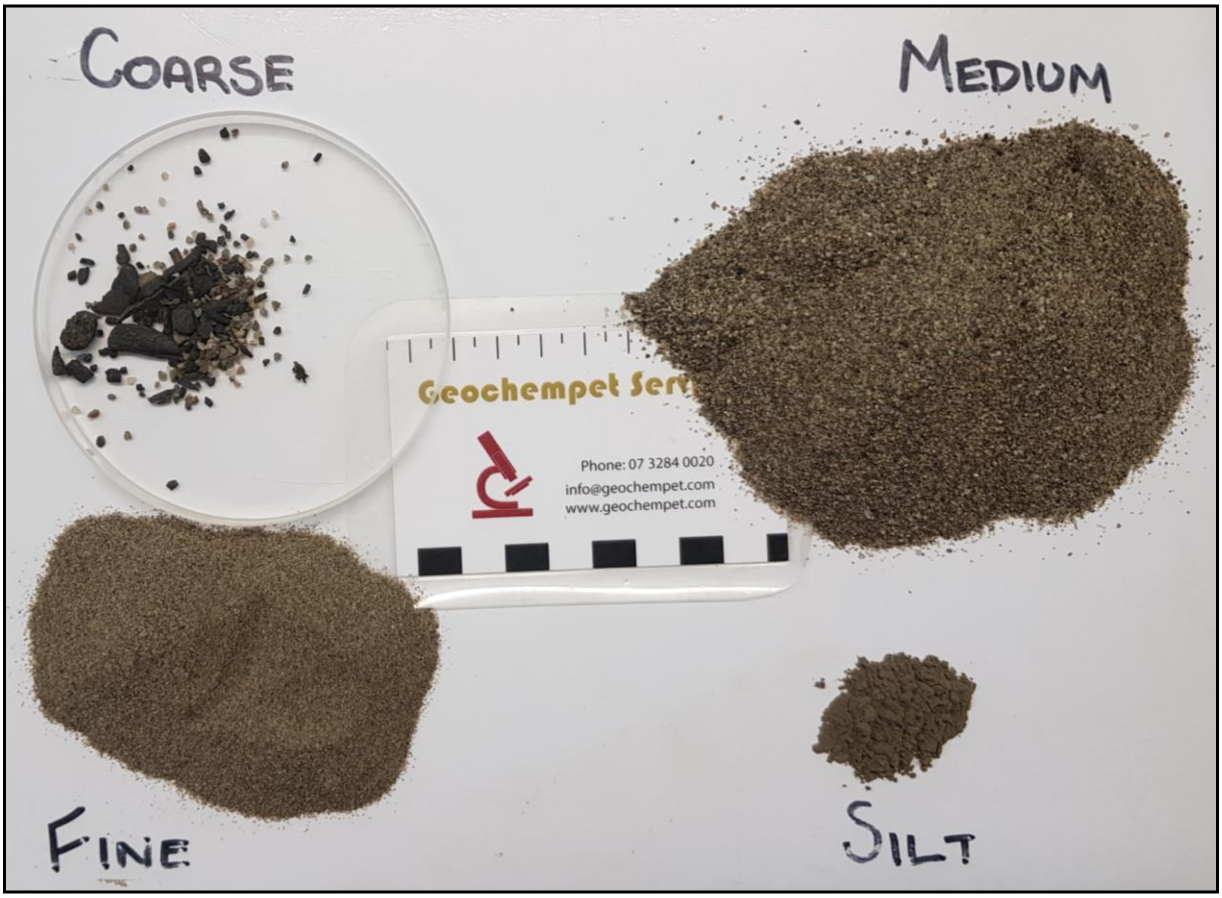



**Figure 2:** Digital image of sieve fractions recorded above.

**Figure 3:** Image of coarse sieve fraction showing abundance of quartz grains and lithic clasts. Note the charcoal fragments and plant matter in this fraction.

A thin section was prepared for microscopic examination in transmitted polarized light. A count of 100 widely spaced points falling within sectioned sand clasts gave the following composition:

| | |
|---|---|
| 27% | quartz as unstrained or mildly strained free grains (24%) and as simple polycrystalline composites (3%) of quartz |
| 8% | moderately strained quartz as free grains |
| <1% | siliceous lithic clasts of cherty style |
| 9% | lithic clasts of quartzite (4% moderately strained) |
| <1% | lithic clasts of vein quartz (highly strained) |
| | |
| 6% | feldspar grains (K-feldspar and plagioclase) |
| 1% | free mica (muscovite and biotite) |
| | |
| 25% | lithic clasts of meta-arenite (8% quartz of which 2% is moderately strained) |
| 3% | lithic clasts of granite (1% quartz) |
| 7% | lithic clasts of quartz-mica schist (<1% quartz) |
| 3% | lithic clasts of intermediate volcanic rock |
| 1% | lithic clasts of acid volcanic/tuffaceous rock |
| | |
| 2% | ferruginous fragments |
| 4% | sericitized clasts |
| 2% | argillized clasts |

2% charcoal / plant matter

Free grains of unstrained or mildly strained quartz amount to about 24% and polycrystalline composite quartz fragments of similarly unstrained or more commonly mildly strained quartz amount to another 3%. Moderately strained quartz amounts to 8%: many such fragments mainly resemble vein fragments and many carry small amounts of other minerals interlocked with the quartz. Other richly siliceous clasts, amounting to <1%, are of impure cherty style (dominated by finely microcrystalline quartz), 9% quartzite and <1% highly strained vein quartz.

Free grains of feldspar amount to 6%, comprising of orthoclase and plagioclase. Free mica grains amount to about 1%.

Lithic clasts comprise acid volcanic/tuffaceous rock (1%), granite (3%), intermediate volcanics (3%), meta-arenite (25%) and quartz-mica schist (7%). Ferruginous fragments are also observed amounting to about 2%, along with sericitized clasts (4%) and argillized clasts (2%).

Plant matter and charcoal is present amounting to less than 4%.

**Comments and Interpretations**

The supplied Shoalhaven River sand sample (labelled 6743/VC304B/1.0-1.5m) is considered to consist of quartzose and lithic sand, which may be regarded as essentially medium to fine grained for engineering purposes. It appears to consist of water-worn river sand. The most abundant clasts in the coarse sand product are sand-sized free quartz grains and rock fragments.

The total free silica content (or quartz plus chert content) of the sand is estimated to be about **53%**, about 35% being free quartz or dominantly quartzose fragments, about 18% being quartz locked within lithic clasts and about <1% being cherty or finely microcrystalline quartz (in lithic clasts of chert and acid volcanic/tuffaceous rock).

Being composed of variously water-worn, sand-sized fragments of durable rock types and mineral grains, the coarse sand product is interpreted to be **physically suitable for use in concrete**.

Some mica is present, variously as free flakes (1%) and as 4% sericitized fragments (most likely after feldspars), which may detract from the quality of the sand. Mica flakes are considered to be undesirable in concrete sand because they represent weak, flexible, cleavable and water absorbent minerals, and because the experience with natural sands is that they may segregate by floating during placement or working of concrete to weaken joints or finished surfaces. For natural sands it is commonly expected that liberated mica flakes should amount to less than about 2% in good quality concrete sand. Conspicuous charcoal fragments (2%) are present in the sand and care is required to keep abundance to low levels. About 2% carbonaceous matter is considered to be the maximum allowable amount in a concrete product.

Specific components in the sand which are perceived to have potential for alkali-silica reaction in concrete comprise about <1% chert clasts (composed mainly of finely microcrystalline, potentially mildly reactive quartz), 14% moderately strained quartz (a mildly reactive form of quartz) and <1% highly strained quartz. Thus, the sand as a whole is predicted to have **potential for mild or slow deleterious alkali-silica reactivity in concrete.**

Thus, the supplied sand is interpreted to be **suitable for use in concrete**, provided that appropriate precautions are taken in mix and engineering design to take account of its perceived potential for mild or slow deleterious alkali-silica reactivity.

Guidance on appropriate precautions can be obtained from the 2015 joint publication of the *Cement and Concrete Association of Australia and Standards Australia*, entitled *Alkali Aggregate Reaction - Guidelines on Minimising the Risk of Damage to Concrete Structures in Australia*.

## Free Silica Content

The free silica content of the supplied product is about 53%.

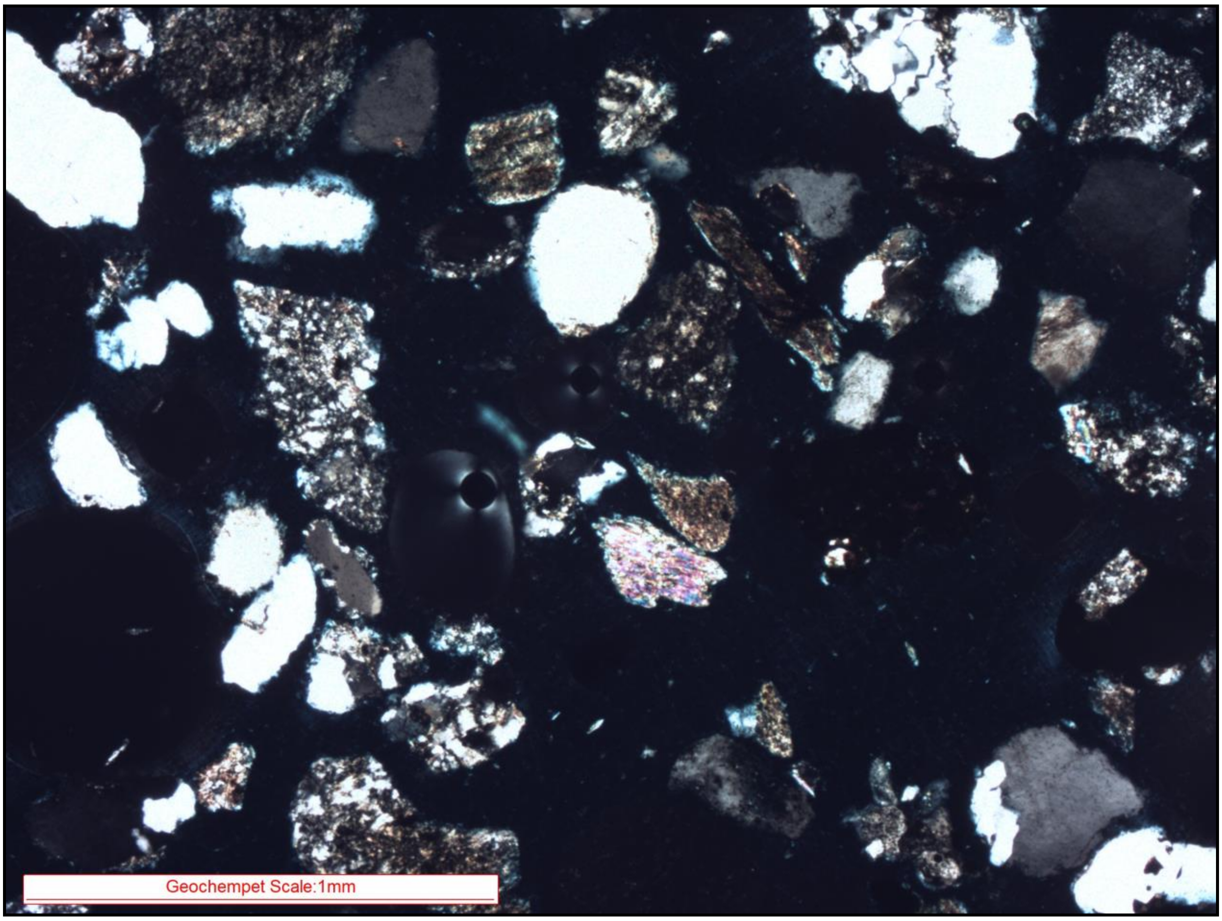



**Figure 4:** Micrograph of supplied sand sample, taken at low magnification with transmitted cross polarised light. Image shows free grains of quartz and numerous lithic clasts.

resource laboratories
AGGREGATE, ROCK, AND SOIL TESTING
**ABN:** 25 131 532 020
**Sydney:** 12/1 Boden Road Seven Hills NSW 2147 | PO Box 45 Pendle Hill NSW 2145
**Ph:** (02) 9674 7711 | **Fax:** (02) 9674 7755 | **Email:** info@resourcelab.com.au

# Test Report

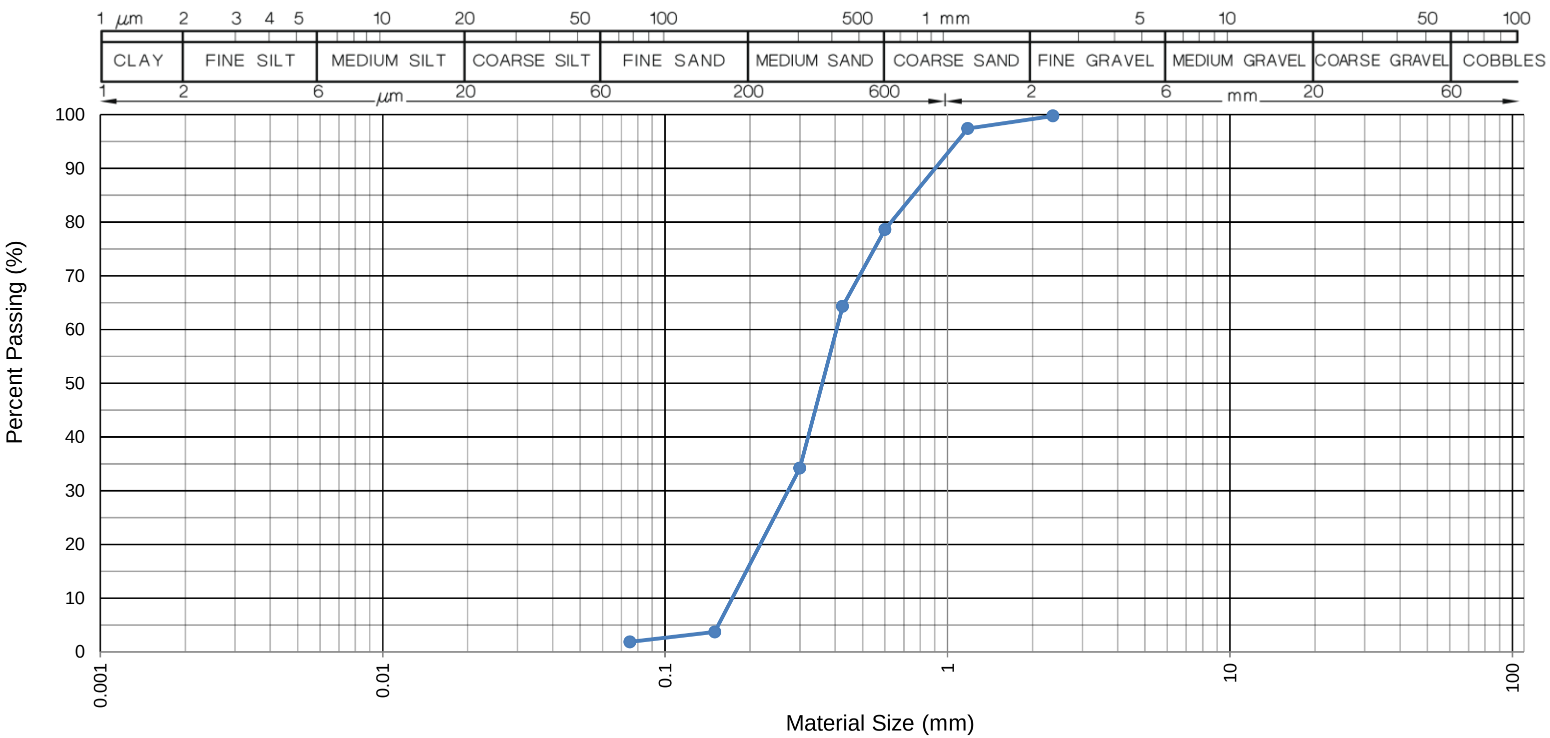
## Particle Size Distribution

**Customer:** Martens & Associates Pty Ltd
**Project:** P1806743
**Location:** Terara Sands, NSW

**Job number:** 18-0138
**Report number:** 1
**Page:** 1 of 3

**Date sampled:** 18/09/2018
**Sampling method:** Sample tested as received
**Test method(s):** AS 1289.1.1, 3.6.1

**Material description:** SAND, trace of silt, grey/dark grey
**Laboratory sample no. :** 16513
**Customer sample no.:** 6743/VC302A/1.1-1.6




| AS Sieve | % Passing |
|---|---|
| 2.36mm | 100 |
| 1.18mm | 97 |
| 600µm | 79 |
| 425µm | 64 |
| 300µm | 34 |
| 150µm | 4 |
| 75µm | 2 |

**Notes:**

**Approved Signatory:** E. Maldonado

**Date:** 05/10/2018

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accredited for compliance with ISO/IEC 17025.

NATA Accredited Laboratory Number: **17062**

ABN: 25 131 532 020
**Sydney:** 12/1 Boden Road Seven Hills NSW 2147 | PO Box 45 Pendle Hill NSW 2145
**Ph:** (02) 9674 7711 | **Fax:** (02) 9674 7755 | **Email:** info@resourcelab.com.au

# Test Report

## Particle Size Distribution

**Customer:** Martens & Associates Pty Ltd
**Project:** P1806743
**Location:** Terara Sands, NSW

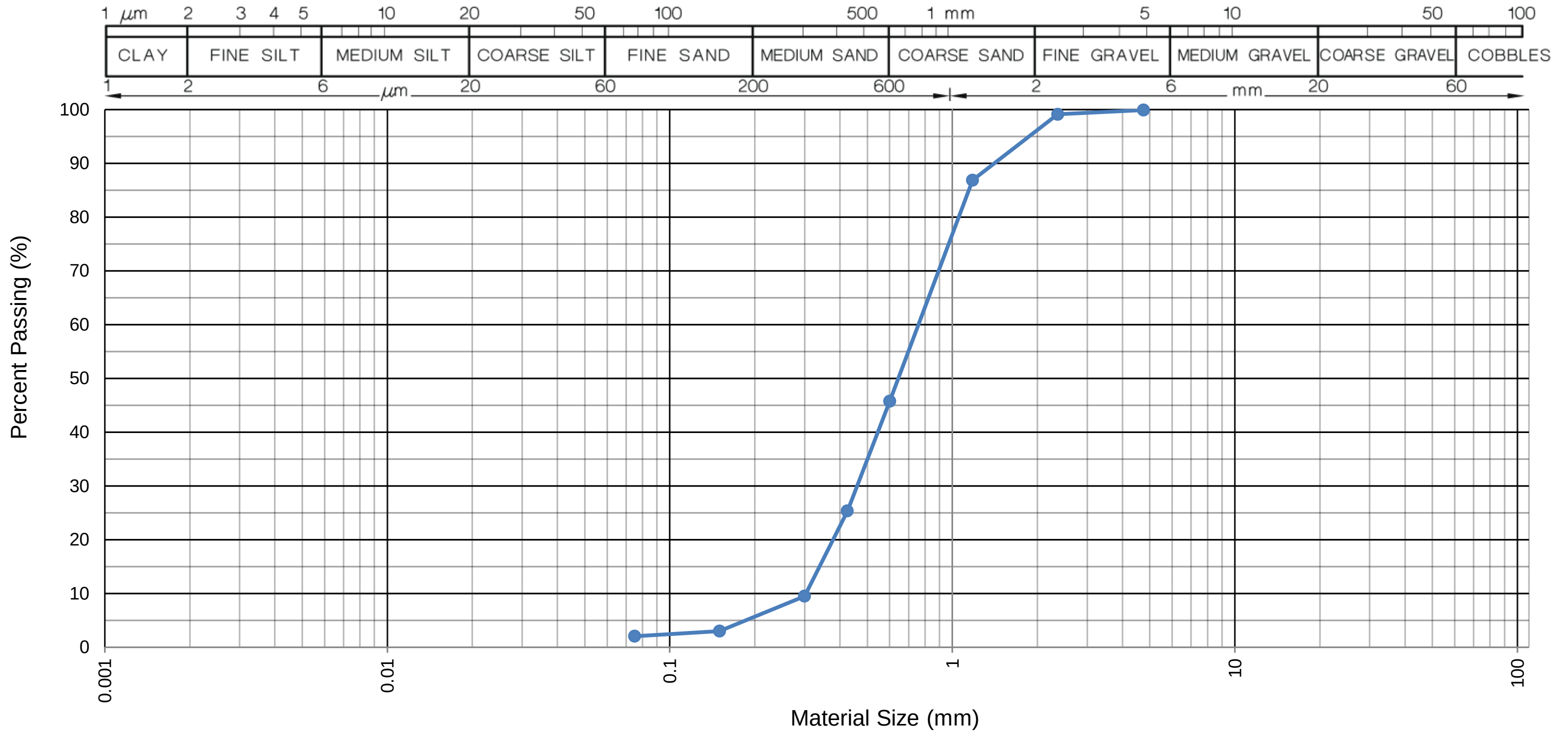
**Job number:** 18-0138
**Report number:** 1


**Date sampled:** 18/09/2018
**Sampling method:** Sample tested as received
**Test method(s):** AS 1289.1.1, 3.6.1

**Material description:** SAND, trace of silt and gravel, grey/ dark grey

**Laboratory sample no. :** 16514

**Customer sample no.:** 6743/VC303/1.5-2.1




| AS Sieve | % Passing |
|---|---|
| 4.75mm | 100 |
| 2.36mm | 99 |
| 1.18mm | 87 |
| 600µm | 46 |
| 425µm | 25 |
| 300µm | 10 |
| 150µm | 3 |
| 75µm | 2 |

**Notes:**

**Approved Signatory:** E. Maldonado

**Date:** 05/10/2018

Accredited for compliance with ISO/IEC 17025.

NATA Accredited Laboratory Number: **17062**

resource laboratories
AGGREGATE, ROCK, AND SOIL TESTING
**ABN:** 25 131 532 020
**Sydney:** 12/1 Boden Road Seven Hills NSW 2147 | PO Box 45 Pendle Hill NSW 2145
**Ph:** (02) 9674 7711 | **Fax:** (02) 9674 7755 | **Email:** info@resourcelab.com.au

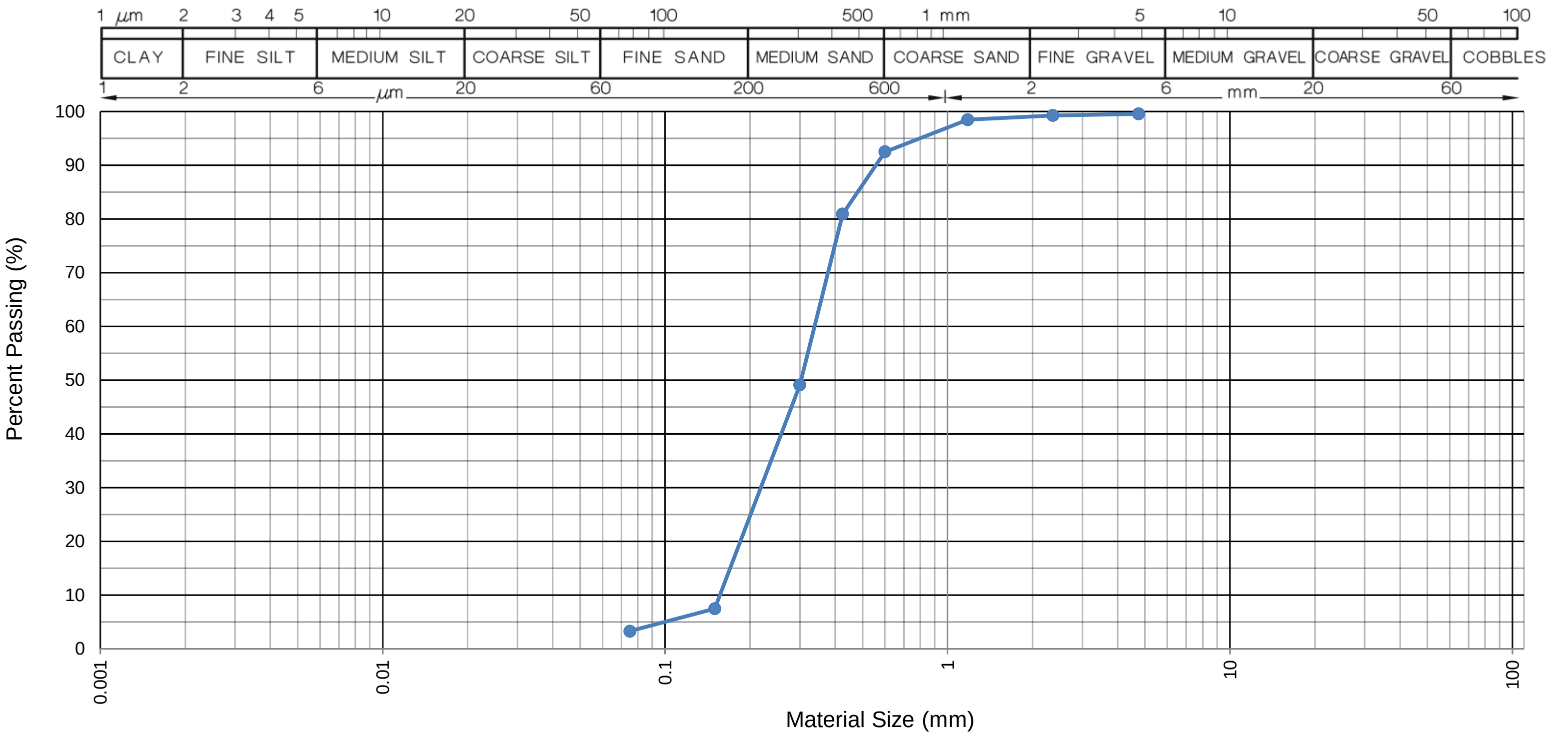
# Test Report
## Particle Size Distribution

**Customer:** Martens & Associates Pty Ltd
**Project:** P1806743
**Location:** Terara Sands, NSW

**Job number:** 18-0138
**Report number:** 1


**Date sampled:** 18/09/2018
**Sampling method:** Sample tested as received
**Test method(s):** AS 1289.1.1, 3.6.1

**Material description:** SAND, trace of silt and gravel, grey/ dark grey
**Laboratory sample no. :** 16515
**Customer sample no.:** 6743/VC304A/2.1-2.5




| AS Sieve | % Passing |
|---|---|
| 4.75mm | 100 |
| 2.36mm | 99 |
| 1.18mm | 98 |
| 600µm | 92 |
| 425µm | 81 |
| 300µm | 49 |
| 150µm | 7 |
| 75µm | 3 |

**Notes:**

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

**Approved Signatory:** E. Maldonado

**Date:** 05/10/2018

Accredited for compliance with ISO/IEC 17025.

NATA Accredited Laboratory Number: **17062**

# 16 Attachment F – General Geotechnical Recommendations

# Geotechnical Recommendations



martens consulting engineers

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

**Batter Slopes**

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

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

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

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

**Earthworks**

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

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

**Excavations**

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

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

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

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

**Fill**

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

**Foundations**

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

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

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

**Shoring - Anchors**

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

**Shoring - Permanent**

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

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

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

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

**Shoring - Temporary**

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

**Soil Erosion Control**

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

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

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

**Trafficability and Access**

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

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

**Vibration Management**

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

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

**Waste – Spoil and Water**

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

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

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

**Water Management - Groundwater**

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

**Water Management – Surface Water**

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

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

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

**Contingency Plan**

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

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

# 17 Attachment G – Notes About This Report

# Information



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

**Engineering Reports - Limitations**

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

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

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

**Engineering Reports – Project Specific Criteria**

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

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

**Engineering Reports – Recommendations**

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

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

**Engineering Reports – Use for Tendering Purposes**

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

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

**Engineering Reports – Data**

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

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

**Engineering Reports – Other Projects**

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

**Subsurface Conditions - General**

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

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

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

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

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

### Subsurface Conditions - Changes

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

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

### Subsurface Conditions - Site Anomalies

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

### Report Use by Other Design Professionals

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

### Subsurface Conditions – Geo-environmental Issues

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

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

### Responsibility

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

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

### Site Inspections

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

## Definitions

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

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

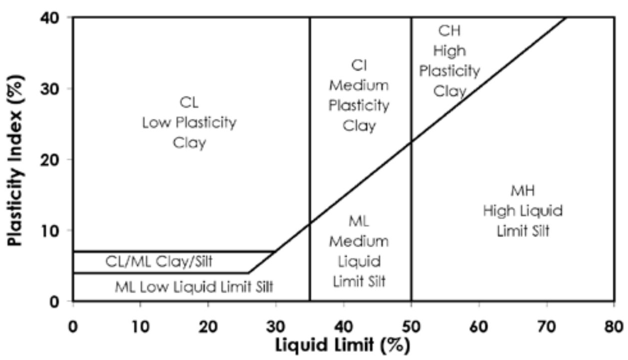
## Particle Size

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

| Division | Subdivision | Size (mm) |
|---|---|---|
| BOULDERS | | >200 |
| COBBLES | | 63 to 200 |
| GRAVEL | Coarse | 20 to 63 |
| | Medium | 6 to 20 |
| | Fine | 2.36 to 6 |
| SAND | Coarse | 0.6 to 2.36 |
| | Medium | 0.2 to 0.6 |
| | Fine | 0.075 to 0.2 |
| SILT | | 0.002 to 0.075 |
| CLAY | | < 0.002 |

## Plasticity Properties

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




## Moisture Condition

| | |
|---|---|
| Dry | Looks and feels dry. Cohesive and cemented soils are hard, friable or powdery. Uncemented granular soils run freely through hands. |
| Moist | Soil feels cool and damp and is darkened in colour. Cohesive soils can be moulded. Granular soils tend to cohere. |
| Wet | As for moist but with free water forming on hands when handled. |

## Consistency of Cohesive Soils

Cohesive soils refer to predominantly clay materials.

| Term | $C_u$ (kPa) | Approx. SPT "N" | Field Guide |
|---|---|---|---|
| Very Soft | <12 | 2 | A finger can be pushed well into the soil with little effort. Sample extrudes between fingers when squeezed in fist. |
| Soft | 12 - 25 | 2 – 4 | A finger can be pushed into the soil to about 25mm depth. Easily moulded in fingers. |
| Firm | 25 - 50 | 4 – 8 | The soil can be indented about 5mm with the thumb, but not penetrated. Can be moulded by strong pressure in the figures. |
| Stiff | 50 - 100 | 8 – 15 | The surface of the soil can be indented with the thumb, but not penetrated. Cannot be moulded by fingers. |
| Very Stiff | 100 - 200 | 15 – 30 | The surface of the soil can be marked, but not indented with thumb pressure. Difficult to cut with a knife. Thumbnail can readily indent. |
| Hard | > 200 | > 30 | The surface of the soil can be marked only with the thumbnail. Brittle. Tends to break into fragments. |
| Friable | - | - | Crumbles or powders when scraped by thumbnail. |

## Density of Granular Soils

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

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

* Values may be subject to corrections for overburden pressures and equipment type.

## Minor Components

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

| Term | Assessment | Proportion of Minor component In: |
|---|---|---|
| Trace of | Presence just detectable by feel or eye. Soil properties little or no different to general properties of primary component. | Coarse grained soils: < 5 %<br>Fine grained soils: < 15 % |
| With some | Presence easily detectable by feel or eye. Soil properties little different to general properties of primary component. | Coarse grained soils: 5 – 12 %<br>Fine grained soils: 15 – 30 % |

## Symbols for Soils and Other

| SOILS | | OTHER |
|---|---|---|
| COBBLES/BOULDERS | SILT (ML OR MH) | FILL |
| GRAVEL (GP OR GW) | ORGANIC SILT (OH) | TALUS |
| SILTY GRAVEL (GM) | CLAY (CL, CI OR CH) | ASPHALT |
| CLAYEY GRAVEL (GC) | SILTY CLAY | CONCRETE |
| SAND (SP OR SW) | SANDY CLAY | |
| SILTY SAND (SM) | PEAT | |
| CLAYEY SAND (SC) | TOPSOIL | |

## Unified Soil Classification Scheme (USCS)

| FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 63 mm and basing fractions on estimated mass) | | | | | | USCS | Primary Name |
|---|---|---|---|---|---|---|---|
| COARSE GRAINED SOILS More than 50 % of material less than 63 mm is larger than 0.075 mm | (A 0.075 mm particle is about the smallest particle visible to the naked eye) | GRAVELS More than half of coarse fraction is larger than 2.0 mm. | CLEAN GRAVELS (Little or no fines) | Wide range in grain size and substantial amounts of all intermediate particle sizes. | | GW | Gravel |
| | | | | Predominantly one size or a range of sizes with more intermediate sizes missing | | GP | Gravel |
| | | | GRAVELS WITH FINES (Appreciable amount of fines) | Non-plastic fines (for identification procedures see ML below) | | GM | Silty Gravel |
| | | | | Plastic fines (for identification procedures see CL below) | | GC | Clayey Gravel |
| | | SANDS More than half of coarse fraction is smaller than 2.0 mm | CLEAN SANDS (Little or no fines) | Wide range in grain sizes and substantial amounts of intermediate sizes missing. | | SW | Sand |
| | | | | Predominantly one size or a range of sizes with some intermediate sizes missing | | SP | Sand |
| | | | SANDS WITH FINES (Appreciable amount of fines) | Non-plastic fines (for identification procedures see ML below) | | SM | Silty Sand |
| | | | | Plastic fines (for identification procedures see CL below) | | SC | Clayey Sand |
| FINE GRAINED SOILS More than 50 % of material less than 63 mm is smaller than 0.075 mm | | IDENTIFICATION PROCEDURES ON FRACTIONS < 0.2 MM | | | | | |
| | | DRY STRENGTH (Crushing Characteristics) | DILATANCY | TOUGHNESS | DESCRIPTION | USCS | Primary Name |
| | | None to Low | Quick to Slow | None | Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity | ML | Silt |
| | | Medium to High | None | Medium | Inorganic clays of low to medium plasticity [1], gravely clays, sandy clays, silty clays, lean clays | CL [2] | Clay |
| | | Low to Medium | Slow to Very Slow | Low | Organic slits and organic silty clays of low plasticity | OL | Organic Silt |
| | | Low to Medium | Slow to Very Slow | Low to Medium | Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts | MH | Silt |
| | | High | None | High | Inorganic clays of high plasticity, fat clays | CH | Clay |
| | | Medium to High | None | Low to Medium | Organic clays of medium to high plasticity | OH | Organic Silt |
| HIGHLY ORGANIC SOILS | | Readily identified by colour, odour, spongy feel and frequently by fibrous texture | | | | Pt | Peat |

**Notes:**

1. Low Plasticity – Liquid Limit $W_L$ < 35 % Medium Plasticity – Liquid limit $W_L$ 35 to 60 % High Plasticity - Liquid limit $W_L$ > 60 %.
2. CI may be adopted for clay of medium plasticity to distinguish from clay of low plasticity.

## Soil Agricultural Classification Scheme

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

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

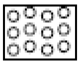
# Rock Data

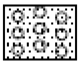


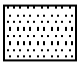
## Symbols for Rock

### SEDIMENTARY ROCK

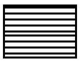
 BRECCIA

 CONGLOMERATE

 CONGLOMERATIC SANDSTONE

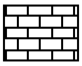
 SANDSTONE/QUARTZITE

 SILTSTONE

 MUDSTONE/CLAYSTONE

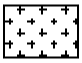
 SHALE

 COAL

 LIMESTONE

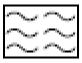
 LITHIC TUFF

### IGNEOUS ROCK

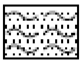
 GRANITE

 DOLERITE/BASALT

### METAMORPHIC ROCK

 SLATE, PHYLLITE, SCHIST

 GNEISS

 METASANDSTONE

 METASILTSTONE

 METAMUDSTONE

## Definitions

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

*Rock Substance* In geotechnical engineering terms, rock substance is any naturally occurring aggregate of minerals and organic matter which cannot be disintegrated or remoulded by hand in air or water. Other material is described using soil descriptive terms. Rock substance is effectively homogeneous and may be isotropic or anisotropic.

*Rock Defect* Discontinuity or break in the continuity of a substance or substances.

*Rock Mass* Any body of material which is not effectively homogeneous. It can consist of two or more substances without defects, or one or more substances with one or more defects.

## Degree of Weathering

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

| Term | Symbol | Definition |
|---|---|---|
| Residual soil[1] | Rs | Soil derived from the weathering of 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. |
| Extremely weathered[1] | EW | Rock substance affected by weathering to the extent that the rock exhibits soil properties - i.e. it can be remoulded and can be classified according to the Unified Classification System, but the texture of the original rock is still evident. |
| Highly weathered[2] | HW | Rock substance affected by weathering to the extent that limonite staining or bleaching affects the whole of the rock substance and other signs of chemical or physical decomposition are evident. Porosity and strength may be increased or decrease compared to the fresh rock usually as a result of iron leaching or deposition. The colour and strength of the original rock substance is no longer recognisable. |
| Moderately weathered[2] | MW | Rock substance affected by weathering to the extent that staining extends throughout the whole of the rock substance and the original colour of the fresh rock is no longer recognisable. |
| Slightly weathered | SW | Rock substance affected by weathering to the extent that partial staining or discolouration of the rock substance usually by limonite has taken place. The colour and texture of the fresh rock is recognisable. |
| Fresh | FR | Rock substance unaffected by weathering |

**Notes:**
1 Rs and EW material is described using soil descriptive terms.
2. The term “Distinctly Weathered” (DW) may be used to cover the range of substance weathering between EW and SW

## Rock Strength

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

| Term | Is (50) MPa | Field Guide | Symbol |
|---|---|---|---|
| Very low | >0.03 ≤0.1 | May be crumbled in the hand. Sandstone is ‘sugary’ and friable. | VL |
| Low | >0.1 ≤0.3 | A piece of core 150mm long x 50mm diameter may be broken by hand and easily scored with a knife. Sharp edges of core may be friable and break during handling. | L |
| Medium | >0.3 ≤1.0 | A piece of core 150mm long x 50mm diameter can be broken by hand with considerable difficulty. Readily scored with a knife. | M |
| High | >1 ≤3 | A piece of core 150mm long x 50mm diameter cannot be broken by unaided hands, can be slightly scratched or scored with a knife. | H |
| Very high | >3 ≤10 | A piece of core 150mm long x 50mm diameter may be broken readily with hand held hammer. Cannot be scratched with pen knife. | VH |
| Extremely high | >10 | A piece of core 150mm long x 50mm diameter is difficult to break with hand held hammer. Rings when struck with a hammer. | EH |

# Rock Data



martens consulting engineers

## Degree of Fracturing

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

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

## Rock Core Recovery

TCR = Total Core Recovery

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

SCR = Solid Core Recovery

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

RQD = Rock Quality Designation

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

## Rock Strength Tests

▼ Point load strength Index (Is50) - axial test (MPa)

▶ Point load strength Index (Is50) - diametral test (MPa)

● Unconfined compressive strength (UCS) (MPa)

## Defect Type Abbreviations and Descriptions

**Defect Type (with inclination given)**

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

**Planarity**

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

**Roughness**

| | |
|---|---|
| Pol | Polished |
| Sl | Slickensided |
| Sm | Smooth |
| Ro | Rough |
| VR | Very rough |

**Thickness**

| | |
|---|---|
| Zone | > 100 mm |
| Seam | > 2 mm < 100 mm |
| Plane | < 2 mm |

**Coating or Filling**

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

**Inclination**

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

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

martens consulting engineers

## Sampling

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

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

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

## Drilling / Excavation Methods

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

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

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

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

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

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

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

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

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

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

## In-situ Testing and Interpretation

Cone Penetrometer Testing (CPT)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

as 4, 6, 7
N = 13

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

as 15, 30/40 mm.

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

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

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

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

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

$q_u = 2 \times C_u$.

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

## Test Pit / Borehole Logs

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

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

## Laboratory Testing

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

## Ground Water

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

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

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

# Test, Drill and Excavation Methods

## Explanation of Terms (3 of 3)

martens consulting engineers

### DRILLING / EXCAVATION METHOD

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

### SUPPORT

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

### WATER

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

GROUNDWATER NOT OBSERVED (NO) — The observation of groundwater, whether present or not, was not possible due to drilling water, surface seepage or cave in of the borehole/test pit.

GROUNDWATER NOT ENCOUNTERED (NX) — The borehole/test pit was dry soon after excavation. However, groundwater could be present in less permeable strata. Inflow may have been observed had the borehole/test pit been left open for a longer period.

### PENETRATION / EXCAVATION RESISTANCE

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

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

### SAMPLING

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

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

### TESTING

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

**Notes:**

| | |
|---|---|
| RW | Penetration occurred under the rod weight only |
| HW | Penetration occurred under the hammer and rod weight only |
| HB 30/80mm | Hammer double bouncing on anvil after 80 mm penetration |
| N=18 | Where practical refusal occurs, report blows and penetration for that interval |

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

### SOIL DESCRIPTION

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

### ROCK DESCRIPTION

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