Boegoebaai Port: Preliminary Geotechnical Investigation (Quarry and Near Port Area): Final Report Rev1

Report Prepared for

PRDW and Nako Iliso

Report Number 526679 / 529671

Report Prepared by

August 2018

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August 2018

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Disclaimer

The opinions expressed in this Report have been based on the information supplied to SRK Consulting (South Africa) (Pty) Ltd (SRK) by Prestedge Retief Dresner Wijnberg (Pty) Ltd (PRDW) and Nako Iliso (Pty) Ltd (Nako). The opinions in this Report are provided in response to a specific request from the Clients to do so. SRK has exercised all due care in reviewing the supplied information. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information and does not accept any consequential liability arising from commercial decisions or actions resulting from them. Opinions presented in this report apply to the site conditions and features as they existed at the time of SRK's investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this Report, about which SRK had no prior knowledge nor had the opportunity to evaluate.

1 Introduction and Scope of Report

SRK Consulting (South Africa) (Pty) Ltd (SRK) were appointed by both Prestedge Retief Dresner Wijnberg (PRDW) and Nako Iliso (Pty) Ltd (Nako) to assist with describing the geotechnical profile linked to quarrying and other activities proposed for the Boegoebaai Port Development.

PRDW are interested in the port precinct of the project (near shore and offshore environment) and identifying a viable quarry site, whilst Nako are interested in the nearshore (land based) port infrastructure and access road area, as well as a viable source of concrete aggregate from the quarry. A secondary requirement for Nako is to assess the feasibility of harvesting groundwater for the project, and this too forms part of SRKs brief, albeit at a prefeasibility level.

The geotechnical (and hydrogeological) investigations carried out to date have relevance to both PRDW and Nako's areas of interest, with a significant amount of overlap. For this reason, the geotechnical and hydrogeological investigation findings are presented in a single report for the benefit of both consultants.

This is the final report (Rev1) and is an update of a previous final report submitted on 18 July 2018. This report covers both factual and interpretive aspects of the geotechnical and hydrogeological scope.

2 Background and Brief

2.1 Background of the project

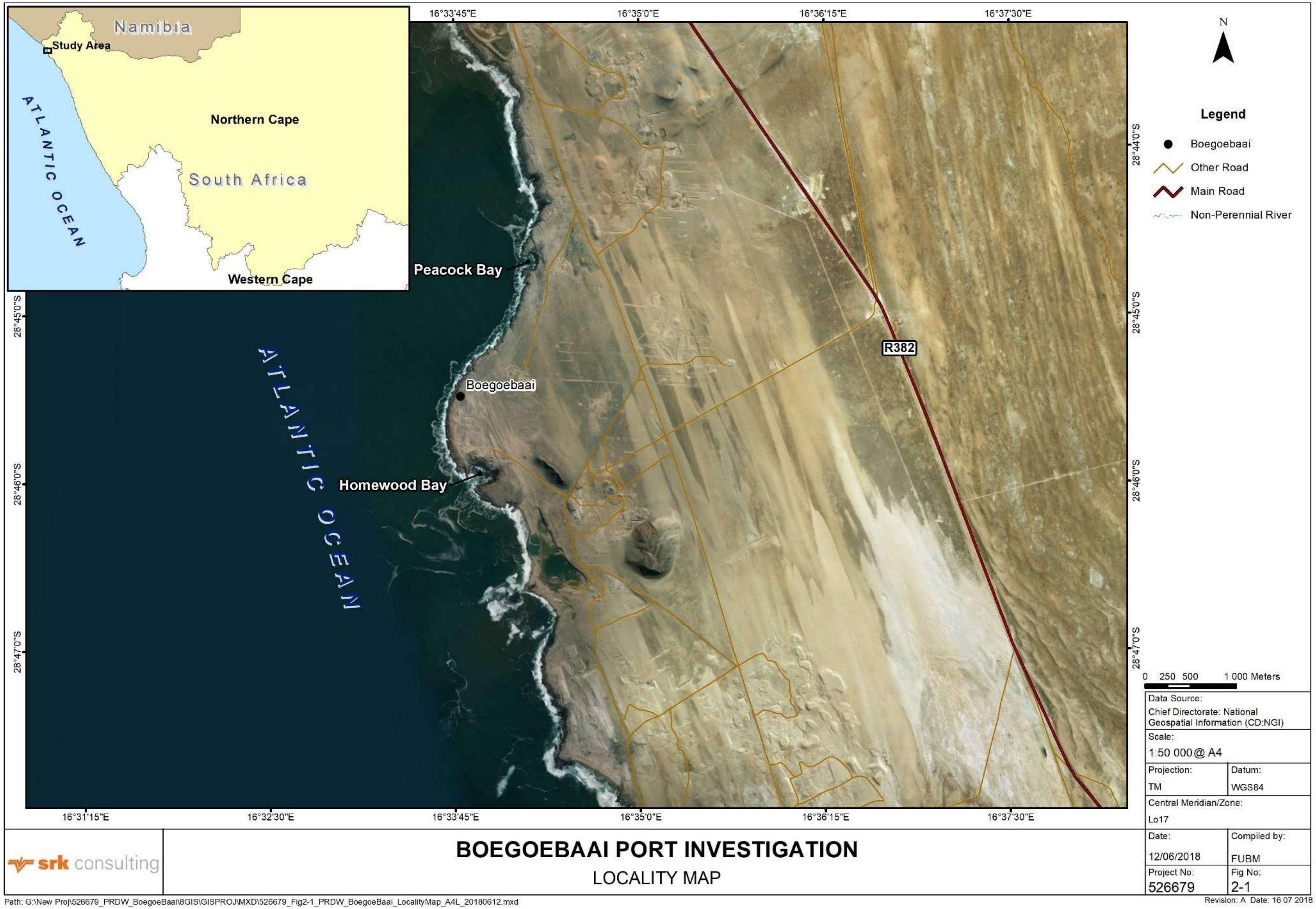
SRK were approached by PRDW to assist with certain geotechnical aspects of the project. From an efficiency viewpoint, it was deemed advantageous that SRK carry out extended investigations to cover Nako's requirements, as this was a logical approach from many viewpoints (specifically financially and logistically).

2.2 Nature of the brief

The geotechnical investigation is required to provide insights into the project feasibility from both a technical and project costing perspective. The SRK scope covered in this project was defined by PRDW and Nako with this in mind.

SRK were involved at an early (pre-proposal) stage, when a site visit was undertaken on 30 January 2018 to familiarise the larger technical team with the project setting. Based largely on discussions at the site visit and in correspondence immediately afterwards, SRK developed a combined costs proposal to cover the project needs for both consultants – this becoming the accepted scope of work, which is described at a high level in Table 2-1 and in more detail in Table 2-2.

The project locality plan is shown in Figure 2-1.



BOEGOEBAAI PORT INVESTIGATION

LOCALITY MAP

Table 2-1: High Level Scope of Work

<table>
<tr><th>Marine Scope (PRDW) 526679</th><th>Terrestrial Scope (Nako Iliso) 529671</th></tr>
<tr><td colspan="2">1a. Site Security, HES and Logistical Preparedness</td></tr>
<tr><td colspan="2">1b. Site Reconnaissance 1, Quarry site Selection, Mapping and Drilling Plan</td></tr>
<tr><td colspan="2">2. Desk Top Study</td></tr>
<tr><td>3. Quarry investigation: provision of marine works construction materials. Quarry investigation: provision of aggregate and road layer materials</td><td></td></tr>
<tr><td></td><td>4. Geotechnical investigation for land-based port development</td></tr>
<tr><td colspan="2">5. Breakwater and Jetty Landside boreholes: to provide properties for the material which can be expected offshore and deep level founding conditions onshore.</td></tr>
<tr><td></td><td>6. Groundwater Supply Feasibility</td></tr>
</table>

*Numbers (#) indicate activity number relevant in the detailed scope below (*Table 2-2*).*

In keeping with the above overall requirements (Table 2-1), SRK derived the following detailed Scope of Works (Table 2-2).

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[1] Site reconnaissance was partially completed on the field visit of 30 January 2018, but was supplemented during the driller mobilisation stage

Table 2-2: Detailed Scope of Work

Activity	Scope	Detailed Activity	Goals
1a	PRDW and Nako	Security, HES and Logistical Preparedness	To be in line with the related requirements of our host (the mine).
1b	PRDW and Nako	Site Reconnaissance, Quarry site Selection, Mapping and Drilling Plan (see Figure 1) including: • Desk top review of available geological information (to be supplied by the mine and from other sources) and high level quarry site selection; • Mapping of exposed outcrop along exposed geological features and seashore cliff face; • Investigation of drilling rig access; • Definition of likely quarry areas.	To identify the drilling sites, and to define the drilling and test pitting investigation scopes more accurately. Detailed mapping to be used as a data source to augment defining the minable block sizes as indicated by the mapped faces.
2	PRDW and Nako	Study of available literature.	To inform quarry site selection and planning of intrusive works, as well as to define the geotechnical setting of the site prior to embarking on field investigations (rocks and soils).
3	PRDW	3a Quarry Investigation Drilling (Vertical Boreholes) including (see Figure 1): • Final borehole siting; • SRK supervision of drilling; • SPT test in soils (at 1.5 m frequency); • Selected point load testing of core; • Logging of borehole core to accepted practice (in line with guidelines from South African Institute of Engineering Geologists (SAIEG)) – information captured on logs to include: o Project name, drilling date, position coordinate, surface elevation, drill supervisor; o Identification of the sub-soils and bedrock including density/consistency, colour, moisture content, structure, geological origin; o Sampler type and depth; o Total Core Recovery (%); o Rock Quality Designation (%); o Strength Index; o Weathering profile; o Discontinuity Orientation (degrees to horizontal). • Sampling of core for laboratory testing within the envelope of the following potential testing scope: o Foundation indicator tests (soils); o Specific Gravity; o Water Absorption; o Unconfined Compressive Strength (UCS); o Moisture content; o Bulk density and dry density; o Uniaxial compression and deformability; o Direct shear tests / Triaxial compression test; o Petrographic test (including evaluation of suitability of rock for use as concrete aggregate).	Data emerging to assist in defining: • likely minable block sizes away from the mapped faces; • material properties (durability, strength etc.); • define properties of road/platform building materials; • quarry run volume estimations; • rock hardness and abrasiveness and impacts on quarrying (e.g. productivity); • quarry cut slope stability (cut slopes will be in excess of 10 m vertical).
	PRDW	3b Quarry Investigation Drilling (Inclined Boreholes – see Figure 1) including the same scope as shown above in 2a, and the following in addition: • Core orientation; • Measurement of discontinuity orientation (referenced dip and strike of discontinuities).	Data emerging to assist in defining likely minable block sizes away from the mapped faces. Inclined boreholes will be drilled perpendicular to primary discontinuity sets identified (e.g. bedding joints). Suitability of quarry run as potential aggregate will be assessed.
	PRDW	3a & 3b Reporting (combined Factual and Interpretive Report) covering: • Desk top Study; • Geological Setting; • Field work outcomes;	Capturing the investigation findings in a report.

Activity	Scope	Detailed Activity	Goals
		• Analysis; • Interpretation of results including: ○ A description of likely rock gradings (block sizes) that can be recovered from the quarry sites; ○ Estimation of material volumes that can be recovered from the quarry sites (breakwater and road/platform construction materials); ○ Recommendations relating to preferred quarry sites.	
4	Nako	4a Machine (TLB) excavation of 25 test pits to reach depth (or earlier refusal) in the proposed port land based development area (see Figure 2), including the following supporting activities: • Test Pit logging (in line with guidelines from South African Institute of Engineering Geologists (SAIEG)) – information captured on logs to include: ○ Project name, position coordinate, surface elevation, logger; ○ Identification of the sub-soils and bedrock including density/consistency, colour, moisture content, structure, geological origin; ○ Sampling of representative soils horizons encountered. • Dynamic Penetrometer Light (DPL) tests to measure near surface soil consistency; • Laboratory testing including: ○ Foundation indicator tests (full particle size distribution and Atterberg Limits); ○ Compaction testing (Mod CBR tests). • Reporting on the above (combined Factual and Interpretive Report).	Defining the founding environment of the land based development and assessing the insitu materials for use as road/platform construction materials.
5	PRDW and Nako	5a Drilling of 5 boreholes in the vicinity of the breakwater/jetty to investigate the near-sea geotechnical profile (see Figure 1) and to provide professional opinion on whether the geotechnical profile encountered can be extrapolated to the shallow marine environment as well as landwards.	Characterisation of the nearshore geotechnical profile to be used to extrapolate likely conditions in the near offshore zone. Similarly, the data emerging from this drilling will be used to extrapolate inland to define founding conditions at depth for the proposed onshore development.
6	Nako	Groundwater Supply Feasibility Study following a phased approach: • Phase 1: ○ Collect available hydrogeological data and information for the area – Department of Water and Sanitation (DWS) National Groundwater Archive, DWA 1: 500 000 scale hydrogeological map, published geological maps, completed EIA reports for surrounding developments (if any), consultancy reports, etc.; ○ Collect available hydrogeological data from the mine; ○ Collect available geotechnical information (depth of sand, clay, hard rock, etc.) if available, to enable a more comprehensive assessment of the local aquifer systems (primary sandy aquifer, secondary hard rock aquifer). Information includes thicknesses of different horizons, any in situ permeability tests, etc.; ○ Collect and collate available GIS/CAD files and prepare maps for inclusion in the Draft Phase 1 Hydrogeological Report. ○ Conduct a geophysical survey and site potential targets for drilling; and ○ Prepare a Phase 1 Hydrogeological Report. • Phase 2 (NOTE: should Phase 1 indicate a low probability of successfully harvesting groundwater as a sustainable supply, Phase 2 will not proceed): ○ Arrange and supervise an exploration / production drilling programme; ○ Arrange and carry out pumping tests; ○ Collect a groundwater sample for chemical analysis (including SANS 51008:2006 Mixing water for concrete list of analysis); and ○ Prepare a Phase 2 Hydrogeological Report.	Characterisation of the sustainable groundwater extraction potential and the groundwater quality regime.

3 Program Objectives and Work Program

3.1 Purpose of the Report

The purpose of this report is to assist PRDW and Nako in defining project feasibility linked to the various consulting responsibilities identified in Table 2-2.

3.2 Project team

The SRK project team consisted of the following:

• SRK Team:	
– Bruce Engelsman (Geotechnical Engineer)	Technical oversight and project management;
– Candice Maduray (Engineering geologist)	Rock characterisation and mapping;
– Daniell du Preez (Engineering geologist)	Field data gathering and analysis;
– Lewis Prince (Field Technician)	Field data gathering and analysis;
– Des Visser (Hydrogeologist)	Groundwater feasibility study;
– John Brown (Engineering geologist)	Reviewer.
• Subcontractors:	
– Geomech Africa (Pty) Ltd	Drilling contractor;
– Rocklab South Africa	Rock Testing Laboratory;
– Soillab South Africa	Aggregate Testing Laboratory;
– Roadlab Laboratories (Pty) Ltd	Soil Testing Laboratory;
– Cape Geophysics	Land based geophysical investigation.

3.3 Statement of SRK Independence

Neither SRK nor any of the authors of this Report have any material present or contingent interest in the outcome of this Report, nor do they have any pecuniary or other interest that could be reasonably regarded as being capable of affecting their independence or that of SRK.

SRK's fee for completing this Report is based on its normal professional daily rates plus reimbursement of incidental expenses. The payment of that professional fee is not contingent upon the outcome of the Report.

3.4 Other data used in compiling this report

In addition to the data gathered by the project team (Section 3.2), the following data was used in compiling this report:

- PRDW Boegoebaai Prefeasibility Study: Phase 1 Report Rev. 00 dated 12 December 2014;
- PRDW Boegoebaai Prefeasibility Study: Phase 1 Report Rev 01 dated 7 May 2015;
- Marine geophysical survey from Tritan Surveys report dated 14 May 2018;
- Lidar data, geological data and hydrogeological data supplied by Alexkor RMC JV.
- The Geological Setting of Diamondiferous Deposits on the Inner Shelf between the Orange River and Wreck Point, Namaqualand – R.H De Decker, 1987; and
- Ontwikkelings potensiaal en Ontwikkelings voortselle. Oorsig en Gedeelte 1 Ontwikkelings potensiaal, Ninham Shand, 1980;
- SRK Report No 407839: Alexkor Groundwater Contamination Risk Assessment: New Waste Water Treatment Works and Golf Course, Alexander Bay, Northern Cape, dated 22 October 2009;

- SRK Report No 407839: Report on the Assessment on the Alexander Bay's Production Boreholes, dated 28 September 2009;
- Water Without Frontiers Report Ref: 2014/ENV008: Geohydrological Impact Assessment For Alexkor Diamond Mine along the west coast Between Port Nolloth and Alexander Bay, Northern Cape Province, dated May 2014.

4 Program Results

4.1 Geological Investigations

The results of the geological investigation involve a desktop study and field mapping of the study area. The main objective was to locate potential quarry sites by identify the physical characteristics of the site with particular focus on the hard rock formations and the general orientation of structures (bedding, joints, lineaments, and fractures) outcropping along the coastline.

4.1.1 Local Geology

According to published geological maps and site observations, the site consists of recent Quaternary sediments underlain by Late Proterozoic metasiliciclastic rocks of the Holgat Formation.

The surrounding surface area is typically characterised by undulating Aeolian sand dune topography (see Photo 4-1) with longitudinal dune structures. The Aeolian sand is poorly graded and consists of predominantly silty, fine sand with minor gravel and cobbles, which is an erosional product of the local lithology. The sand cover on the site is relatively stabilised by scattered indigenous vegetation.

Photo 4-1: Undulating sand dune topography and scattered indigenous vegetation with Boegoeberg North in the background

The Holgat Formation of the Gariep Group is a thick sequence of folded sediments consisting of arkoses and greywacke at the base, overlain by aluminium-rich schist which are covered by quartzitic schists and quartzites. Conglomerates, hornfels, limestones and tillites are also found within the study area. A brief description of the geology is presented in Table 4-1 and illustrated in Figure 4-1 below. Note: no sand (Qs) cover is shown in the map.

Table 4-1: Stratigraphy and lithology of the site

SRK Classification	Formation	Group	Lithology
Sand (Qs)			Unconsolidated white to beige sand with comminuted gravel and shell fragments
Quartzite (Qtz)	Holgat	Gariep	White and light grey quartzite; dark grey to black greywacke
Schist (Sht)	Holgat	Gariep	Schist, quartz schist, phyllite, slate, and arkose - interbedded

The quartzite and greywacke outcrops along the coastline and inland towards Boegoeberg North (from here onwards known as Boegoeberg) are extremely hard and relatively massive. The underlying and interbedded schists are considerably softer and more closely jointed than the quartzites – hence the schists are more weathered. The study area has been subjected to extensive folding and uplifting, resulting in extremely fractured and jointed rocks.

The structural trend of the metasediments found in the study area has a main bedding (B) azimuth of N 28° W. The cliffs towards the North and West of Boegoeberg (see Photo 4-2) are shallow dipping (ranging between 28° and 40°) at Quarry Site 2 (see Figure 4-2), with more steeply dipping cliffs (ranging between 48° and 82°) towards the South (see Photo 4-3) of Boegoeberg. All the outcrops dip away from Boegoeberg towards the sea. It is therefore inferred that Boegoeberg shows distinctive antiform characteristics (of the Neoproterozoic Gariep Fold Belt). The antiform dips towards the West with the fold hinge slightly leaning towards the South (asymmetrical). This explains the steep dipping outcrop at Quarry Site 1 (see Figure 4-2).

Photo 4-2: Shallow dipping cliff ranging between 28° and 45° at the Quarry Site 2

Photo 4-3: Steep dipping cliff ranging between 48° and 82° at Quarry Site 1

An antiform is generally associated with open joints and fractures and allows for joint infill such as sand, silt, and clay material. This was observed within the joints during window mapping and borehole drilling programme. Quartz veining was also observed within the open jointed metasiliciclastic rocks (these open joints could also act as good groundwater conduits). The main joint azimuth (orientation) is N 48° E for bedding joint set one (J1), N 56° E for joint set two (J2), and N 67° E for joint set three (J3) (refer to Figure 4-6).

The outcrops close to the surface appear to be more highly weathered and fractured. It was also observed that outcrops towards the naturally occurring bays such as Homewood Bay and Peacock Bay appear to be more highly weathered and fractured. This is due to the strike of the outcrops being perpendicular to oceanic wave action, exposing the rocks to high wave energy and more extreme weathering conditions, thus allowing the sea to cave away the softer interbedded schists.

The immediate site was assessed for lineaments during the desktop study and field campaigns. A strongly developed NW-SE (azimuth of 75°) lineament (possible fault) was identified and confirmed in the field during mapping (see Photo 4-4). Various other smaller potential lineaments were identified.

Based on surface mapping/walkovers, the localised site geology is depicted as accurately as data allows in Figure 4-1.

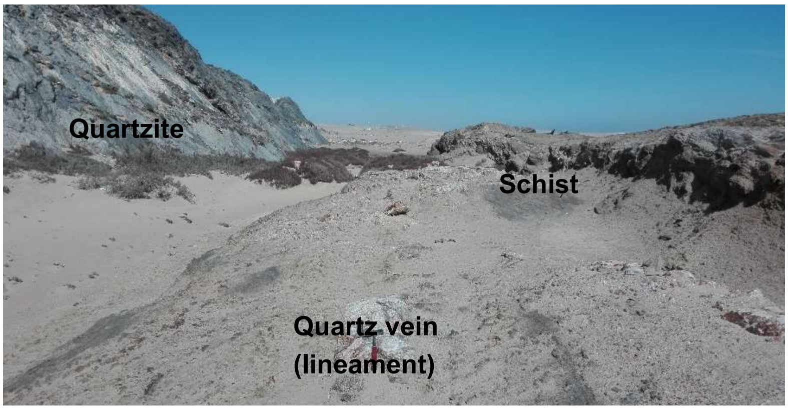


Photo 4-4: Massive quartz vein observed at a quartzite and schist contact near Quarry Site 1

4.1.2 Quarry Site Identification

Potential quarry sites were visually identified by assessing and delineating geological outcrops which visibly conformed to the required rock quality. This was based on accessibility, rock hardness, and degree of weathering, but most significantly on the observed 'blockiness' or degree of jointing of the outcrops, with the primary aim of producing armour rock for use in the breakwater construction. Several outcrops were mapped using window mapping techniques to capture accurate data required for assessing the likely block size distribution of quarried rock (based on joint spacing and orientations).

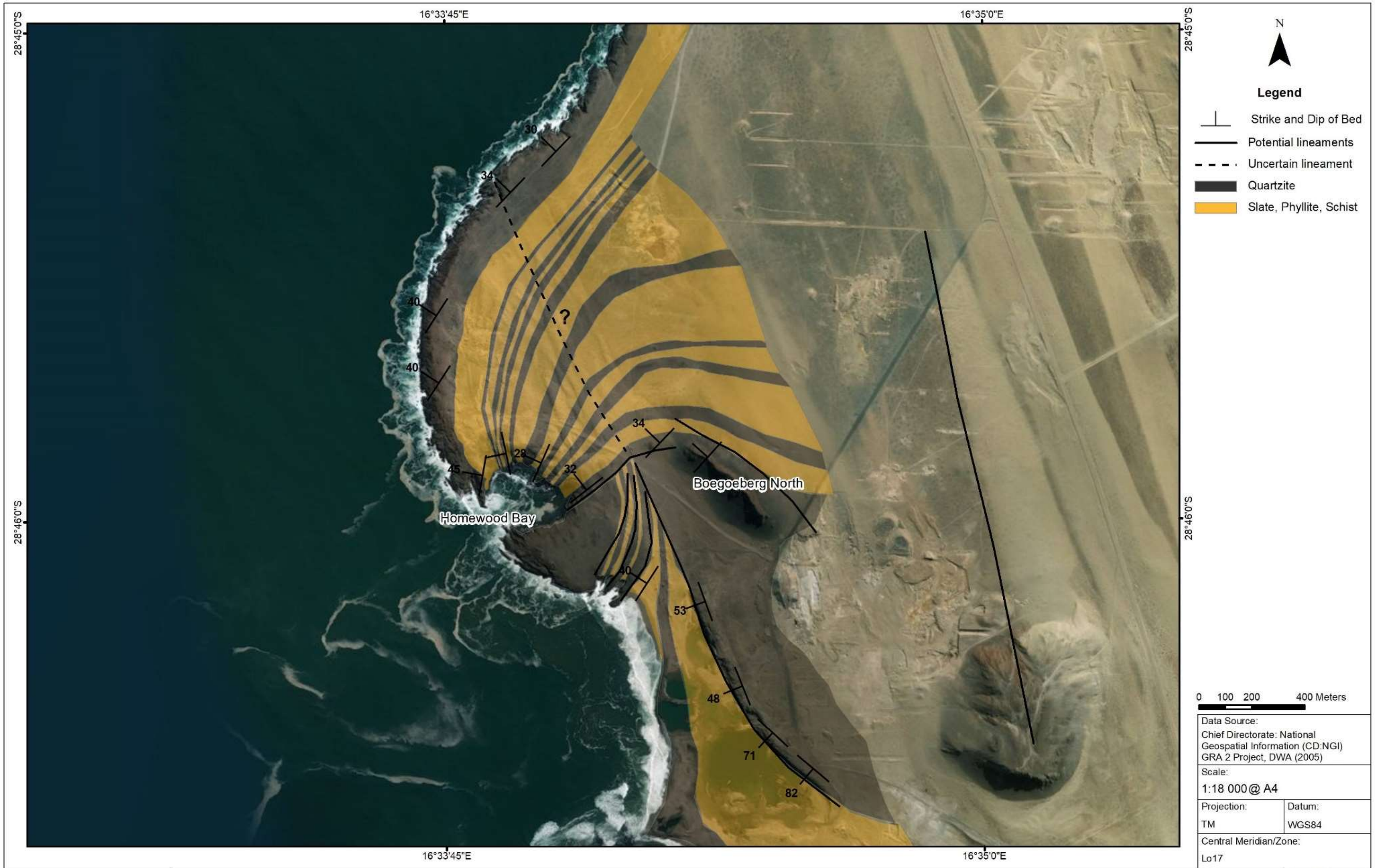
Figure 4-2 indicates the areas mapped and the quarry sites identified. In summary, the following is noted from Figure 4-2:

- The southern quarry site (Quarry Site 1) aligns with an exposed face (possibly resulting from previous quarrying activities), and the extent of the exposed face shows competent quartzite and greywacke, with varying degrees of jointing; and
- The northern quarry site / Port Site (Quarry Site 2) aligns with the proposed breakwater start point – the rationale being that a certain extent of excavation will be required (on land) in this area to link the breakwater with the proposed land-based Port infrastructure.

Table 4-2 lists the rock types encountered on site including the rock properties and the quarrying potential of each rock type.

Table 4-2: Classification schemes and the rock hardness encountered on site including the quarrying potential.

SRK Classification	Metamorphic Classification	Protolith	Hardness	Quarry Potential
Greywacke	Metasiliciclastic	Argillaceous sandstone	Hard rock	Good
Quartzite	Metasiliciclastic	Sandstone, arkose sandstone	Hard rock	Good
Arkose	Metasiliciclastic	Feldspathic Sandstone	Soft to medium hard rock	Poor to Moderate
Phyllite	Low-strain metamorphism, foliated	Mudstone, Siltstone, Shale	Soft rock	Poor
Quartz Schist	Low-strain metamorphism	Subarkose, immature sandstone	Soft to medium hard rock	Poor
Schist	Low-strain metamorphism, foliated	Shale	Soft rock	Poor



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GRA 2 Project, DWA (2005)

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Projection:	Datum:
TM	WGS84

Central Meridian/Zone:
Lo17

BOEGOEBAAI PORT INVESTIGATION

LOCAL GEOLOGY

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Scale:
1:18 000@ A4

Projection:	Datum:
TM	WGS84

Central Meridian/Zone:
Lo17

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BOEGOEBAAI PORT INVESTIGATION

MAPPING SITES AND TARGET QUARRY SITES

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14/07/2018	DUPD
Project No:	Fig No:
526679	Figure 4-2

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4.2 Onshore Geotechnical Investigation

The onshore geotechnical investigation involved test pitting and drilling of boreholes for the Quarry Site 1 and Quarry Site 2 (Port) investigations.

4.2.1 Test Pit Soil Profile

Twenty-five test pits were machine excavated (TLB) to assist in describing the near surface onshore geotechnical profile, particularly in the area where onshore development of infrastructure is proposed. Several test pits were also excavated along the existing access road to explore the geotechnical profile along this potential access.

Twenty-four test pits encountered Aeolian sand at the surface to between 0.1 m and 3.1 m below surface. Only test pit eleven (TP11) had little to no sand at the surface. Areas that were previously mined and/or stripped had shallow Aeolian sand deposits (recent) and were generally characterised with minor vegetation growth. The site soil profile consists predominantly of non-cohesive, poorly graded, silty, fine sand with minor gravel and shell fragments at the surface. The average consistency of very loose to loose sand was found to extend to about 1.3 m below the surface

Clay was only randomly encountered in test pits (TP) 1, 5, 6, and 25 at an average depth of 0.5 m below the surface (but varying from 0.3 to 0.9 m) where schist was encountered at the base.

Bedrock was encountered in 13 test pits at an average depth of approximately 1.30 m (ranging from 0.45 to 2.45 m). The rock types encountered were predominantly schist and quartzitic schist, and only occasionally quartzite or greywacke. The hardness of the encountered rocks during test pitting was soft rock to medium hard rock for the schists, medium hard rock to hard rock for quartzitic schists, and hard rock to very hard rock for the quartzites and greywackes.

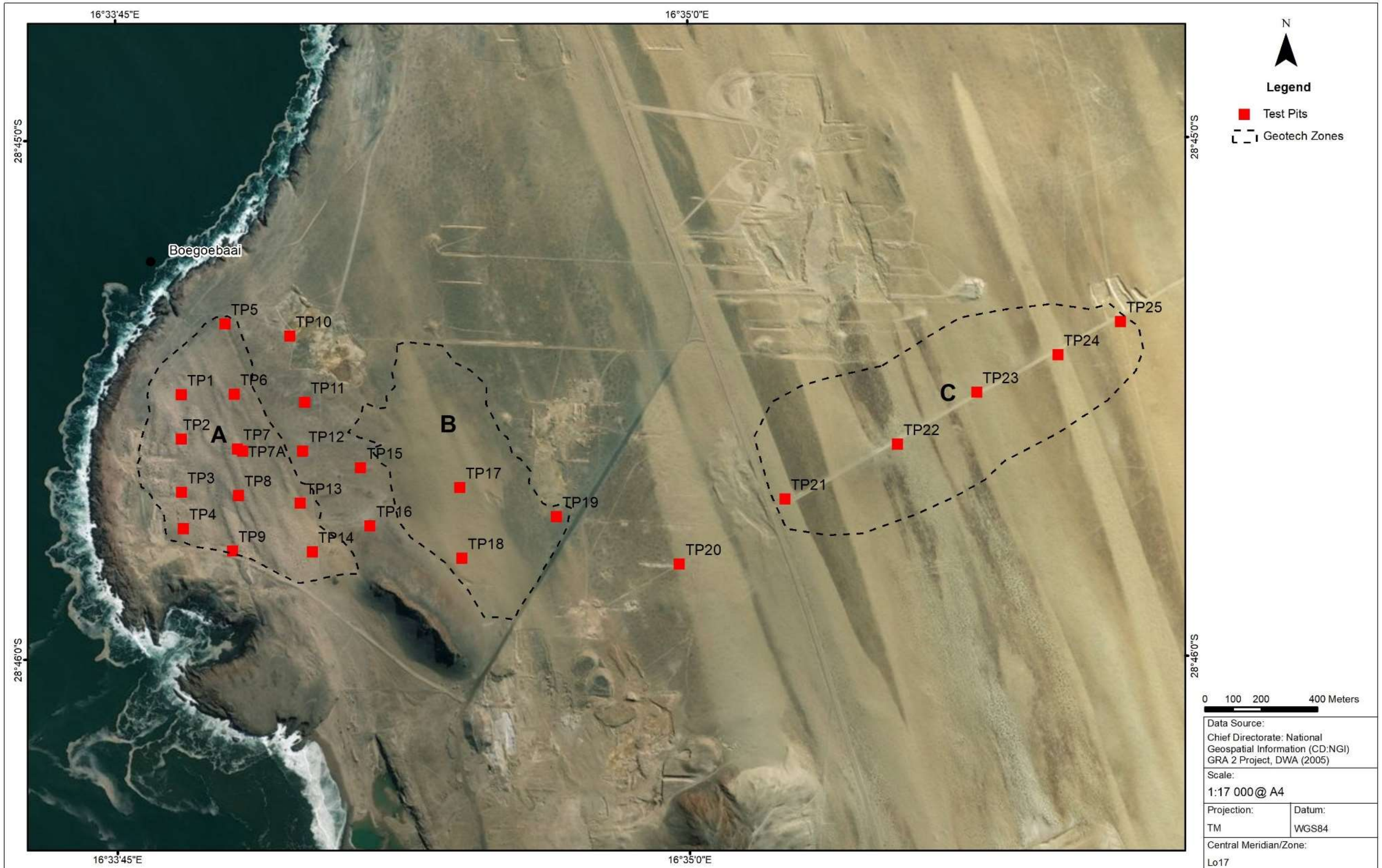
The three zones A, B and C, shown in Figure 4-3, indicate the regions where very loose to loose sand material can be expected to occur to a depth greater than 0.4 m below the surface (average depth about 0.8 m).

The upper 0.35 m of the soil profile generally contains minor organic material, with abundant fine rootlets, and minor thicker indigenous bush roots extending to a depth of up to 1.0 m.

The generalised soil profile (refer to Photo 4-5 and Photo 4-6) is summarised as follows:

0 – 0.80 m	Dry, beige brown, *very loose to loose*, silty, fine SAND with minor shell fragments and abundant fine roots. Aeolian.
0.80 – 1.30 m	Slightly moist, beige brown, *loose to medium dense*, silty, fine SAND with minor angular quartz gravel. Aeolian.
1.30 – 1.60 m	Slightly moist, beige, *dense to very dense*, kaolinized, silty, fine SAND with abundant angular quartzitic schist gravel. Reworked residual schist.
1.60 – 2.00 m +	Grey and orangey brown, highly weathered, closely jointed, very thinly laminated, *soft rock to medium hard rock*, quartzitic SCHIST with off-white, kaolin, silty, clay infill. *Holgat Formation.*

Detailed soil profiles and test pit photographs are contained in Appendix A.



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BOEGOEBAAI PORT INVESTIGATION

SOIL ZONING

Data Source: Chief Directorate: National Geospatial Information (CD:NGI) GRA 2 Project, DWA (2005)	
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Photo 4-5 and Photo 4-6 below indicate the two typical soil profiles present at the site.

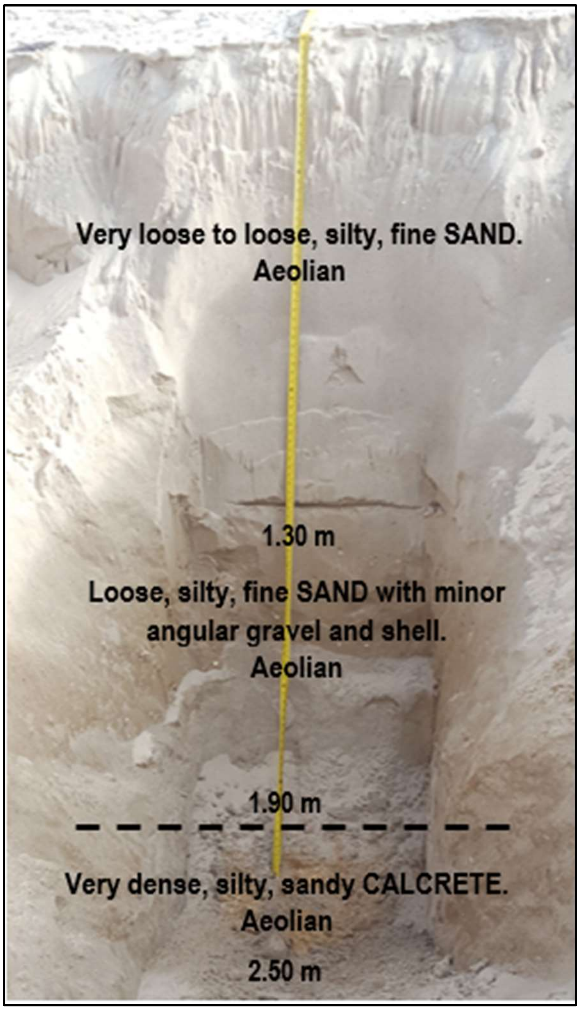

Photo 4-5: Soil profile of TP 2

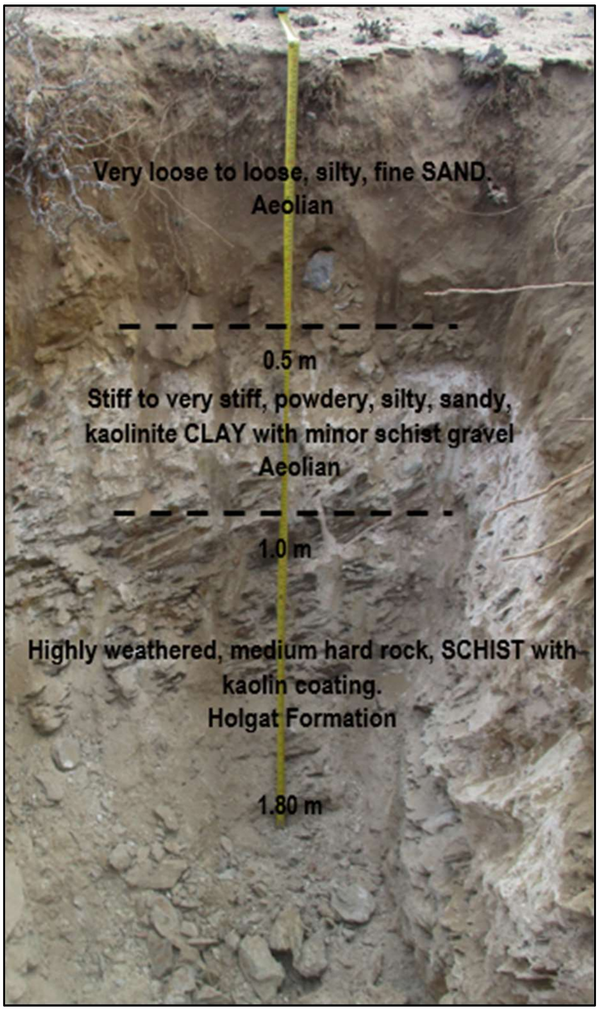

Photo 4-6: Soil profile of TP 5

4.2.2 Water Table and Drainage

No water seepage was encountered within any of the test pits (to a maximum excavation depth of 3.10 m below surface). It therefore seems unlikely that groundwater will have an impact on the site development. It must be noted that the geotechnical investigation was conducted during a drought period, and it is possible that a perched water table could develop within 2 m of the surface during wet periods.

The site appears to be well-drained. The elevated Boegoeberg antiform (associated with open joints and fractures) along with the predominantly seaward dipping structures and sandy soil cover appears to be free-draining.

4.2.3 Soil Laboratory Test Results

Laboratory tests were conducted on representative samples of the underlying soils. The soil profiles and the laboratory test results indicate that a high degree of homogeneity exists in the site soils, as most soils encountered were poorly graded, silty, fine sand of Aeolian origin (either undisturbed or re-worked Aeolian sands).

Details of the samples tested are indicated in Table 4-3 and Table 4-4. The detailed laboratory test results are included in Appendix C.

Table 4-3: Soils Laboratory Test Results

Test Pit	Depth (m)	Soil Type	Grading Analysis				LS %	LL %	PI %	USCS Class.	Pot. Exp.
			Clay %	Silt %	Sand %	Gravel %					
TP2	1.30 – 1.90	Olive green to beige, homogeneous, silty, fine SAND with minor angular quartzite cobbles, gravel, and shell fragments. Aeolian.	5	3	86	6	0	NP	NP	SW-SM	LOW
TP5	0.60 – 1.00	Off-white, powdery, sandy, silty, kaolinite CLAY with minor schist gravel. Transport.	26	18	36	20	5.4	31	11	CL	LOW
TP7A	0.80 – 1.70	Whitish beige, homogeneous, silty, fine SAND with minor gravel, shell fragments and abundant fine rootlets. Aeolian.	1	3	96	0	0	NP	NP	SP	LOW
TP17	0.90 – 1.60	Beige, silty, fine SAND with some angular gravel, minor shell fragments, and abundant fine rootlets at the top 0.35 m. Aeolian.	1	1	98	0	0	NP	NP	SP	LOW

LL = Liquid Limit PI = Plasticity Index LS = Linear Shrinkage NP = Non Plastic

Pot. Exp. = Potential Expansiveness (vd Merwe Classification)

Table 4-4: Compaction Properties and TRH 14 Material Classification

Test Pit	Depth (m)	Soil Type	CBR @					PI %	Mod AASHTO Density kg/m3	OMC %	TRH 14 Class.
			100 %	98 %	95 %	93 %	90 %				
TP2	1.30 – 1.90	Olive green to beige, homogeneous, silty, fine SAND with minor angular quartzite cobbles, gravel, and shell fragments. Aeolian.	23	20	17	15	13	NP	1769	7.5	G7
TP7A	0.80 – 1.70	Whitish beige, homogeneous, silty, fine SAND with minor gravel, shell fragments and abundant fine rootlets. Aeolian.	16	14	10	8	4	NP	1685	9.2	G9
TP17	0.90 – 1.60	Beige, silty, fine SAND with some angular gravel, minor shell fragments, and abundant fine rootlets at the top 0.35 m. Aeolian.	17	14	11	10	7	NP	1736	9.3	G8

CBR = Californian Bearing Ratio OMC = Optimum Moisture Content
TRH = Road Materials Classification

It is evident that the soils are dominated by Aeolian sands (sand fraction ~90% and above) with minor cohesive soil occurrences (fines fraction clay + silt = ~45%). The soils exhibit low CBR values, and since the CBR test is a saturated test, and it is therefore necessary to point out that the soils will not behave favourably under loaded conditions during/after rain events. The soils classify as G7 to G9 (according to the TRH 14 Materials Classification System) and will be suitable for use as subgrade in road construction only.

4.2.4 Material Characteristics and Suitability as Construction Material

The soils to a depth of at least 1.30 m consist of poorly graded fine sand (Aeolian origin) and well graded, fine to coarse sand (with minor silt and clay) to about 1.90 m, where sand to this depth was encountered prior to refusal on rock (TP 2, 3, 4, 7, 7A, 8, 9, 14 and 17). It is also noticeable from the test results in Table 4-3 that the soils are dominated by cohesionless Aeolian sand (i.e. non-plastic sand), with minor exceptions where clay pockets were encountered. The Aeolian sands (and the clay) do not exhibit the potential to expand upon wetting. It is therefore inferred that these soils (namely the cohesionless sands that classify as G7 to G9 materials) are suitable for use as subgrade, and may also be suitable as selected material, if appropriately engineered. Clay lenses are not considered suitable for these purposes. Subbase quality material will have to be imported to site or produced at the quarry. The soils are also suitable as general engineered fill and for use as pipe bedding material.

It is probable that compaction specifications of 100% Mod AASHTO will not be onerous for contractors to achieve as there is a lack of fines (particularly silt) in the soils – this statement refers to cohesionless sands and not clayey materials.

4.2.5 Potentially Problematic Soils

The silty, fine Aeolian sand down to a depth of at least 1.30 m is poorly consolidated, and will be prone to settlement under loading. Variations in the soil consistency are apparent (naturally transported and re-worked mining areas), with the bulk of the near-surface sand being of very loose or loose consistency. This variability is exacerbated when considering that this is a mining site and random disturbances have occurred (i.e. material excavated and backfilled randomly, or simply pushed around randomly).

4.2.6 Excavation Classification, Slope Stability and Erosion

The soils to a depth of more than 1.30 m will classify as “soft” excavation according to the SANS 1200 D Earthworks specification. The Aeolian sand and weathered schist was easily excavatable with a TLB, but excavation was more challenging where calcrete, quartzitic schist, and quartzite was encountered.

Deep excavation sidewalls will be prone to collapse or ravelling failure over time due to the non-cohesive nature of the sand (potentially problematic where deep service trenches are required), and such excavations will need to be cut back to safe angles or temporarily shored.

The Aeolian sand will be very prone to wind erosion where left exposed.

Excavations into rock will be characterised by variability linked to:

- Variably interbedded quartzite (hard) and schist (soft) zones;
- Variability in jointing in this folded environment, where joints can vary from very closely spaced to widely spaced and this will impact on the excavatability of rocks on this site;
- Weathering profile changing with depth (rocks become less weathered with depth, therefore harder).

As such, any excavations planned into rock will probably require some blasting depending on the extent (depth or laterally) of said excavations.

4.2.7 Founding Discussion – Onshore Port Infrastructure

Development proposals for the onshore port infrastructure are not yet finalised, but will probably include:

- A control tower of approximately 30m height with a relatively small footprint – hence very high bearing load;
- Buildings of between 2 – 4 storeys high, with moderate to high bearing loads;
- Industrial warehouses – probably steel structures with moderate bearing loads; and
- Hard standings for storage of the bulk product, such as Iron ore etc.

With this in mind, it is noted that some structures will probably require founding on bedrock (e.g. the control tower) and others could be founded on appropriately engineered platforms. It is again noted that up to an average depth of 1.30 m, the soils are poorly consolidated and cannot be reliably founded in. In addition, and considering that there will be random pockets of disturbed ground characteristic of a mining site, lateral variability will be encountered in the site soils from a founding perspective. It is therefore likely that ground improvement measures will be required to mitigate the risks of differential settlement linked to lateral (and vertical) variability. Founding approaches may therefore consist of:

- Construction of appropriately engineered platforms by removing and re-compacting on average 1.3 m of loose sand, and spoiling any clay material encountered. Figure 4-4 provides an indication of depth to bedrock – NB: please note that contours of depth to bedrock >2.5 m could mean that bedrock was not intersected and this needs to be checked against the individual test pit logs;
- Specialised founding solutions for other structures that are more heavily loaded – it will be necessary to do site specific geotechnical investigations once the port layout has been finalised – a good example to illustrate this approach is that the proposed control tower with a small footprint (meters) will require more detail than that provided by the test pits excavated at >150 m spacing.

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BOEGOEBAAI PORT INVESTIGATION

DEPTH TO BEDROCK

Date: 17/07/2018	Compiled by: DUPD
Project No: 526679	Fig No: Figure 4-4

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Revision: A Date: 17 07 2018

4.2.8 Borehole Drilling

Six vertical and five inclined boreholes (BHs) were drilled across the study area (with reference to Figure 4-5):

- At Quarry Site 2 (i.e. the Port Site) – 1 inclined BH, 5 vertical BHs;
- At Quarry Site 1 – 1 vertical BH and 4 inclined BHs.

Table 4-5 lists the boreholes drilled and their specifications.

Table 4-5: Boreholes Drilled

Site	**BH ID**	**Vertical Boreholes (WGS 84 - 3 000 000 X constant)**			**Inclined Boreholes (WGS 84 - 3 000 000 X constant)**		
		Y Coord	**X-Coord**	**Z-Coord**	**Y Coord**	**X-Coord**	**Z-Coord**
Port Site	VBH1	-42725	-182964	20.26			
	VBH2	-42696.7	-182859	22.356			
	VBH3	-42769	-182822	19.48			
	VBH4	-42692	-182787	24.17			
	VBH5	-42720.7	-182641	22.32			
	IBH1				-42662.3	-182764	25.9
Southern Quarry Site	VBH6	-41530.8	-183938	29.4			
	IBH3				-41593.6	-184054	21.33
	IBH4				-41471.1	-184283	18.56
	IBH5				-41457.3	-184112	25.9
	IBH6				-41378.2	-184303	24.13

Detailed borehole logs and core photographs are contained in Appendix B.

Inclined Borehole 2 (IBH2) was not drilled as Quarry Site 2 (i.e. the Port Site) had sufficient data to make an assessment of the suitability of the site for quarrying purposes, and sufficient sample was available for laboratory testing.

Core was geotechnically logged per drilling interval in such a way that the dominant rock mass rating schemes could be applied, including Laubscher RMR, Hoek and Diederichs GSI, Barton Q as well as Bieniawski$_{89}$ rock mass rating systems. Empirical methods were used to assign strength parameters to the rock mass, which is a quantitative measure of the expected behaviour of the rock mass. The recorded parameters include:

- rock type;
- rock hardness;
- core recovery;
- rock quality designation;
- fracture frequency; and
- joint surface conditions.

Structural logging was also carried out, where joints were recorded together with their orientations and surface conditions. The results of this logging together with that of the window mapping was used to determine the expected sizes and distribution of blocks that are expected as discussed in more detail in Section 4.2.10.

Data Source:
Chief Directorate: National Geospatial Information (CD:NGI) GRA 2 Project, DWA (2005)

Scale:
1:16 500@ A4

Projection: TM	Datum: WGS84
Central Meridian/Zone: Lo17	
Date: 14/07/2018	Compiled by: DUPD
Project No: 526679	Fig No: Figure 4-5

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BOEGOEBAAI PORT INVESTIGATION

INTRUSIVE GEOTECHNICAL INVESTIGATION

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Revision: A Date: 17 07 2018

Rock Mass Rating (RMR) results as structural data collected was then also used in the empirical slope design of the planned quarry as discussed in Section 4.5.

4.2.9 Rock Laboratory Test Results

A number of samples were collected to analyse various characteristics of the rock and its suitability for use in construction of the breakwater or for use as concrete aggregate. Strength characteristics were also analysed and these parameters also serve as input into a preliminary quarry highwall design (see Section 4.5). Table 4-6 summarises the rock testing programme.

Table 4-6: Rock Laboratory Test Samples

Test Goal	Test Conducted	Quantity	Boreholes Targeted
Suitability of Rock Quarry Materials for use in Constructing a Breakwater	Resistance to Weathering (Manganese Sulphate Soundness)	2	VBH1; VBH6
	Methylene blue test	2	IBH3; IBH4
	Rock Petrographic Analyses for analysing mineral compositions, specifically any deleterious materials.	2	VBH2; IBH5
	Specific Gravity	10	Random
	Water absorption	10	Random
	Resistance to wear	2	IBH5; IBH6
	Resistance to breakage (Point Load Strength tests)	20	Random
	Resistance to breakage (Rock UCM tests)	10	VBH1; VBH2; VBH6; IBH1; IBH3; IBH4; IBH5; IBH6
	Resistance to breakage (Rock Fracture Toughness)	6	VBH3; VBH4; VBH6; IBH3; IBH4; IBH5
Suitability of Rock Quarry Materials for use as Concrete Aggregate	Flakiness Index	2	Composite sample from IBH6 & VBH6
	ARD, BRD & water absorption	4	
	ACV (wet or dry)	4	
	10% FACT (wet or dry)	4	
	ASR	4	
	Petrographic analysis	2	
	Methylene blue value	2	
	Organic impurities	2	
	Chloride content	4	
	Water soluble sulfates	4	
	Soluble deleterious materials	2	
	Soundness of aggregate	2	
	Sugar	2	
	Aggregate shrinkage and expansion	4	

Table 4-7 and Table 4-8 show the consolidated laboratory test results – detailed results are contained in Appendix C. Note in Table 4-8 that the aggregate testing programme required that the samples indicated in Table 4-6 targeted for aggregate testing were composited into a single sample.

Table 4-7: Consolidated Breakwater Laboratory Test Results

Site Location	Borehole ID	Sample	Rock Type	Strength (UCS)	Elastic Modulus (Gpa)	Poisson's Ratio	Point Load Strength IS	Micro-Deval Abrasion (%)	Water Absorption (%)	Specific Gravity (g/cm^3)	Fracture Toughness KIC (MN/m)	Petrographic Analysis (%)		
												Quartz	Muscovite	Kaolinite
Port (Quarry Site 2)	IBH1 - 11.39 - 11.7	S9	Quartz Schist	13.0	0.53	0.16								
Port (Quarry Site 2)	VBH1 - 9.44 - 9.94	S10	Quartzite	63.7	85.70	0.21			0.12%	2.61				
Port (Quarry Site 2)	VBH2 - 11.39 - 11.74	S11	Quartzite	68.9	77.30	0.17	11.8							
Port (Quarry Site 2)	VBH2 - 16.48 - 16.84	S12	Quartzite	193.6	76.40	0.11	5.1							
Port (Quarry Site 2)	VBH2 11.02 - 11.13	S6	Quartzite									99.00	1.00	0.00
Port (Quarry Site 2)	VBH2 - 11.39 - 11.74	S11	Quartzite				11.5							
Port (Quarry Site 2)	VBH2 - 11.39 - 11.74	S11	Quartzite				10.3							
Port (Quarry Site 2)	VBH2 - 11.39 - 11.74	S11	Quartzite				8.3							
Port (Quarry Site 2)	VBH2 - 16.48 - 16.84	S12	Quartzite				4.6							
Port (Quarry Site 2)	VBH2 - 16.48 - 16.84	S12	Quartzite				6.5							
Port (Quarry Site 2)	VBH2 - 16.48 - 16.84	S12	Quartzite				7.4							
Port (Quarry Site 2)	VBH2 - 16.48 - 16.84	S12	Quartzite				4.9							
Port (Quarry Site 2)	VBH2 - 16.48 - 16.84	S12	Quartzite				5.3							
Port (Quarry Site 2)	VBH3 13.09 - 13.40	S19	Quartzite				12.5		0.11%	2.62	2.85			
Port (Quarry Site 2)	VBH3 13.09 - 13.40	S19	Quartzite				12.2							
Port (Quarry Site 2)	VBH3 13.09 - 13.40	S19	Quartzite				11.8							
Port (Quarry Site 2)	VBH3 13.09 - 13.40	S19	Quartzite				12.7							
Port (Quarry Site 2)	VBH3 13.09 - 13.40	S19	Quartzite				11.5							
Port (Quarry Site 2)	VBH4 16.05 - 16.37	S20	Quartzite				9.4		0.06%	2.64	3.25			
Port (Quarry Site 2)	VBH4 16.05 - 16.37	S20	Quartzite				9.7							
Quarry Site 1	IBH 5 3.24 - 3.73	S14	Quartzite	9.18	49.30	0.14	5.5							
Quarry Site 1	IBH 6 3.74 - 4.04	S13	Quartzite	61.05	46.50	0.09	5.9							
Quarry Site 1	IBH 4 17.95 - 18.35	S15	Quartzite	61.46	20.30	0.15								
Quarry Site 1	IBH 3 4.56 - 4.91	S16	Quartzite	205.7	69.30	0.12	4.7		0.43%	2.57				
Quarry Site 1	VHB6 7.33 - 7.77	S18	Quartzite	239.3	82.30	0.11	10.6							
Quarry Site 1	IBH 3 11.03 - 11.45	S17	Quartzite	297.8	72.70	0.17	10.4		0.76%	2.60				
Quarry Site 1	IBH5 6.16 - 6.22	S5	Quartzite									98.00	1.00	1.00
Quarry Site 1	IBH5 11.03 - 11.24	S7	Quartzite					4.45						
Quarry Site 1	IBH5 11.03 - 11.24	S7	Quartzite					3.60						
Quarry Site 1	IBH5 11.03 - 11.24	S7	Quartzite					4.34						
Quarry Site 1	IBH5 11.03 - 11.24	S7	Quartzite					3.42						
Quarry Site 1	IBH6 15.40 - 15.74	S8	Quartzite					4.76						
Quarry Site 1	IBH6 15.40 - 15.74	S8	Quartzite					5.41						
Quarry Site 1	IBH6 15.40 - 15.74	S8	Quartzite					4.22						
Quarry Site 1	IBH6 15.40 - 15.74	S8	Quartzite					3.44						
Quarry Site 1	IBH 6 3.74 - 4.04	S13	Quartzite				6.3							
Quarry Site 1	IBH 5 3.24 - 3.73	S14	Quartzite				5.7							
Quarry Site 1	IBH 5 3.24 - 3.73	S14	Quartzite				4.6							
Quarry Site 1	IBH 5 3.24 - 3.73	S14	Quartzite				5.5							

Site Location	Borehole ID	Sample	Rock Type	Strength (UCS)	Elastic Modulus (Gpa)	Poisson's Ratio	Point Load Strength IS	Micro-Deval Abrasion (%)	Water Absorption (%)	Specific Gravity (g/cm^3)	Fracture Toughness KIC (MN/m)	Petrographic Analysis (%)		
												Quartz	Muscovite	Kaolinite
Quarry Site 1	IBH 3 4.56 - 4.91	S16	Quartzite				5.3							
Quarry Site 1	IBH 3 4.56 - 4.91	S16	Quartzite				4.5							
Quarry Site 1	IBH 3 4.56 - 4.91	S16	Quartzite				5.4							
Quarry Site 1	IBH 3 11.03 - 11.45	S17	Quartzite				13.4							
Quarry Site 1	IBH 3 11.03 - 11.45	S17	Quartzite				12.1							
Quarry Site 1	VHB6 7.33 - 7.77	S18	Quartzite				10.2							
Quarry Site 1	VHB6 7.33 - 7.77	S18	Quartzite				8.7							
Quarry Site 1	VHB6 7.33 - 7.77	S18	Quartzite				9.7							
Quarry Site 1	VHB6 7.33 - 7.77	S18	Quartzite				10.8							
Quarry Site 1	VHB6 5.10 - 5.35	S21	Quartzite				12.3		0.02%	2.64	2.96			
Quarry Site 1	VHB6 5.10 - 5.35	S21	Quartzite				13.7							
Quarry Site 1	VHB6 5.10 - 5.35	S21	Quartzite				12.6							
Quarry Site 1	VHB6 5.10 - 5.35	S21	Quartzite				15.0							
Quarry Site 1	VHB6 5.10 - 5.35	S21	Quartzite				14.6							
Quarry Site 1	VHB6 5.10 - 5.35	S21	Quartzite				12.7							
Quarry Site 1	IBH 3 6.39 - 6.73	S22	Quartzite				7.7		0.16%	2.54	2.94			
Quarry Site 1	IBH 3 6.39 - 6.73	S22	Quartzite				5.7							
Quarry Site 1	IBH 3 6.39 - 6.73	S22	Quartzite				5.7							
Quarry Site 1	IBH4 12.06 - 12.40	S23	Quartzite								3.11			
Quarry Site 1	IBH5 14.38 - 14.80	S24	Quartzite				10.3		0.24%	2.58	2.55			
Quarry Site 1	IBH5 14.38 - 14.80	S24	Quartzite				10.1							
Quarry Site 1	IBH5 14.38 - 14.80	S24	Quartzite				14.3							
Quarry Site 1	VHB6 9.83 - 10.09	S26	Quartzite				7.5		0.11%	2.60				
Quarry Site 1	VHB6 9.83 - 10.09	S26	Quartzite				7.2							
PRDW Screening Values (Draft RFQ S2023-0-RFQ-SI-002)				Filter/Armour 100 (min): Core 70 (min)	-	-	Filter/Armour 4 (min): Core 3 (min)	-	Filter/Armour 2 (max): Core 3 (max)	Filter/Armour 2.6 (min): Core 2.4 (min)	-	-	-	-
SANS 1083:2014				-	-	-	-	-	-	-	-	-	-	2%
Other Industry Norms				120 (min)	-	-	5 (min)	30% (max)	2.0%	-	-	-	-	-

The laboratory test results have been assessed against various screening levels to highlight suitability of the proposed quarried rock for use in constructing the breakwater. Test results are colour coded: green to indicate compliance, red to indicate non-compliance and orange to indicate marginal non-compliance.

Table 4-8: Consolidated Aggregate Laboratory Test Results

Site Location	Borehole ID	Sample	Rock Type	Mg Sulfate Sound. (%)	Flakiness Index (%)	ACV Wet (%)	ACV Dry (%)	10% FACT Wet (kN)	10% FACT Dry (kN)	Rel. Dens. (g/cm^3)	Water Absorp. (%)	Chloride Content (%)	Soluble Sulphate as SO_3(%)	Sugar	Methyl. Blue Absorp.	AAR (%)	Micro-Deval Abrasion (%)	Organic Impurities	Shrinkage as % of Quartzite ref.	Expansion as % of Quartzite ref.
Quarry Site 1	VBH6 6.32 - 6.81	S1	Quartzite	0,43%																
Port (Quarry Site 2)	VBH1 9.44 - 9.94	S2	Quartzite	0,16%																
Quarry Site 1		Comp. (S25-34)	Quartzite		30,7%	16,10	15,00	270,00	295,00	2,52	0,7%	0,0117%	0,0175%	0,00%	0,05	0,0600%		Lighter Than Indicator	84,3%	73,3%
Quarry Site 1		Comp. (S25-34)	Quartzite		30,7%	16,10	15,00	270,00	295,00	2,52	0,7%	0,0131%	0,0178%	0,00%	0,05	0,0640%			84,3%	73,3%
Quarry Site 1		Comp. (S25-34)	Quartzite		26,5%	16,10	15,00	270,00	295,00	2,52	0,7%	0,0106%	0,0171%	0,00%		0,0670%			84,3%	73,3%
Quarry Site 1		Comp. (S25-34)	Quartzite		26,5%	16,10	15,00	270,00	295,00	2,52	0,7%	0,0106%	0,0171%	0,00%		0,0640%			84,3%	73,3%
Quarry Site 1	IBH3 13.08 - 13.44	S3	Quartzite												0,05					
Port (Quarry Site 2)	IBH4 9.16 - 9.73	S4	Quartzite												0,05					
Port (Quarry Site 2)	VBH1 9.44 - 9.94	S10	Quartzite								0,12%									
Port (Quarry Site 2)	VBH3 13.09 - 13.40	S19	Quartzite								0,11%									
Port (Quarry Site 2)	VBH4 16.05 - 16.37	S20	Quartzite								0,06%									
Quarry Site 1	IBH 3 4.56 - 4.91	S16	Quartzite								0,43%									
Quarry Site 1	IBH 3 11.03 - 11.45	S17	Quartzite								0,76%									
Quarry Site 1	VHB6 5.10 - 5.35	S21	Quartzite								0,02%									
Quarry Site 1	IBH 3 6.39 - 6.73	S22	Quartzite								0,16%									
Quarry Site 1	IBH5 14.38 - 14.80	S24	Quartzite								0,24%									
Quarry Site 1	VHB6 9.83 - 10.09	S26	Quartzite								0,11%									
Quarry Site 1	IBH5 11.03 - 11.24	S7	Quartzite														4,45			
Quarry Site 1	IBH5 11.03 - 11.24	S7	Quartzite														3,60			
Quarry Site 1	IBH5 11.03 - 11.24	S7	Quartzite														4,34			
Quarry Site 1	IBH5 11.03 - 11.24	S7	Quartzite														3,42			
Quarry Site 1	IBH6 15.40 - 15.74	S8	Quartzite														4,76			
Quarry Site 1	IBH6 15.40 - 15.74	S8	Quartzite														5,41			
Quarry Site 1	IBH6 15.40 - 15.74	S8	Quartzite														4,22			
Quarry Site 1	IBH6 15.40 - 15.74	S8	Quartzite														3,44			
SANS 1083:2014					35 % (max)	29% (max)		110 (min)	110 (min)			RC (max) 0.03%		Zero Sugar		0.1% (max)	30% (max)	Not be darker than		
Other Industry Norms				10% (Max)			30% (max)				2% (max)		0.4% (max)							
COLTO SECTION 6402																			Prestressed Conc. 130% (max) RC Conc. 150% (max) Mass Conc. 200% (max)	

The laboratory test results have been assessed against various screening levels to highlight suitability of the proposed quarried rock for use as aggregat. Test results are colour coded: green to indicate compliance, red to indicate non-compliance and orange to indicate marginal non-compliance.

Comments on the laboratory test results:

- Breakwater Materials Testing Programme:
  - Apart from a few UCS test results that do not comply with PRDWs screening values, the materials analysed from both Quarry site 1 and Quarry Site 2 are in general compliance from a rock quality perspective when assessed against the range of criteria shown at the bottom of Table 4-7;
  - When comparing the UCS results that appear to fall short to the point load test results, it is evident that the point load test results far exceed the screening criteria, and it is without doubt that the UCS test results were impacted by micro-fractures in the rock specimens submitted for analysis – it is also noted that these fractures were not visible to the naked eye when the samples were selected.
- Concrete Aggregate Testing Programme:
  - The rock samples analysed indicate high compliance with aggregate requirements shown at the bottom of Table 4-8;
  - Aggregate shrinkage and expansion characteristics test results are not yet available and will be included in a final version of the report.

4.2.10 Quarry Block Size Analysis

Based on the geotechnical mapping and drilling data, an assessment has been made of the likely block sizes that will be produced from quarrying which show marginal rock quality. Only areas considered as viable quarry sites were included in the analysis (as shown in Figure 4-2). Representative images of these locations which clearly depict the reason for their selection, are presented in Figure 4-7.

The output of the face mapping exercise includes identification of major joint sets, their orientation and spacing. These parameters are used directly in the calculation of average block volume driven by jointing. Palmstrom (2005) devised a formula taking into consideration the interaction of the major joint sets as shown in

$$Vb = \frac{S1\ x\ S2\ x\ S3}{SinY1\ x\ SinY2\ x\ SinY3}$$

Where Vb = Block Volume

S1 = Joint Spacing (Joint set 1)

S$_Y$1 = Angle between Joint sets

Joint spacing was derived directly from mapping data, whereas the angle between joints were determined by plotting the average joint set orientations planes on a stereonet, and then directly determining the angle between each plane. This was carried out directly in DIP's software, an example of which is shown in Figure 4-6.

4.2.11 Other Quarrying Considerations

A cursory glance at the borehole logs (Appendix B) and the laboratory test results (Appendix C2) will show that the quartzite is (on average) at least very hard rock, but sometimes logged as extremely hard rock. When considering specifications for quarrying contractors, it is absolutely imperative that this excessively hard, brittle nature of the quartzite is emphasised as wear and tear on all manner of equipment (from tyres to any manner of cutting/drilling equipment) will be extreme. Failure to stress this will probably result in all manner of claims when the contractor encounters these trying conditions in reality.

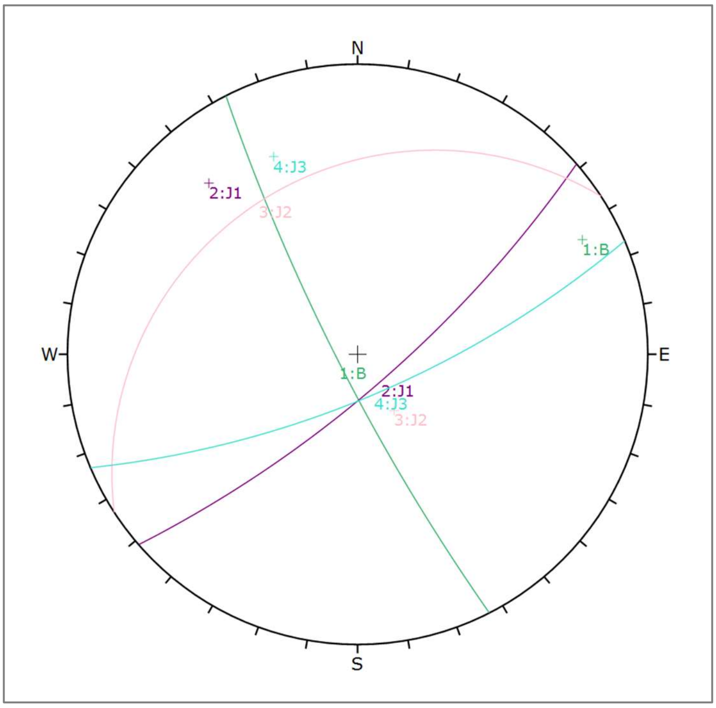
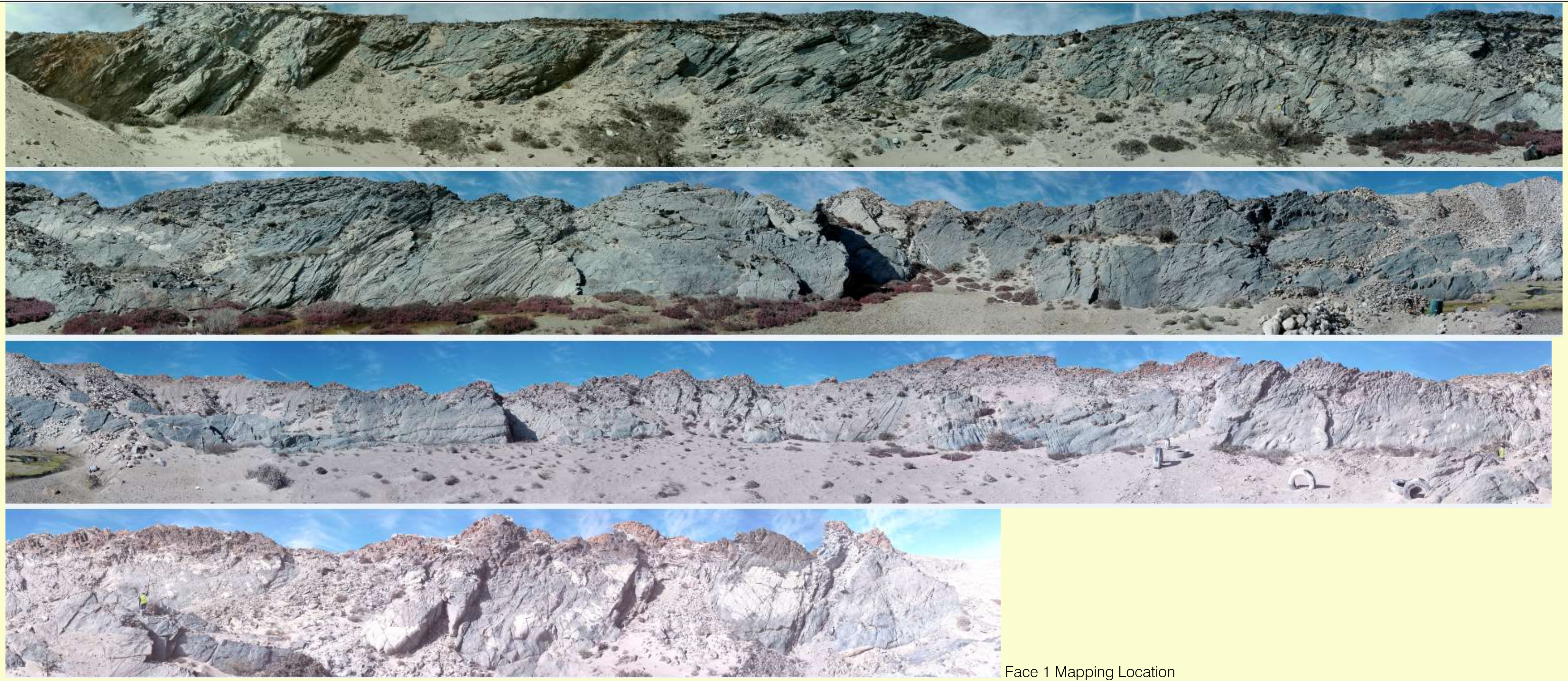
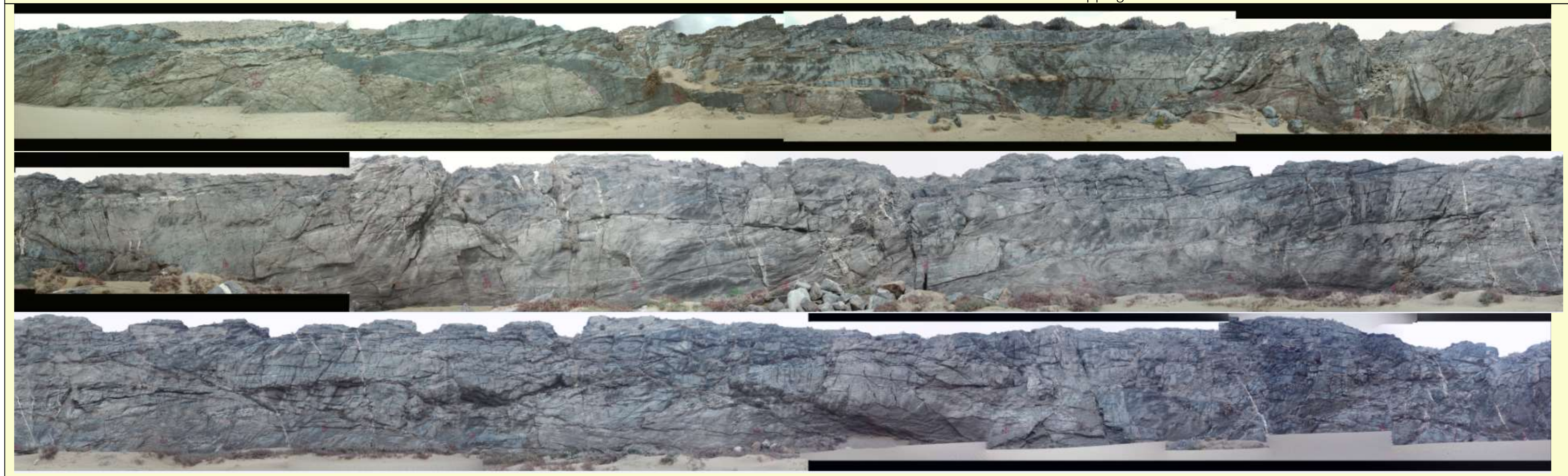


Figure 4-6: Stereographic Projection: Great planes Intersections of major joint sets for Mapping Location 7 (Quarry Site 1)



Face 1 Mapping Location



Face 2 Mapping Location

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Face 1 and 2 Mapping

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Figure 4-7: A) Face 1 Mapping Images and B) Face 2 Mapping Images

The results showed expected average block sizes for the selected quarry locations to be in the range of 0.50 to 0.65 m^3.

In order to firm up on these average block sizes, JBlock was utilised. JBlock is a software package developed for the estimation of size of blocks that are likely to form in the roof of underground mines. It takes into account the variability of the joint set characteristic to provide a distribution of block sizes likely to form (Esterhuizen, 1996). This is useful in that it shows a spread of what can be expected from quarrying, to better ascertain whether this meets the requirements for construction purposes.

Figure 4-8 presents a histogram of the JBlock analysis results (considering all mapping data in the identified quarry locations) output presented in kg. It is obvious that the distribution of block sizes is skewed towards the 10 kg to 400 kg size ranges, with some outliers in much larger block sizes.

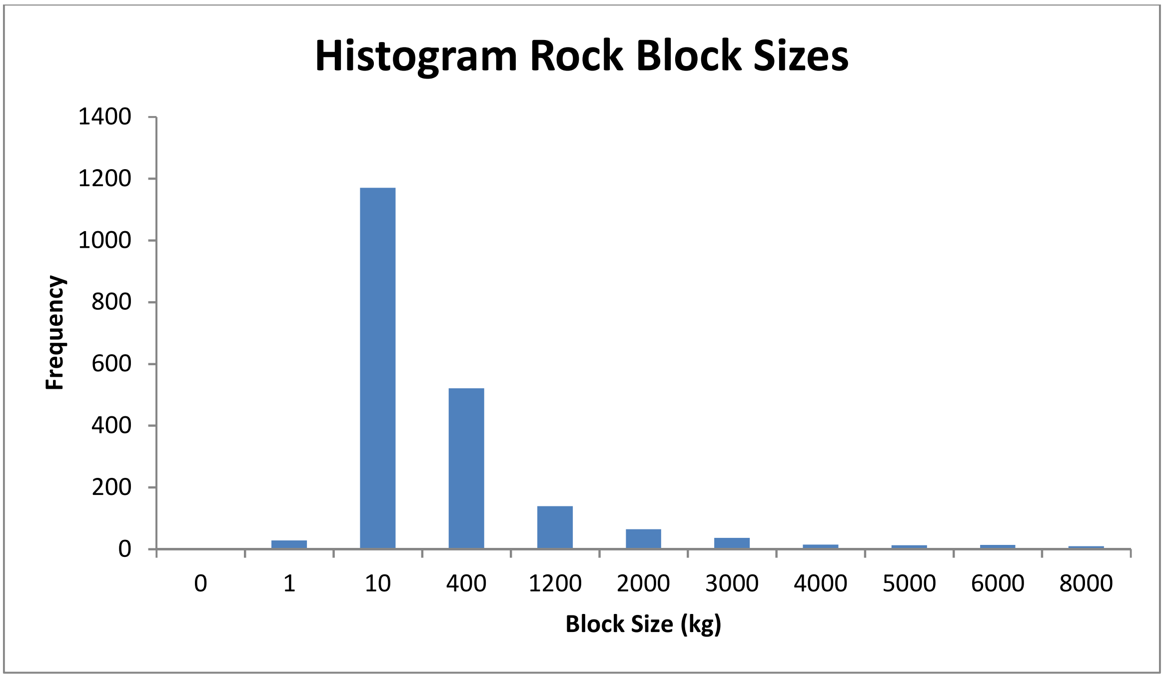

Figure 4-8: Histogram of Rock Block Sizes

A production estimated for a hypothetical quarry developed at the southern quarry site (Quarry Site), tabulated against the required block sizes (ref the PRDW terms of reference) is shown in Table 4-9.

Table 4-9: Preliminary Estimate of Southern Quarry Site Block Production

Target Materials (kg)	PRDW Volumes Required (m^3)	Estimated Production Based on Figure 4-8 (m^3)
Quarry run (0-400)	2 900 000	1 972 600
400-1200	60 000	857 900
2000-4000	100 000	164 700
3000-6000	100 000	103 800
5000-8000	100 000	57 800
Totals	**3 260 000**	**3 156 800**

Although there is an indication in Table 4-9 that the larger (2000-8000 kg) block targets could be produced, we are of the opinion that the practicalities of quarrying (in particular basting and material handling) in this very hard/brittle material may result in larger blocks breaking up, and the ultimate production skewing even more to the lower size ranges.

A glance at the rock laboratory test results in Table 4-7 (and contained in detail in Appendix C) shows that it is evident that the UCS measured in quartzite samples varies considerably (from 9.2 MPa to 297.8 MPa). The lower range of UCS values obtained is almost certainly attributed to the presence of micro fractures in the rock which present as non-visible planes of weakness along which failure occurs during testing. Although this may not be representative of the actual intact rock strength, it does present a concern related to the practicalities of producing larger block sizes when quarrying commences. Blasting vibrations may in fact result in dilating of these micro fractures, which will result in increased breakage along these planes. The rock size distributions calculated above do not consider this, and it is highly likely that the size distribution quoted above may not be realised and that it will skew to smaller rock sizes. It is therefore, in our professional opinion, likely that the quarry may not produce sufficient armour size material.

It is probably sound advice to assume that further quarry investigations will need to be carried out, or better yet, a trial quarry developed to determine the actual impact of blasting and to validate the findings of this study.

4.3 Offshore Geotechnical Setting

With reference to the model (Section 4.4 below), and extrapolation of data to the offshore environment, the following is noted:

- The onshore site is characterised by a succession of hard rock quartzite and interbedded soft rock quartz schist / schist – there is no logical reason to assume that this succession (which is linked to the original depositional environment of the sedimentary rocks prior to being metamorphosed) does not repeat offshore and in the breakwater founding zone;
- It is probable that any occurrences of (offshore) schist (which is weathered to soils in places onshore) in the high wave energy environment may have eroded preferentially compared to the more competent quarzite, potentially manifesting in erosion channel (depressions) parallel to the coastline;
- Although it is likely that less competent schist may have eroded in the offshore environment, it is still possible that completely weathered schist can be encountered further down the geotechnical profile as was evident onshore (e.g. IBH1 7.5 to 8.48 m depth);
- Local geological distributions (presumably from mapping of surface expressions in mined out areas) received from the mine indicate that there are random outcrops of limestone. SRK did not encounter any limestone during the drilling or mapping, and it is therefore uncertain whether limestone will be encountered in the geotechnical profile offshore.

The following comments are made with respect to closing out uncertainties in the investigative phases related to the offshore geotechnical profile:

- Additional onshore investigations will not provide more certainty to the anticipated offshore geotechnical profile because of the irregularity of the quartzite / schist horizons.
- Offshore investigations (i.e. drilling) would largely close out uncertainties, but offshore drilling will be very expensive, particularly if contemplated prior to the breakwater being constructed (i.e. drilling in a rough sea environment);
- Once the breakwater is constructed, boreholes could be drilled more efficiently, but it must be noted that with the randomly distributed sequence of quartzite / schist noted onshore, extensive drilling would be required to close out all uncertainties (i.e. to usefully delineate the schist horizons, many boreholes will be needed) – this too will prove to be very expensive;
- Directional drilling (from onshore) is another option of gathering the requisite offshore data, but the following will be challenging:
  - There is a *c.*20 m level difference from the onshore environment that is accessible to drilling rigs and mean sea level (>25 m to the sea bed);
  - Directional drilling is by nature extremely costly.

Based on the complexity of the challenges described above, it may prove to be more practical to investigate the profile during construction – e.g. by drilling ahead of the quay construction teams.

The above all considered, founding approaches could be developed as discussed below:

- Piled foundations:
  - Because of the likely variability on the founding materials (alternating very competent quartzites and weak schists), piled foundations will be more challenging to design and implement (construct) – this may require an approach of having two pile designs (one for quatzite and one for schists) and implementing the appropriate design once the geotechnical profile is known at individual piling positions.
  - In addition, and against the backdrop of the likely variability in founding conditions (alternating quartzite and schist), it would probably reduce risks to not rely on tension piles as critical tension piles could end up needing to be founded in poor schist materials – reliance on compression piles reduces these risks somewhat as the schist materials will be more reliable in compression as they are generally confined (between quartzite layers) – however, should extensive / thick distributions of schist occur as were mapped onshore, reliance on compression piles will again become a risk as the confining effects will abate;
  - For these reasons, it may be necessary to plan for extensive investigational drilling ahead of the quay construction teams to ensure that a piling founding solution is successful – this would probably require a full time geotechnical engineer on site to assist in taking appropriate decisions.
- Gravity foundations:
  - It is our professional opinion that gravity foundations will carry a lower risk considering the probable variability in the geotechnical profile – the main idea being that loads are more effectively spread with gravity foundations;
  - Risks that remain are linked to possible differential settlement should the caissons need to be founded on two different material types (i.e. schist and quarzite), of if adjacent caissons are founded on different material types;
  - Another risk could be related to extensive distributions of clay (weathered schist) material that will be saturated and potentially have very low bearing capacity, as this could result in late design changes that will stress time and budgets during construction – as stated previously, however, it is probable that the high energy sea environment could possibly have ‘eroded out’ such weak zones.

In summary, the offshore geotechnical profile remains an area of uncertainty, and the only data at our disposal is the onshore data that has been gathered for this report. Both offshore piled and gravity foundations carry risks with associated costs and design/construction complexities. The choice of founding solution needs to be evaluated holistically within the project context before a specific founding type is selected. Choice of foundation type may be sensitive to construction programme and/or cost, and it is possible that the more complex the founding solution is, the more likely that claims could arise during the construction thereof.

4.4 Geological and Geotechnical Model

The data described in Section 3.4 and Sections 4.1 to 4.2, as well as the intrusive data obtained from the drilling and test pitting programmes was used to build a Geological/Geotechnical Model using Leapfrog™. The model was built from the following information:

- Geometric data obtained from Alexkor RMC JV – Lidar data in particular;
- Land based geophysical investigation results (ref Cape Geophysics) – specifically cross sections produced;

- Marine geophysical investigation results (ref Tritan Surveys) – specifically bathymetric data and sediment/bedrock contact data emerging from the investigation[2];
- The intrusive investigation results.

The model has extensive value in the form of a digital viewer file that is freely downloaded from the Leapfrog™ website, and the viewer files are appended to this report. That said, and for the purposes of illustration, several screen grabs from the model are shown (along with comments below) in:

- Figure 4-9: The Basic Leapfrog™ Model Setup (looking North):
  - The model setup has a vertical:horizontal scale of 2:1;
  - Boegoeberg and the Geophysical Traverses are clearly seen.
- Figure 4-10: Geology and Geophysical Traverses (looking North):
  - Bands of softer quartz schist / schist is noted;
  - The remainder of the geological profile (as assumed with the available data) is competent quartzite;
  - The bedrock is overlain by (predominantly) Aeolian sand.
- Figure 4-11: Bedrock Geology and Geophysical Traverses (looking North):
  - This figure has the same aspect as Figure 4-10, but has the sand layer removed to expose the bedrock profile.
- Figure 4-12: Cross Section through Port Site (looking North);
  - Similar detail to the preceding figures is shown, but in cross section in the vicinity of the proposed Port site;
  - Integrated data indicates that the softer quartz schist / schist bands dips towards the sea close;
  - The value of this site as a potential quarry site is severely reduced by this softer quartz schist / schist horizon indicated in the section;
  - It would be short sighted to assume that the succession of harder quartzite interbedded with softer quartz schist / schist does not continue offshore and that soft quartz schist / schist could be encountered in the founding zone of the proposed breakwater.
- Figure 4-13: Cross Section through Southern Quarry Site (looking North):
  - A preliminary design of the quarry (linked to achieving the volumes quoted in Table 4-9) is superimposed in this section;
  - The southern quarry site exhibits competent quartzite from the exposed face in a direction away from the sea;
  - The vertical face that was mapped (ref Figure 4-2) is seen in the centre of the figure;
  - Varying degrees of sand cover (quarry overburden) is evident, with less cover near the mapped face.

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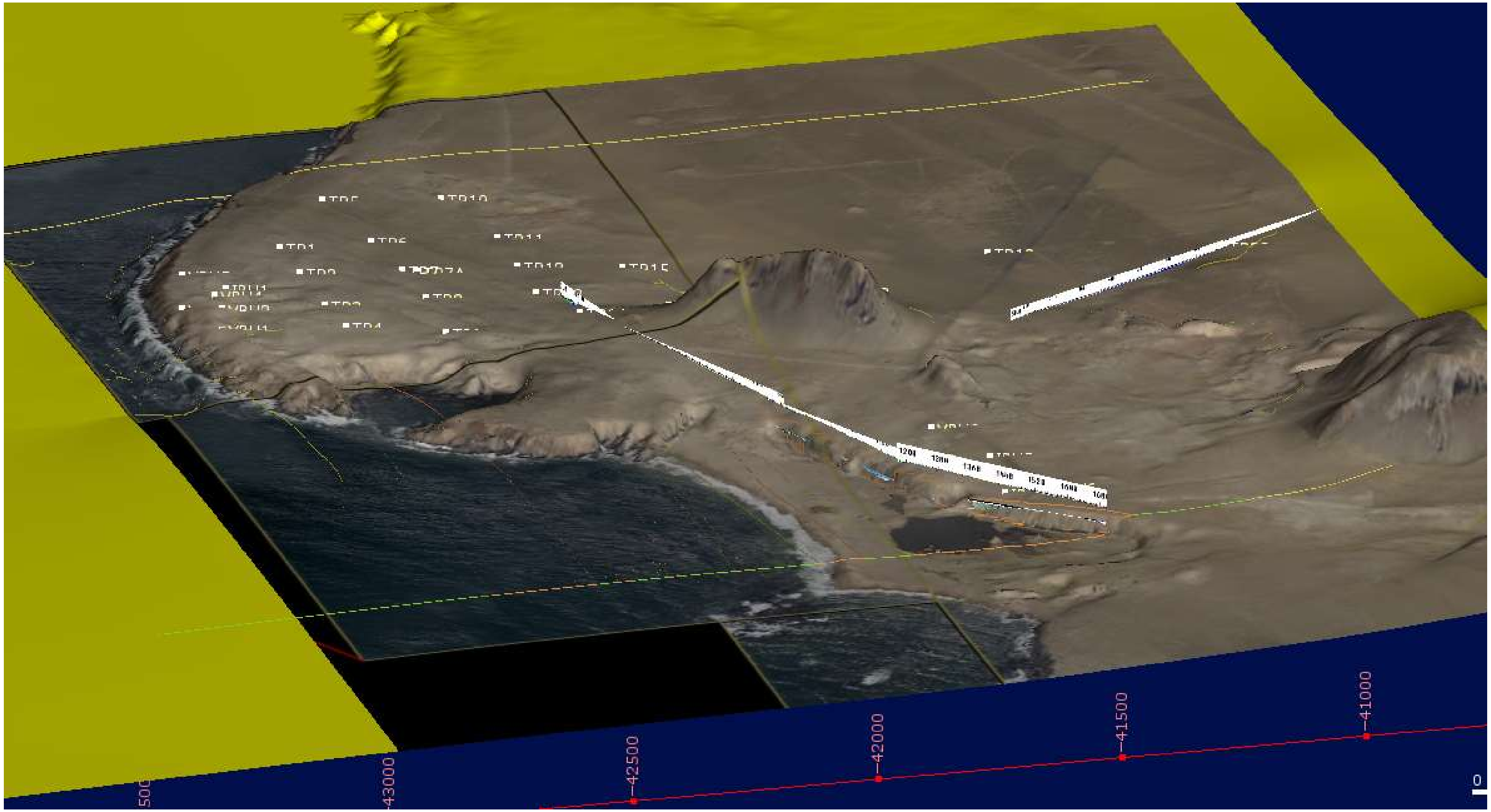
[2] These data are in draft format in this draft report.



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LEAPFROG™ MODEL SETUP

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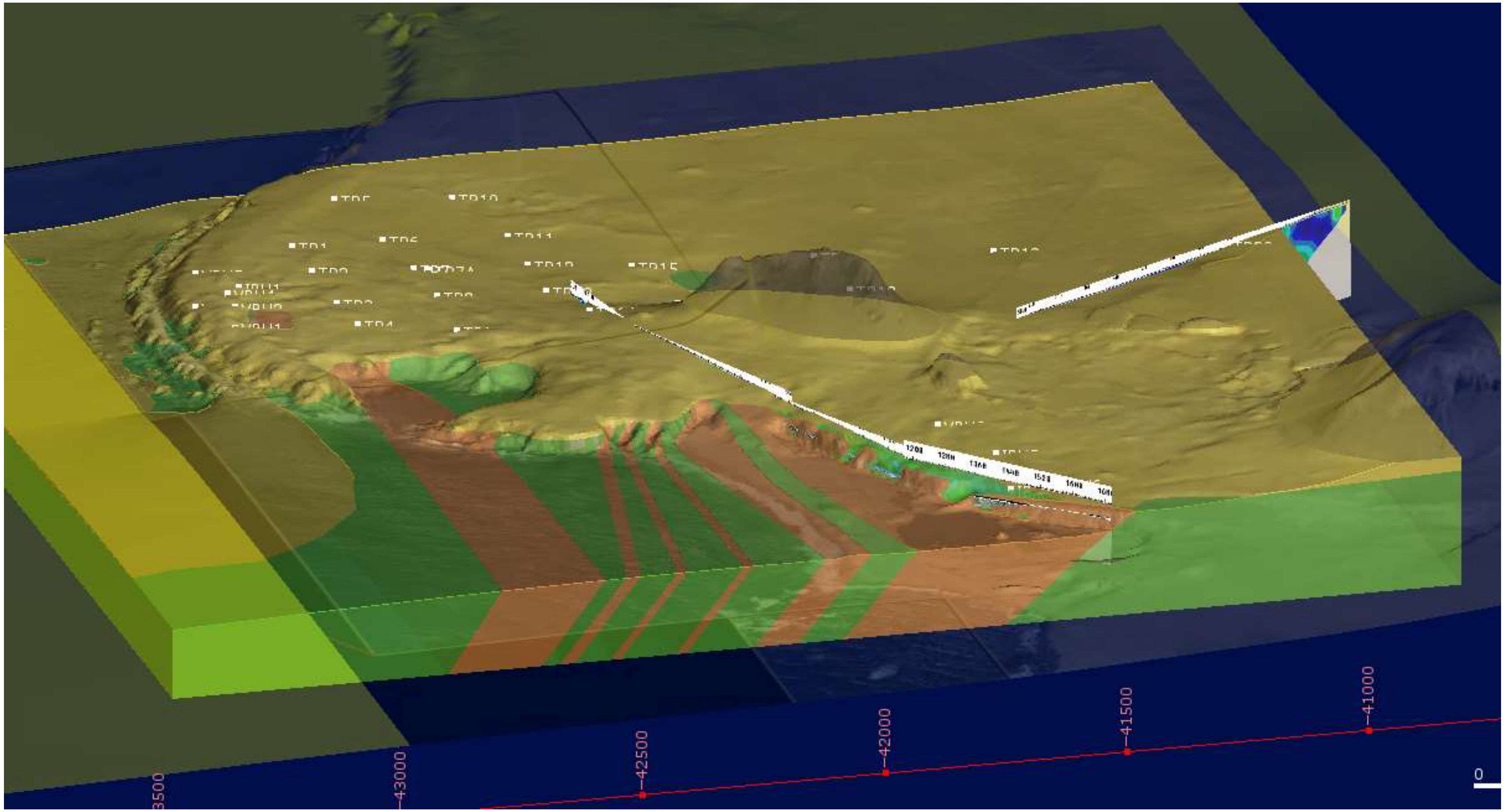
Figure 4-9: Leapfrog™ Model Setup



BOEGOEBAAI PORT GEOTECHNICAL INVESTGATION
LEAPFROG™ GEOLOGY AND GEOPHYSICAL TRAVERSES

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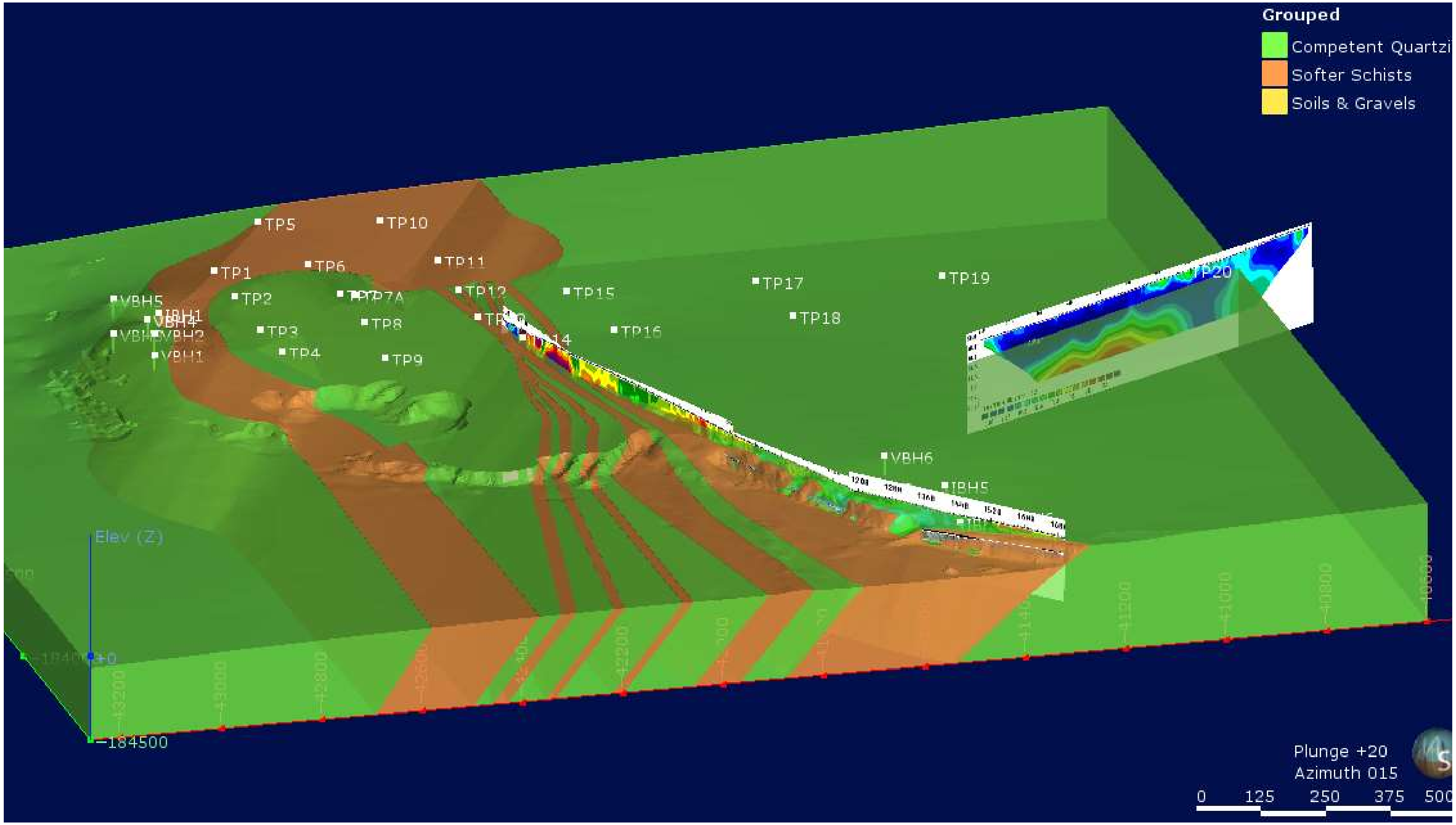
Figure 4-10: Geology and Geophysical Traverses



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LEAPFROG™ BEDROCK GEOLOGY AND GEOPHYSICAL TRAVERSES

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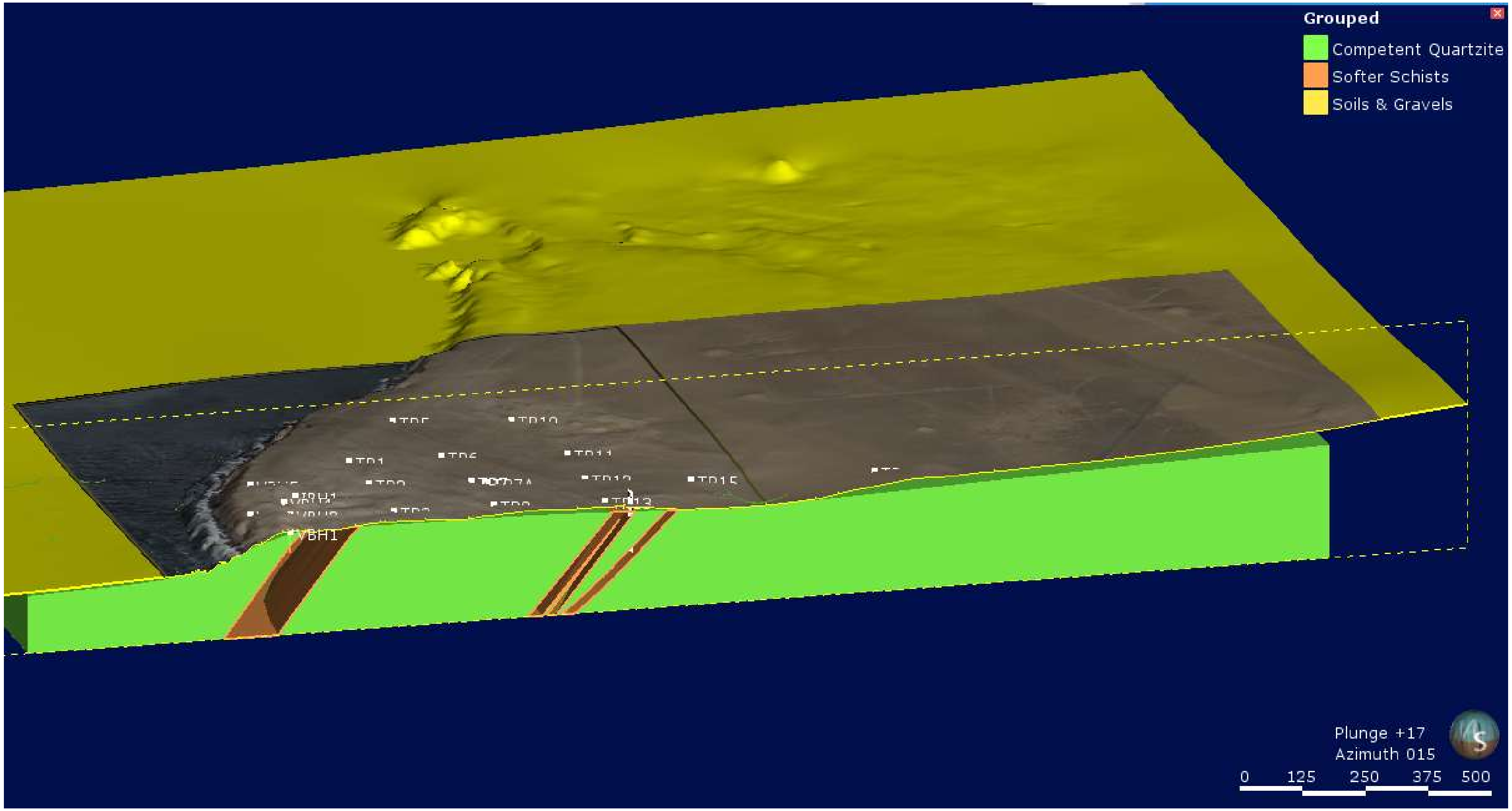
Figure 4-11: Bedrock Geology and Geophysical Traverses



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LEAPFROG™ CROSS SECTION THROUGH PORT SITE

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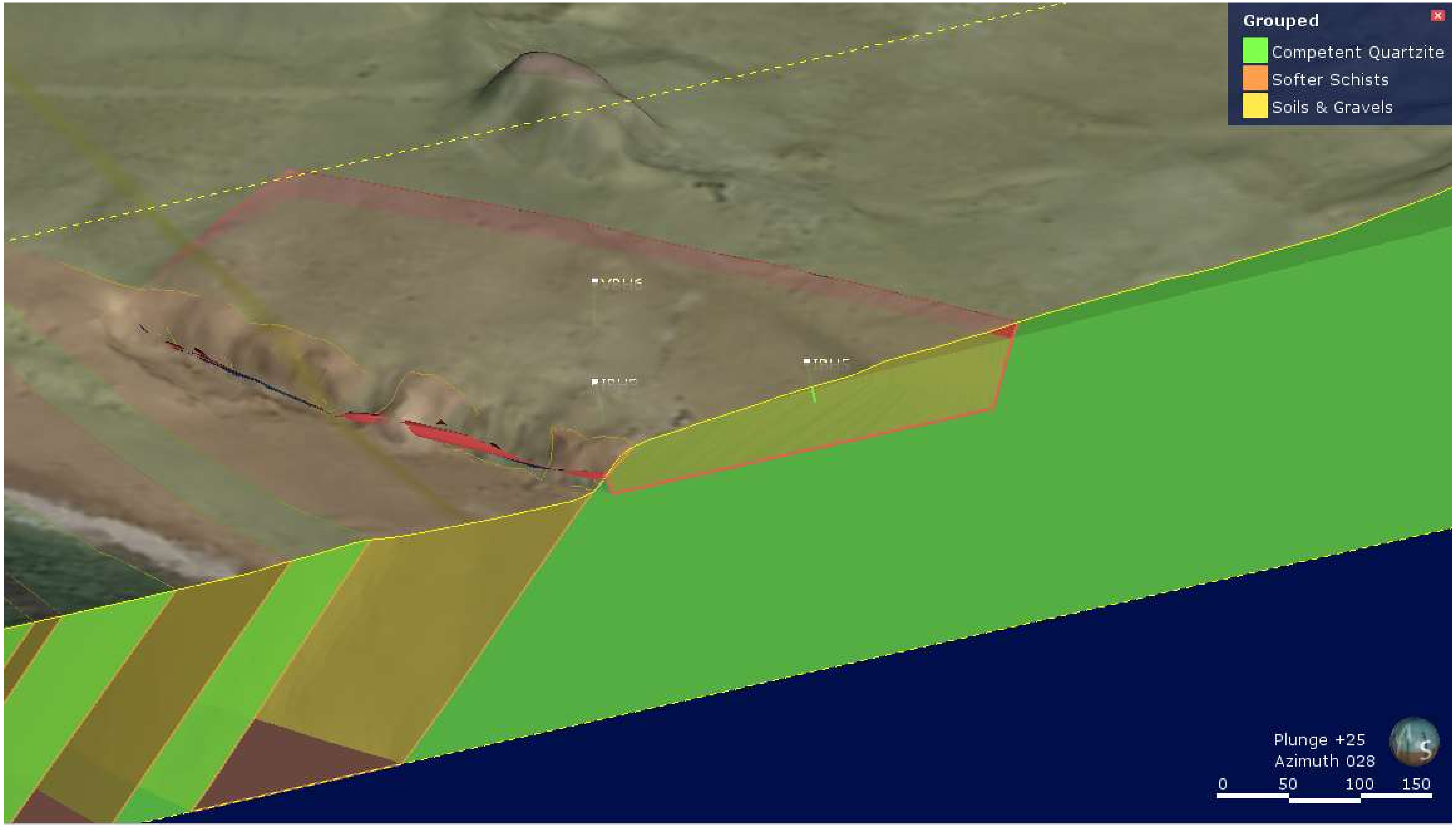
Figure 4-12: Cross Section through Port Site



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LEAPFROG™ CROSS SECTION THROUGH SOUTHERN QUARRY SITE

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Figure 4-13: Cross Section through Southern Quarry Site

4.5 Quarry Design

4.5.1 Rock Mass Conditions

The quarry design (for a 20 m deep quarry) was based on a simplified profile comprising 3 m sand underlain by hard rock quartzite. This was based on geological conditions observed in the geotechnical drill holes as discussed in detail in Section 4.2.8. The geotechnical parameters used to represent the rock mass in the model include the inputs into the Generalized Hoek-Brown Criterion, which is an empirical failure criterion that establishes the strength of rock in terms of major and minor principal stresses. The values used in the model are based on the results of the laboratory testing and the data collected from the geotechnical core logging. The methodology used for estimating the rock mass strength parameters is illustrated in the flow chart below (Figure 4-14), and this process has been used for all lithologies in each formation. It must be noted that very limited testing data was available, and due to the scale of the operation it was deemed appropriate to use published values where data was not available.

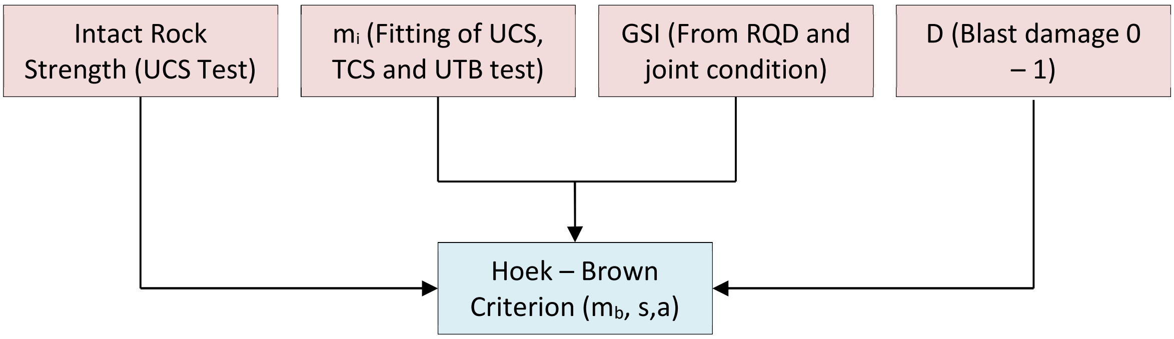


Figure 4-14: Methodology for the estimation of rock mass strength parameters

Intact rock strength

Intact rock strength (IRS) was based on the results of uniaxial compressive strength (UCS) tests on samples of intact rock between joints. A total of 10 UCS tests were carried out across the site, predominantly in the quartzite units. Failure modes (as indicated in the lab test forming Appendix C), show that the majority of samples tested failed on discontinuities. If this is the exception, typically these values are excluded from the analysis, as other strength inputs already account for the reduction in rock mass strength as a result of the presence of joints. Where failure on discontinuities does occur, this is more often than not thought to be a representation of the rock fabric itself, and therefore needs to be included in the analysis. For the purpose of this study, due to the variability in strength from 9 MPa to ~ 300 MPa, outliers (< 15 MPa) were excluded from the analysis and all other values included. Statistics on the IRS and density parameters used in the analysis are included in Table 4-10.

Table 4-10: Lab Results Summary

Sample	Density g/cm^3	UCS (MPa)
Mean	**2.56**	**149**
St Dev	0.02	96
Max	2.62	298
Min	2.56	61

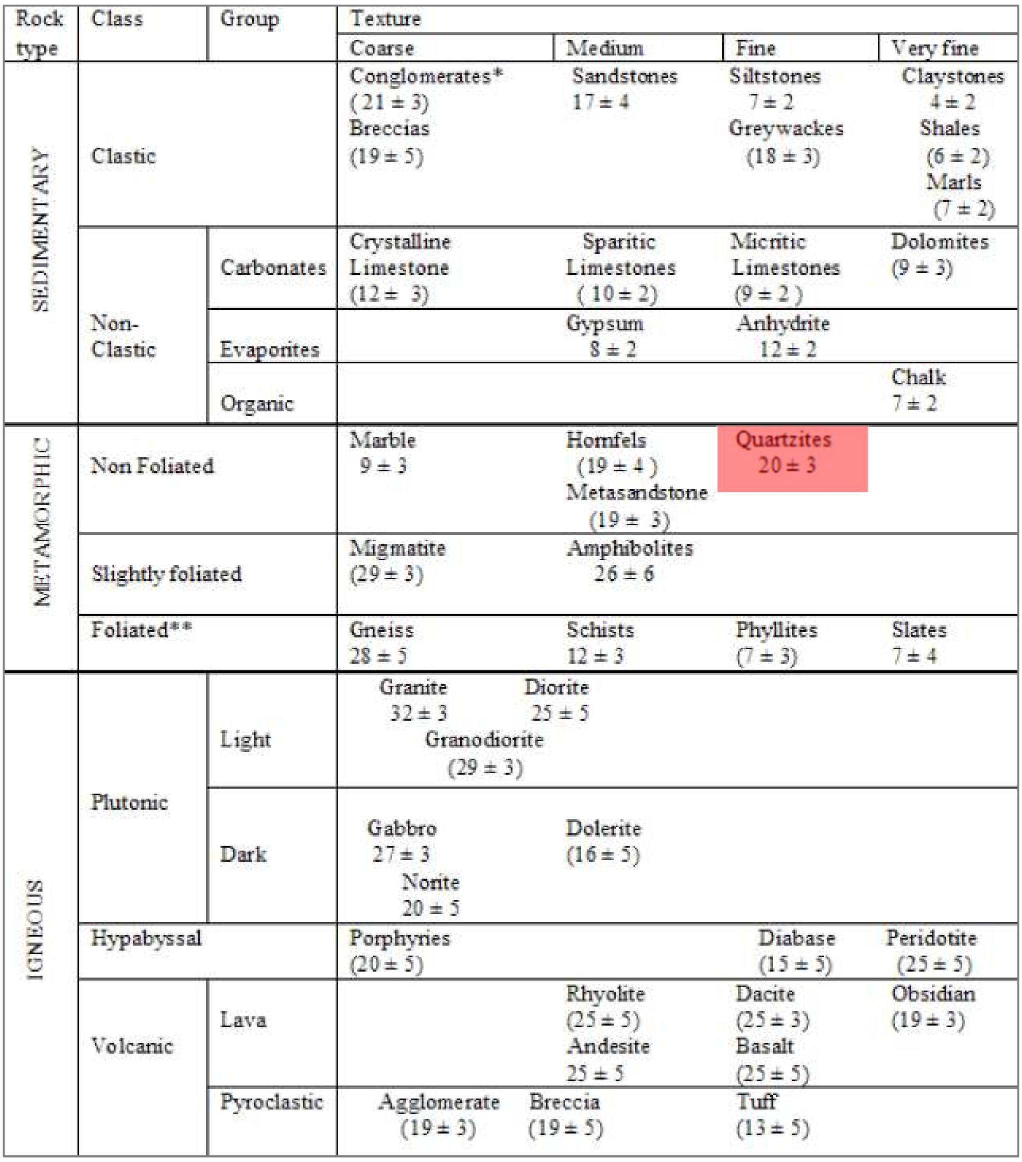
These values are considered conservative and the laboratory that analysed the samples is of the opinion that the mean will be in the region of 200 MPa.

Material constant m_i

m_i is a material constant that describes the relationship between the principle stresses at failure. There are a number of methodologies that may be used in the calculation of m_i all considering the results of laboratory strength tests. Typically, brazilian tensile strength (BTS), UCS and triaxial compressive strength (TCS) are used in the calculation of m_i values based on fitting a straight line to the test results. In this case, for the scale of the study, this process was not deemed necessary, and instead published values were used in the analysis as presented in Figure 4-15 in red. A value of 20 was considered appropriate, as it is representative of a hard brittle rock.

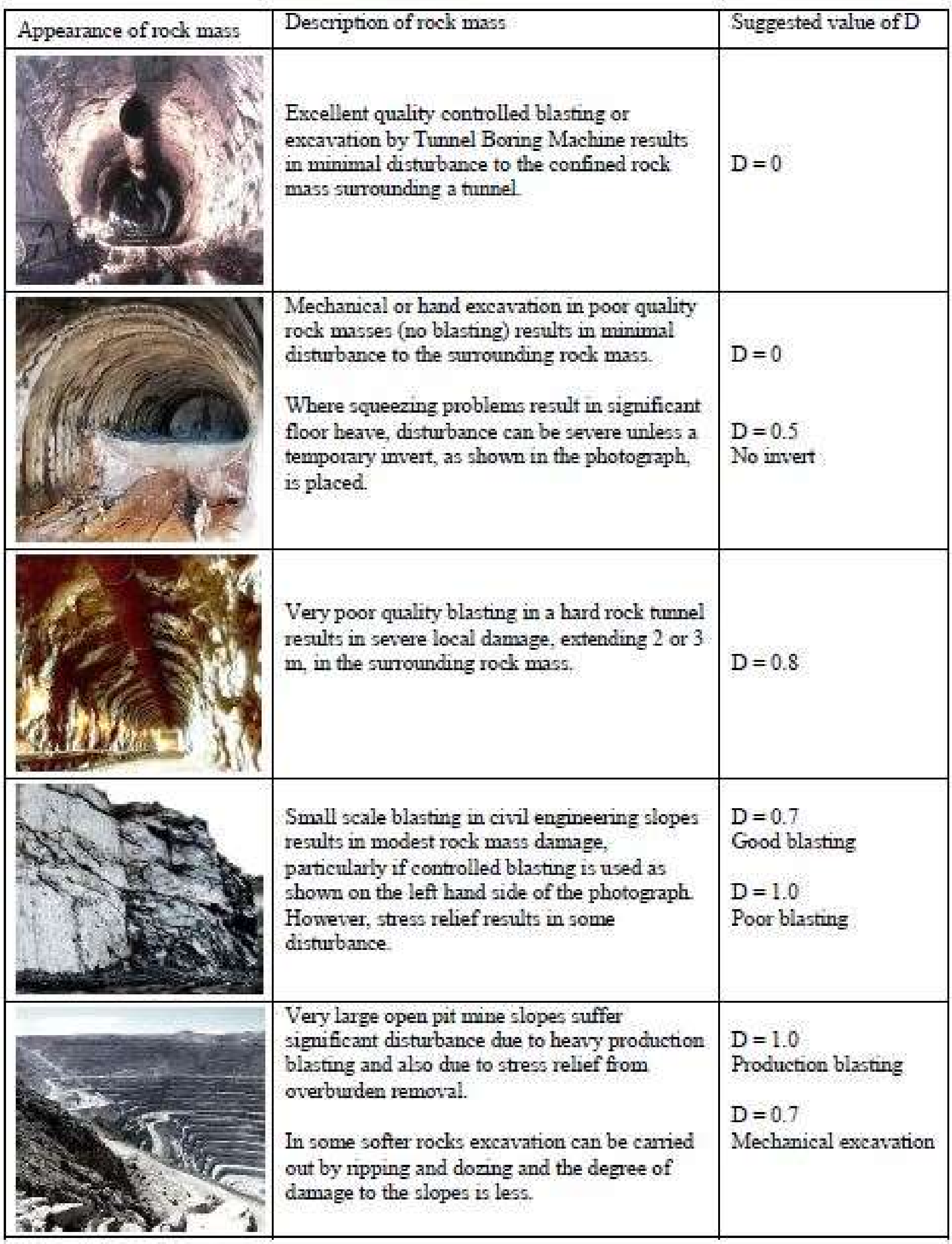
Blasting Damage Factor (D)

Blasting was mentioned in Section 4.2.10 as having an impact on the anticipated block sizes. Further to this, the energy emanating from a blast is also transferred into the rock face, particularly in small quarrying scenarios where blast design is not a priority. Blast energy leads to the dilation of joint surfaces and a reduction in the shear strength properties of the joints and unfavourably affects the general highwall conditions. Guidelines for assigning blast damage factors are presented in Figure 4-16. Blast damage factors of 0.7 and 1.0 were selected to assess the sensitivity of the slope to poor blasting techniques.



Rock type	Class	Group	Texture			
			Coarse	Medium	Fine	Very fine
SEDIMENTARY	Clastic		Conglomerates* (21 ± 3) Breccias (19 ± 5)	Sandstones 17 ± 4	Siltstones 7 ± 2 Greywackes (18 ± 3)	Claystones 4 ± 2 Shales (6 ± 2) Marls (7 ± 2)
	Non-Clastic	Carbonates	Crystalline Limestone (12 ± 3)	Sparitic Limestones (10 ± 2)	Micritic Limestones (9 ± 2)	Dolomites (9 ± 3)
		Evaporites		Gypsum 8 ± 2	Anhydrite 12 ± 2	
		Organic				Chalk 7 ± 2
METAMORPHIC	Non Foliated		Marble 9 ± 3	Hornfels (19 ± 4) Metasandstone (19 ± 3)	Quartzites 20 ± 3	
	Slightly foliated		Migmatite (29 ± 3)	Amphibolites 26 ± 6		
	Foliated**		Gneiss 28 ± 5	Schists 12 ± 3	Phyllites (7 ± 3)	Slates 7 ± 4
IGNEOUS	Plutonic	Light	Granite 32 ± 3 Diorite 25 ± 5 Granodiorite (29 ± 3)			
		Dark	Gabbro 27 ± 3 Norite 20 ± 5	Dolerite (16 ± 5)		
	Hypabyssal		Porphyries (20 ± 5)		Diabase (15 ± 5)	Peridotite (25 ± 5)
	Volcanic	Lava		Rhyolite (25 ± 5) Andesite 25 ± 5	Dacite (25 ± 3) Basalt (25 ± 5)	Obsidian (19 ± 3)
		Pyroclastic	Agglomerate (19 ± 3)	Breccia (19 ± 5)	Tuff (13 ± 5)	

Figure 4-15: Published m_i for various rock types to apply where limited data is available (Modified from Hoek, 2006)

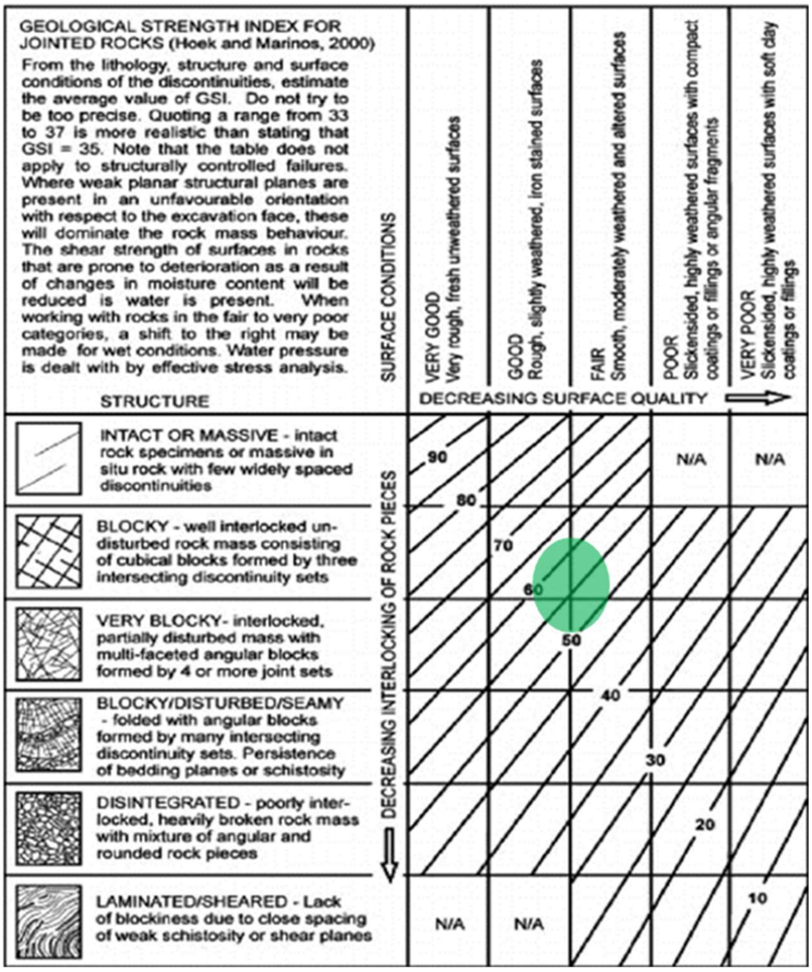


Appearance of rock mass	Description of rock mass	Suggested value of D
	Excellent quality controlled blasting or excavation by Tunnel Boring Machine results in minimal disturbance to the confined rock mass surrounding a tunnel.	D = 0
	Mechanical or hand excavation in poor quality rock masses (no blasting) results in minimal disturbance to the surrounding rock mass. Where squeezing problems result in significant floor heave, disturbance can be severe unless a temporary invert, as shown in the photograph, is placed.	D = 0 D = 0.5 No invert
	Very poor quality blasting in a hard rock tunnel results in severe local damage, extending 2 or 3 m, in the surrounding rock mass.	D = 0.8
	Small scale blasting in civil engineering slopes results in modest rock mass damage, particularly if controlled blasting is used as shown on the left hand side of the photograph. However, stress relief results in some disturbance.	D = 0.7 Good blasting D = 1.0 Poor blasting
	Very large open pit mine slopes suffer significant disturbance due to heavy production blasting and also due to stress relief from overburden removal. In some softer rocks excavation can be carried out by ripping and dozing and the degree of damage to the slopes is less.	D = 1.0 Production blasting D = 0.7 Mechanical excavation

Figure 4-16: Guidelines for assigning blast damage factor (D) (Hoek, 2006)

GSI

The GSI is measure of the blockiness of the rock mass and the surface conditions of the discontinuities that create these blocks. It is based on the assumption that the rock mass is sufficiently blocky so that is will behave like a homogeneous material, when considered over the scale of the analysis (in this case, for a depth of 20 m and a width of ~300 m). The GSI was calculated from the geotechnical core logging data from the drilling programme. Considering the small scale of the operation, the requirement for detailed calculations on GSI values was considered superfluous and therefore the GSI selected for the analysis was based on visual observation and obtaining a general idea of the joint conditions from logging and mapping data. The visual assessment chart as presented in Figure 4-17 was used to form an assessment of the GSI.



GEOLOGICAL STRENGTH INDEX FOR JOINTED ROCKS (Hoek and Marinos, 2000)

From the lithology, structure and surface conditions of the discontinuities, estimate the average value of GSI. Do not try to be too precise. Quoting a range from 33 to 37 is more realistic than stating that GSI = 35. Note that the table does not apply to structurally controlled failures. Where weak planar structural planes are present in an unfavourable orientation with respect to the excavation face, these will dominate the rock mass behaviour. The shear strength of surfaces in rocks that are prone to deterioration as a result of changes in moisture content will be reduced is water is present. When working with rocks in the fair to very poor categories, a shift to the right may be made for wet conditions. Water pressure is dealt with by effective stress analysis.

Figure 4-17: GSI field estimation chart (Hoek, 2006)

As Figure 4-18 shows, the rock mass tends to range from blocky to very blocky in localised areas, with 2 – 4 joint sets identified in the different mapping areas (as well as some random joints). The joint conditions range from rough to smooth planar to undulating, often stained with occasional calcite and up to 15 mm clay infill. Based on these general conditions, a range of GSI values (50 – 65) were selected as representative of the face conditions. An analysis was carried out for a 80˚, 20m high slope in the quartzite, and results using a GSI input of 50 (lower bound) and the result is presented in Figure 4-19. The results, as expected, for such shallow slopes in hard brittle rock, suggest that no rock mass failure is expected and yields a Factor of Safety (FoS) of >5 that far exceeds general acceptance criteria of 1.2 – 1.5.

Figure 4-18: Representative face conditions for Quarry Site 2

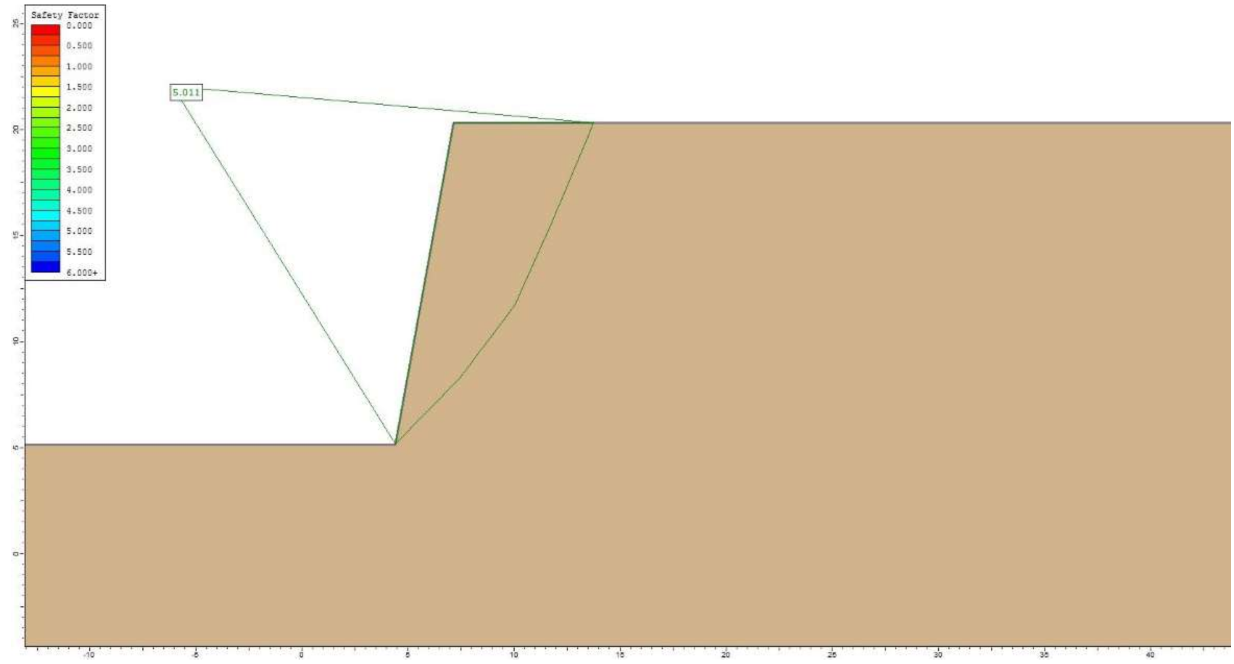


Figure 4-19: Slope stability analysis for 80˚, 20 m high slope in quartzite

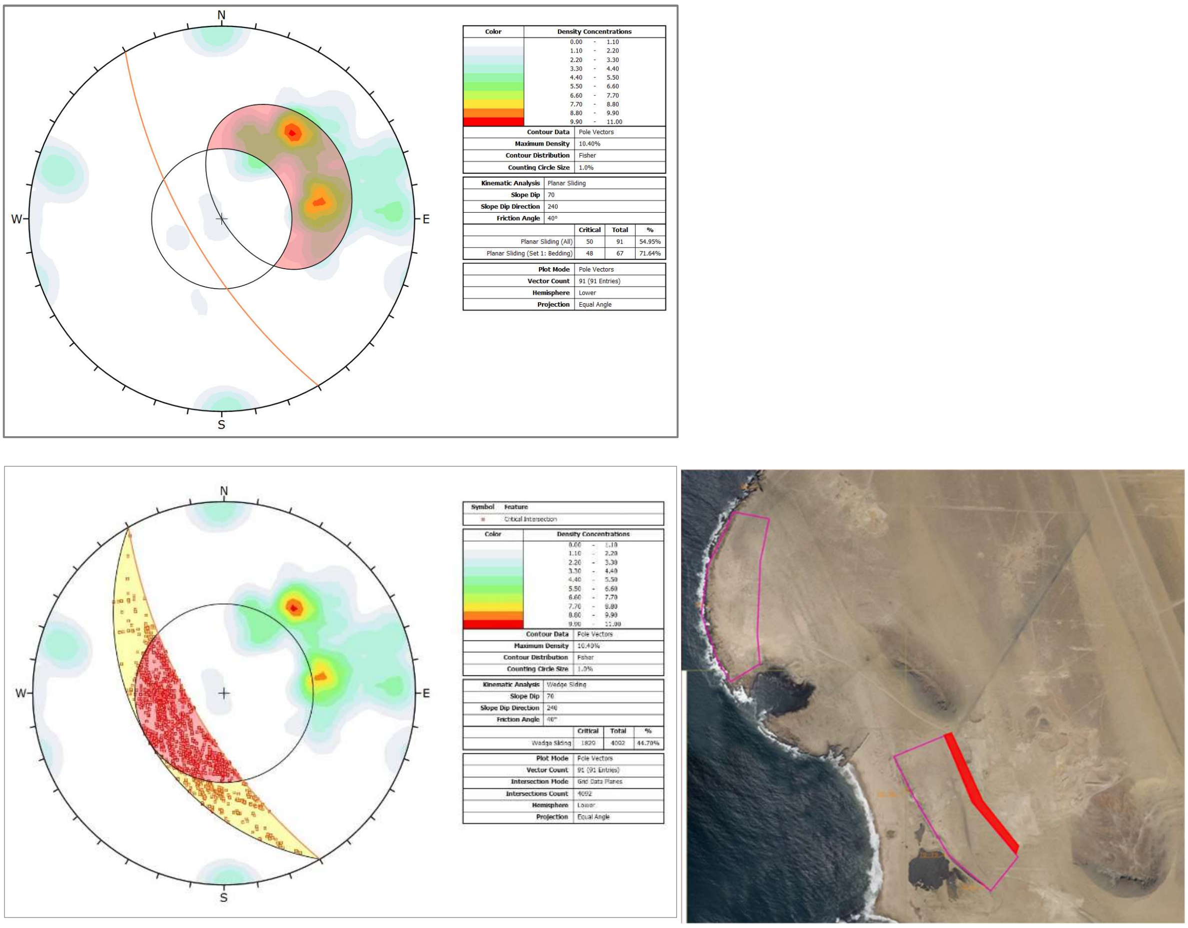
Kinematic Analysis

The rock mass displays very high strength parameters and the stability analysis suggests that the slopes will be very stable, and no rock mass failure can be expected. That said, stability of the quarry slopes and the geometry of the final walls will most likely be controlled by structures daylighting in the face that may cause unstable planes and/or wedges.

Three major joint sets were identified from the inclined borehole joint logs, and these are presented in Table 4-11. A kinematic analysis was carried out in DIPs to determine the PoO of planar, wedge and toppling failure. The results show that the moderately to steeply dipping Joint sets J1 and J2, which dip unfavourably out of the east wall of the quarry site present the potential for wedges and planes daylighting in the face. The results of the analysis, for the critical slope direction (dipping south west) and the results as well as the critical quarry face (highlighted in red) is presented in Figure 4-20. Planar and wedge failure was then analysed using Rocplane and Swedge respectively.

Table 4-11: Major joint sets identified in the quarry area (from drillhole data)

Joint Set/ Structure	Orientation	
	Dip	Dip direction
J1	51	214
J2	60	264
J3	81	106



Color	Density Concentrations
	0.00 - 1.10
	1.10 - 2.20
	2.20 - 3.30
	3.30 - 4.40
	4.40 - 5.50
	5.50 - 6.60
	6.60 - 7.70
	7.70 - 8.80
	8.80 - 9.90
	9.90 - 11.00
Contour Data	Pole Vectors
Maximum Density	10.40%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Planar Sliding		
Slope Dip	70		
Slope Dip Direction	240		
Friction Angle	40°		
	Critical	Total	%
Planar Sliding (All)	50	91	54.95%
Planar Sliding (Set 1: Bedding)	48	67	71.64%

Plot Mode	Pole Vectors
Vector Count	91 (91 Entries)
Hemisphere	Lower
Projection	Equal Angle

Symbol	Feature
■	Critical Intersection

Color	Density Concentrations
	0.00 - 1.10
	1.10 - 2.20
	2.20 - 3.30
	3.30 - 4.40
	4.40 - 5.50
	5.50 - 6.60
	6.60 - 7.70
	7.70 - 8.80
	8.80 - 9.90
	9.90 - 11.00
Contour Data	Pole Vectors
Maximum Density	10.40%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Wedge Sliding		
Slope Dip	70		
Slope Dip Direction	240		
Friction Angle	40°		
	Critical	Total	%
Wedge Sliding	1829	4092	44.70%

Plot Mode	Pole Vectors
Vector Count	91 (91 Entries)
Intersection Mode	Grid Data Planes
Intersections Count	4092
Hemisphere	Lower
Projection	Equal Angle

Figure 4-20: Planar and wedge failure analysis for north west dipping quarry face

The Rocplane and SWedge analyses were carried out to determine the FoS of planes and wedges that are expected to form in the face. For RocPlane, joint set J1 was analysed, as it is sub-parallel to the east wall and dips out of the face. It must be noted that due to the absence of reliable joint strength data, conservative joint strength parameters were applied. Cohesion of 0kPa was applied as it is assumed that even if some cohesion is present on these surfaces, this will be significantly reduced during blasting. A friction angle of 40˚ was applied as a conservative input based on experience in similar material. The results of the analyses is presented in Table 4-12.

SWedge analysis was carried out to ascertain risk to wedge failure by analysing the intersection of major joint sets with respect to the highwall, that is also based on the critical slope orientation coming out of the kinematic analysis in DIPs (i.e. the eastern wall). The results are presented in Table 4-13. Both tables highlight critical planes and wedges in pink.

Table 4-12: Results of RocPlane analysis

Failure Surface	Slope Orientation			Wedge Stability	
	Dip	Direction	Slope Height	FOS	Wedge Volume (m^3)
J1	80	210	20	**0.8**	143
	70			**0.8**	97
	80		10	**0.8**	36
	70			**0.8**	24

Table 4-13: Results of Swedge Analysis

Intersecting Joint Sets	Slope Orientation			Wedge Stability	
	Dip	Direction	Slope Height	FOS	Wedge Volume (m^3)
J1 and J2	80	210	20	**0.7**	8239
	70			**0.7**	3874
	80		10	**0.7**	1030
	70			**0.7**	484
J1 and J3	80		20	**1.2**	9599
	70			**1.2**	4272
	80		10	**1.2**	1200
	70			**1.2**	590
J2 and J3	80		20	**4.6**	2773
	70			**4.6**	2092
	80		10	**4.6**	347
	70			**4.6**	261

The results show unstable planes (Table 4-12) and wedges (Table 4-13) are likely to form in the face. What these analyses do not consider, is the spacing of the discontinuities that are likely to limit the size of these wedges. As shown in Section 4.2.10, block sizes that are likely to form are a factor of both the orientation and spacing of joints, and the results present much smaller blocks than those shown to form in the face. It is anticipated that the likelihood of very large blocks forming in the face is not high, however, some failure of smaller must be accommodated for (for HES reasons).

In order for safe working conditions to be achieved, it is recommended that mining of these slopes should be done in two benches. This has a dual purpose in that limiting the bench height will also limit the height of planes and wedges forming, but more so that a berm of 5 m will allow for some catch capacity to accommodate loose blocks and minimise the risk to men and machines working under the face.

The proposed design for the quarry site is presented in Figure 4-21.

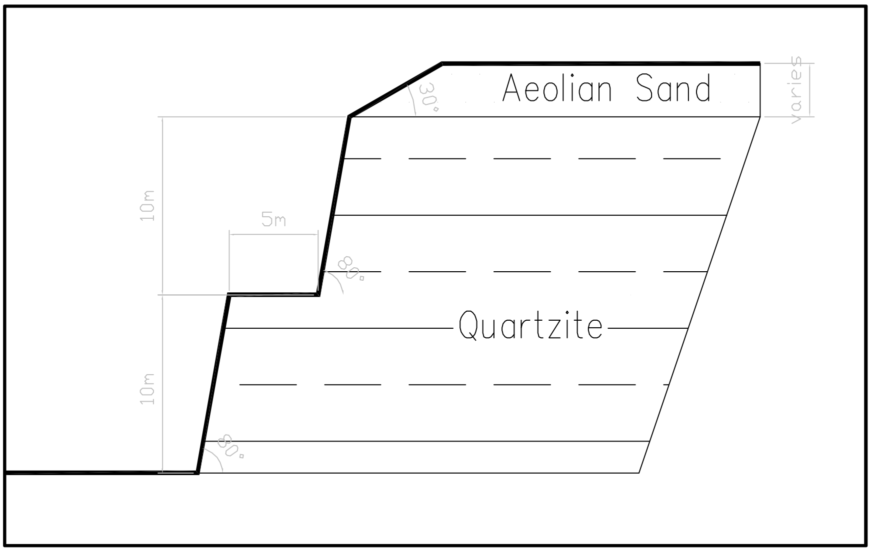


Figure 4-21: Proposed design for the Quarry High Wall

5 Groundwater Supply Feasibility Study (Phase 1)

5.1 Methodology

5.1.1 Approach

The approach undertaken for the groundwater feasibility study included the following tasks:

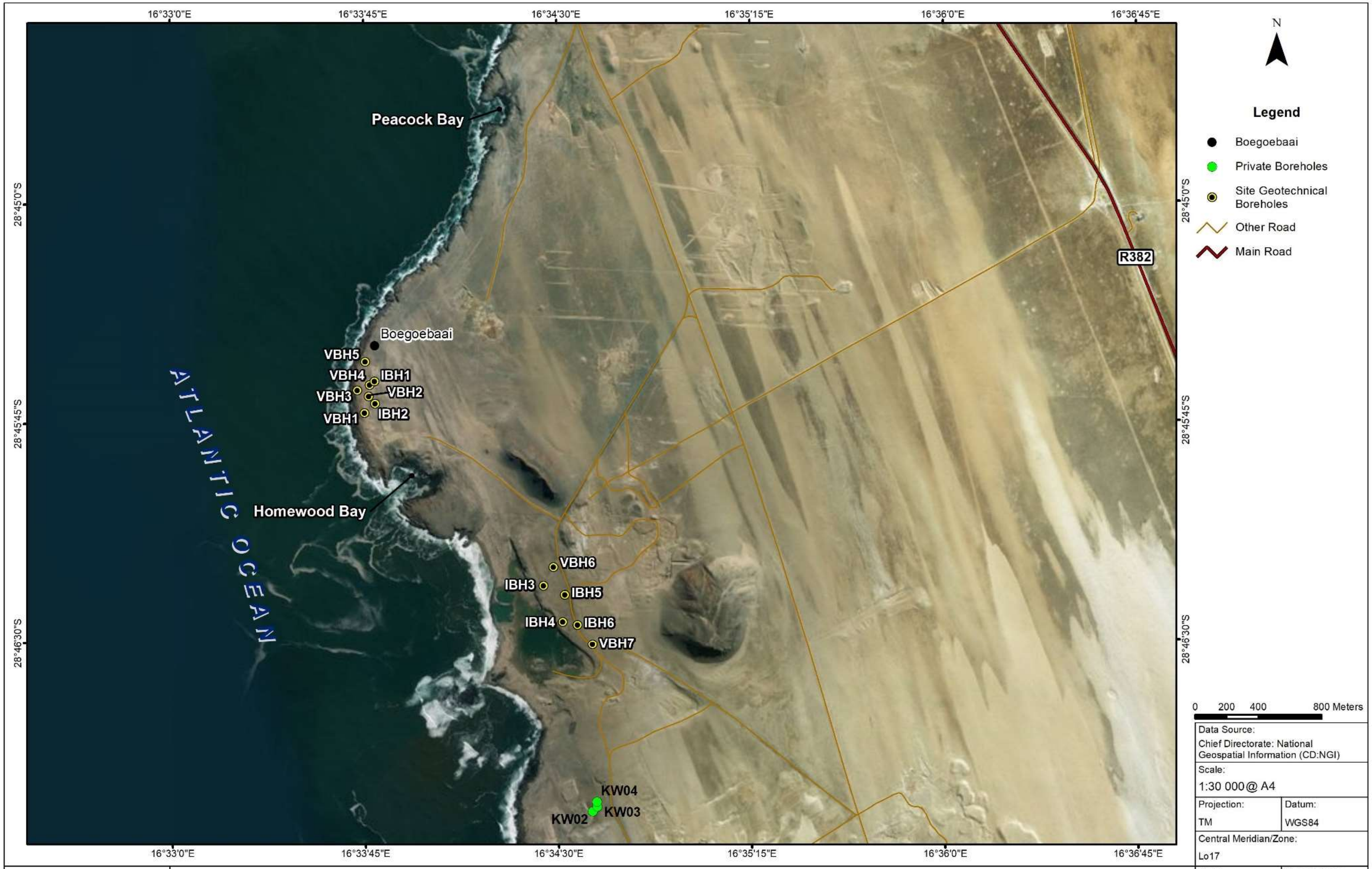
- Collect available hydrogeological data and information for the area – Department of Water and Sanitation (DWS) National Groundwater Archive, DWA 1: 500 000 scale hydrogeological map, published geological maps, completed EIA reports for surrounding developments (if any), consultancy reports, etc.;
- Collect available hydrogeological data from the mine;
- Collect available geotechnical information (depth of sand, clay, hard rock, etc.) if available, to enable a more comprehensive assessment of the local aquifer systems (primary sandy aquifer, secondary hard rock aquifer). Information includes thicknesses of different horizons, any in situ permeability tests, etc.;
- Collect and collate available GIS/CAD files and prepare maps;
- Determine positions of potential water bearing structures/lineaments/faults within the property by examining Google Earth and satellite images and published geological and hydrogeological maps;
- Carry out geological field mapping and electrical resistivity tomography (ERT) surveys to pinpoint the position of these structures under the soil and alluvial/eluvial overburden and site potential targets for water borehole drilling; and
- Document results.

5.1.2 Information Sources

Data sources used in this groundwater study included the following:

- Geological and hydrogeological maps (GSSA, 2006);
- National Groundwater Archive (NGA) data for the Richtersveld, including the following data sets where available: Borehole ID; Co-ordinates; Water use; Borehole depth; Field measurements, i.e. Electrical Conductivity (EC) and pH; Water level measurements; and Yield and discharge data;
- Geotechnical boreholes on site, as drilled to a depth of *c*.20 m, both vertical and inclined, during the geotechnical field investigations of this study;
- Hydrocensus of the local area during the field study, although this yielded no additional boreholes in a 2 km radius of the site; and
- Previous studies including:
    - Alexkor Groundwater Contamination Risk Assessment: Alexander Bay, Northern Cape (SRK, 2009); and
    - Geohydrological Impact Assessment for Alexkor Diamond Mine (Waters without Frontiers, 2014).

The borehole network is displayed in Figure 5-1.



Data Source:
Chief Directorate: National Geospatial Information (CD:NGI)

Scale:
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Projection: TM
Datum: WGS84

Central Meridian/Zone: Lo17

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BOEGOEBAAI PORT INVESTIGATION

BOREHOLE NETWORK

Date: 12/06/2018
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Project No: 526679
Fig No: 5-1

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Revision: A Date: 16 07 2018

5.2 Geographical Setting

5.2.1 Topography and Drainage

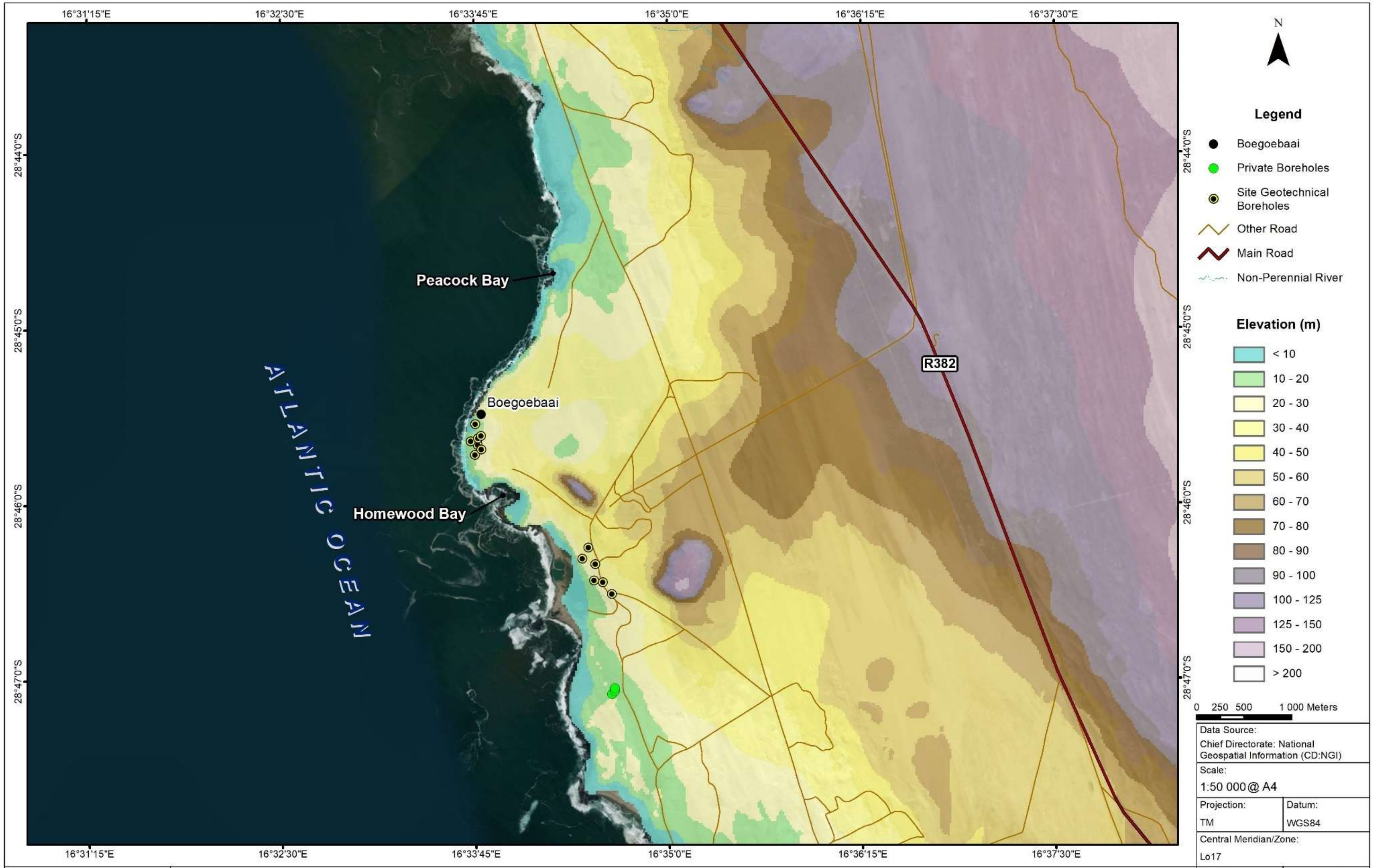
The Boegoebaai site is located within quaternary catchment F10C, which falls within the Lower Orange Water Management Area. The site is situated along flat coastal lowland. The topography reflects the gently undulating nature of the predominantly sand covered land surface. Ground elevation at the site ranges from 0 to 40 metres above mean sea level (mamsl). A few pans occur in the area, with the largest being Visagiespan, *c*.3.5 km to the south-east of site. Drainage is predominantly westwards into the Atlantic Ocean, however there are no perennial rivers in the vicinity of the site, and the only mapped non-perennial streams are *c*.2 km to the north of the site (Figure 5-2).

Climate

The Boegoebaai site is located within an arid region with a climate characterised by relatively cool and dry desert conditions. The low temperatures and low rainfall are controlled by the South Atlantic subtropical anticyclone, which maintains an almost isothermal atmosphere over the Namaqualand coast (Nieman, 1981). The predominant southerly winds cause the upwelling of the Benguela system, which cools and stabilises the near surface air mass and reduces the potential for rainfall occurrence.

The region receives *c*.20 mm of rain per year during winter (as recorded for Alexander Bay). Rainfall events are distributed between April and August and peak during May, June and July. The lowest rainfall (*c*.0 mm) occurs in January and the highest (*c*.6 mm) in June. Fog develops frequently as a result of oceanic surface evaporation which saturates the cool coastal air mass.

The average midday temperatures range from *c*.20°C in July to *c*.28°C in January. The coldest temperatures occur during July when the temperature drops to *c*.8°C on average during the night. The Atlantic Ocean has a significant moderating effect on the coastal temperature regime. Minimum temperatures are particularly stable and are not subject to large fluctuations (Waters Without Frontiers, 2014).



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Chief Directorate: National Geospatial Information (CD:NGI)

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Projection: TM
Datum: WGS84

Central Meridian/Zone: Lo17

Date: 12/06/2018
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Project No: 526679
Fig No: 5-2

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TOPOGRAPHY AND DRAINAGE

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Revision: A Date: 16 07 2018

5.3 Geohydrological Setting

5.3.1 Geology

The site consists of recent Quaternary sediments underlain by Late Proterozoic metasiliciclastic rocks of the Holgat Formation. Section 4.1.1 should be referenced for further details regarding local geology.

5.3.2 Aquifer Type

Typically, primary aquifers are associated with the unconsolidated deposits, however, at the site the overlying dune sands are thin (between 0 m to *c*.3 mbgl) and unsaturated and thus do not constitute an aquifer. The secondary aquifer is associated with fractures and fissures in the bedrock of the Holgat Formation consisting of quartzites, schist, conglomerates, hornfels and limestone. These rocks typically possess extremely small primary porosity and hydraulic conductivity and therefore typically have low groundwater potential for water supply. Secondary processes, however, improve their groundwater potential through fracturing and weathering.

Several different modes of groundwater occurrence have been recognised as follows:

- Jointing and fracturing associated with faulting;
- Fracturing at contacts between lithologies;
- Partings between bedding planes; and
- Solution cavities in limestone.

According to the hydrogeological map sheet of the Republic of South Africa (Figure 5-3), the groundwater yield potential in the study area is low with borehole yield generally less than 0.1 L/s.

No groundwater levels have been measured on site, however groundwater must be less than 20 mbgl, as noted during the geotechnical work to this depth.

5.3.3 Groundwater Quality

Groundwater quality is typical of arid regions, which is generally poor and characterised by high salinity. Electrical conductivity generally exceeds 300 mS/m, as shown on Figure 5-3. The poor water quality is attributed to several factors including:

- Very low groundwater recharge (estimated at 0 to 5 mm per annum);
- Marine origin of gravels forming terraces extending *c*.2 km inland and rising to about *c*.90 mamsl;
- Leaching and dissolution of terrestrial salts emanating from salt outfall from the sea;
- Ancient (old) water in paleao-drainage channels, recharged during periods of less arid regional climate in the past; and
- Excessive surface water evaporation relative to rainfall, resulting in the concentration of salts (Waters Without Frontiers, 2014).

Production boreholes close to the sea have a strong risk of seawater intrusion into coastal aquifers.

5.3.4 Aquifer Classification

An aquifer classification system provides a framework and objective basis for identifying and setting appropriate levels of ground water resource protection. This facilitates the adoption of a policy of differentiated ground water protection.

Other uses include:

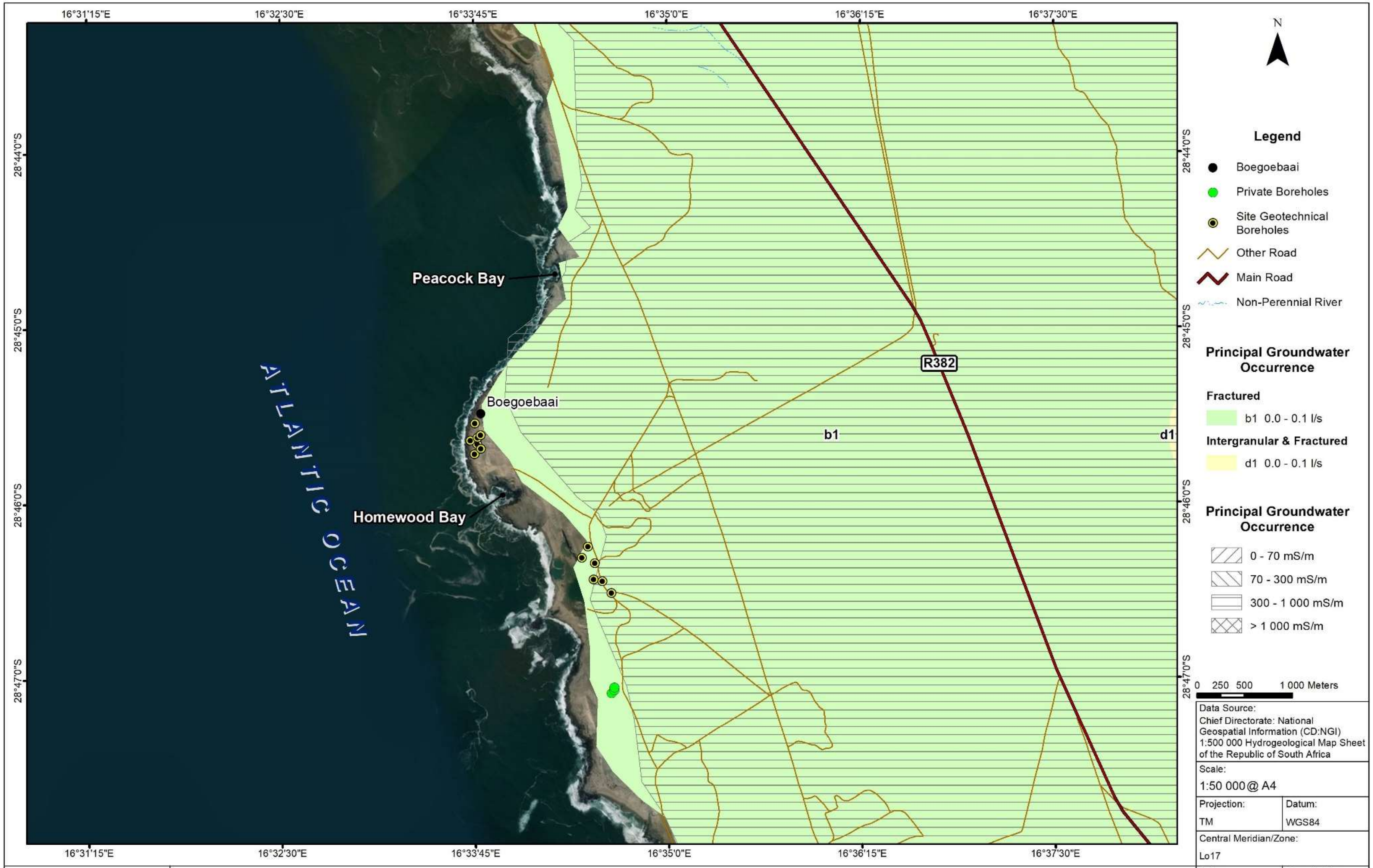
- Defining levels of investigation required for decision making;
- Setting of monitoring requirements; and
- Allocation of manpower resources for contamination control functions.

The aquifer classification system used to classify the aquifers is the proposed National Aquifer Classification System of Parsons (1995). This system has a certain amount of flexibility, and can be linked to secondary classifications such as a vulnerability or usage classification. Parsons suggests that aquifer classification forms a very useful planning tool that can be used to guide the management of ground water issues. He also suggests that some level of flexibility should be incorporated when using such a classification system.

The DWS Aquifer Classification Map of South Africa (DWS, 2012) presents three classes of aquifers, namely:

- Poor;
- Minor; and
- Major.

The aquifer in the site area is classified as having a very low vulnerability (Figure 5-4), but is a poor aquifer system (Figure 5-5), according to the DWS classification system (DWS, 2012).



Data Source:
Chief Directorate: National Geospatial Information (CD:NGI)
1:500 000 Hydrogeological Map Sheet of the Republic of South Africa

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Projection: TM

Datum: WGS84

Central Meridian/Zone: Lo17

Date: 12/06/2018

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Project No: 526679

Fig No: 5-3

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HYDROGEOLOGY

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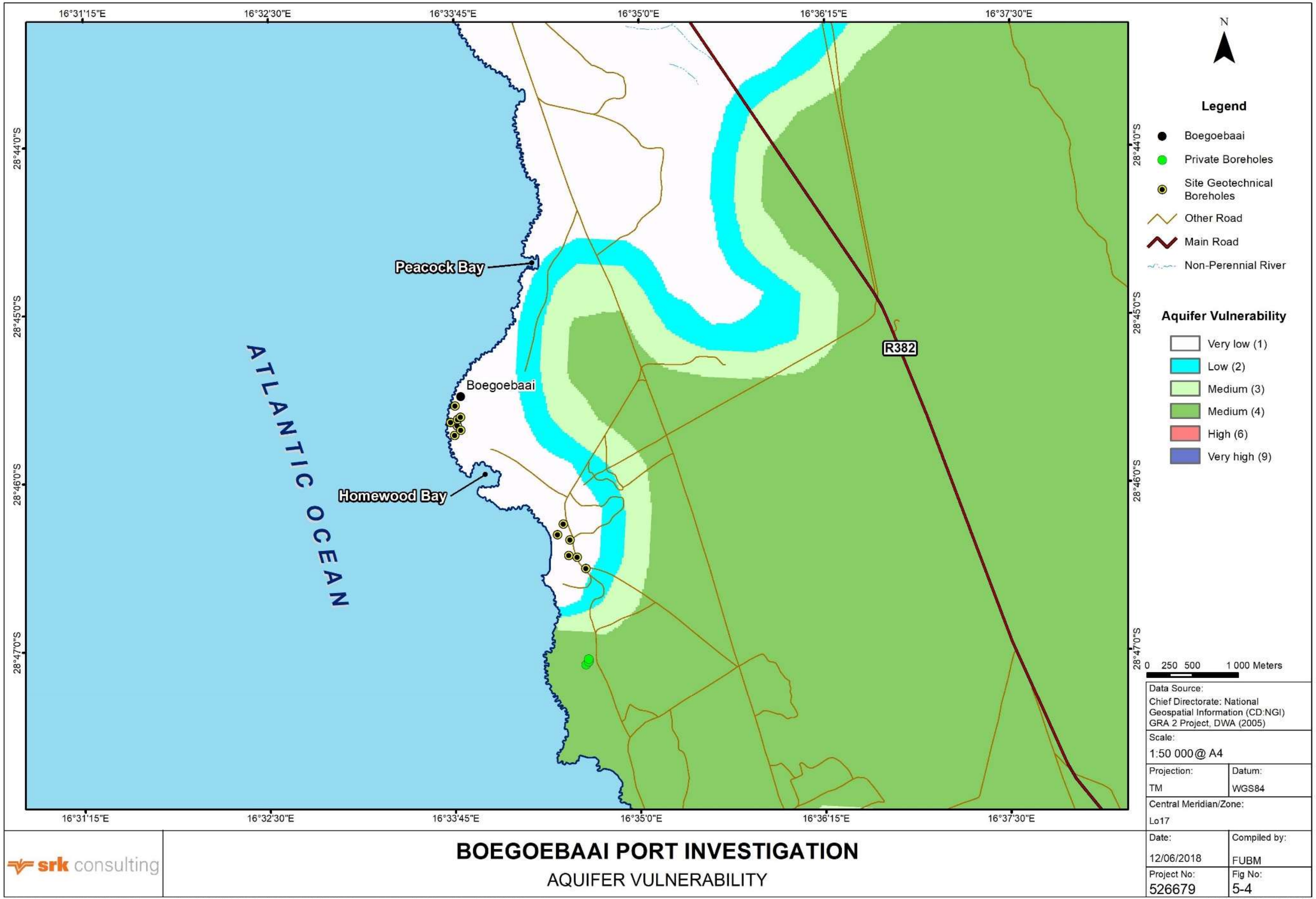

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GRA 2 Project, DWA (2005)

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AQUIFER VULNERABILITY

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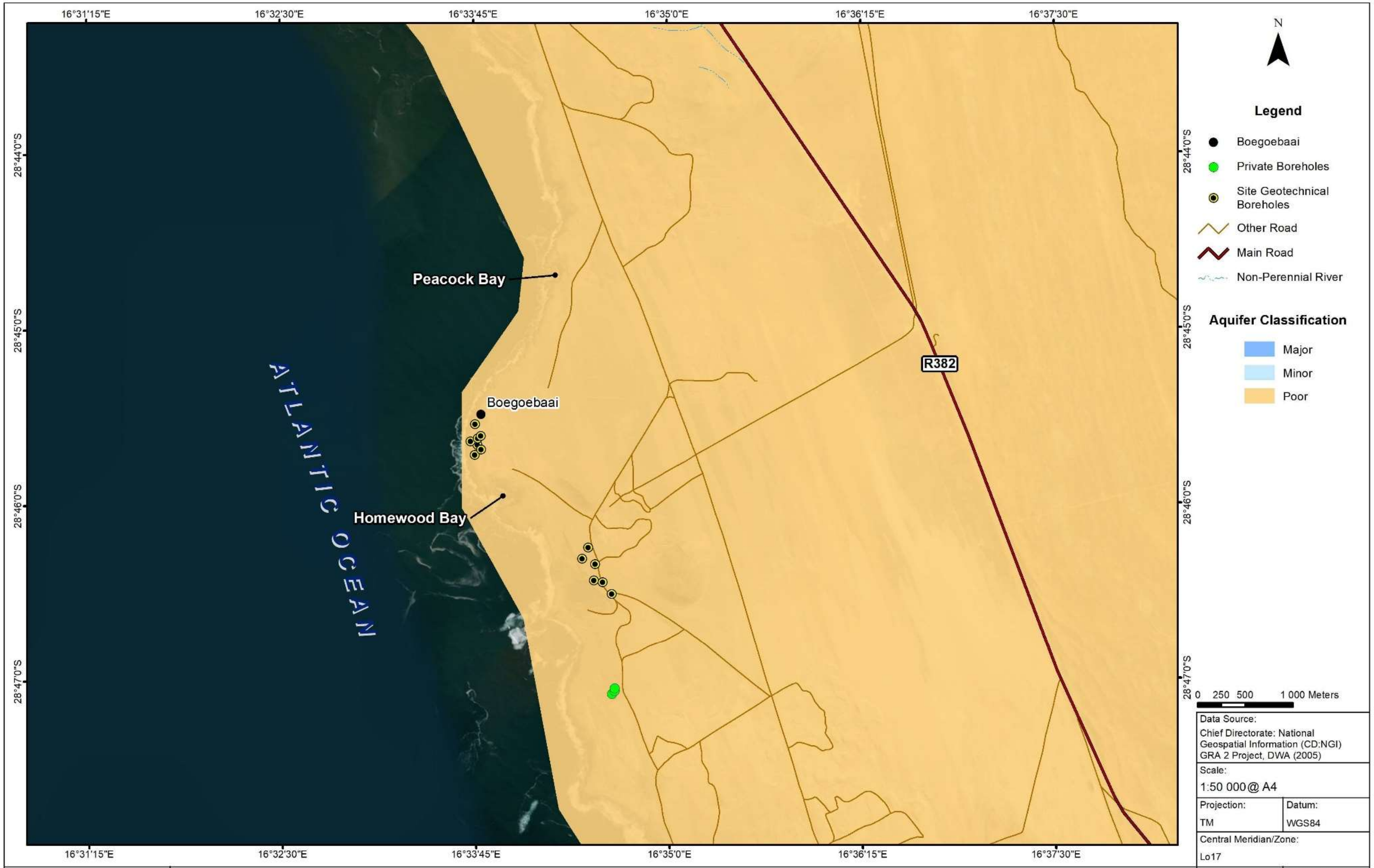

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Datum: WGS84

Central Meridian/Zone: Lo17

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AQUIFER CLASSIFICATION

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5.4 Geophysical Survey and Results

5.4.1 Geophysical Survey Technique

DC resistivity techniques, sometimes referred to as electrical resistivity tomography (ERT), 2D(3D) resistivity imaging or vertical electric sounding (VES) are used to measure earth resistivity by driving a direct current (DC) signal into the ground and measuring the resultant potentials (voltages) created in the earth (Figure 5-6). The electrical properties of the subsurface are inferred from this data.

The electrical resistivity varies between different geological materials, depending primarily on variations in water content and dissolved ions in the groundwater. Resistivity investigations are therefore used to identify zones with different electrical properties, which can then be used to delineate different geological strata. Resistivity is also called specific resistance, which is the inverse of conductivity or specific conductance. The most common mineral-forming soils and rocks have very high resistivity in dry conditions; as such, the resistivity of soils and rocks is normally a function of the amount and quality of water in pore spaces and fractures contained in the media, as well as the degree of weathering of the formation.

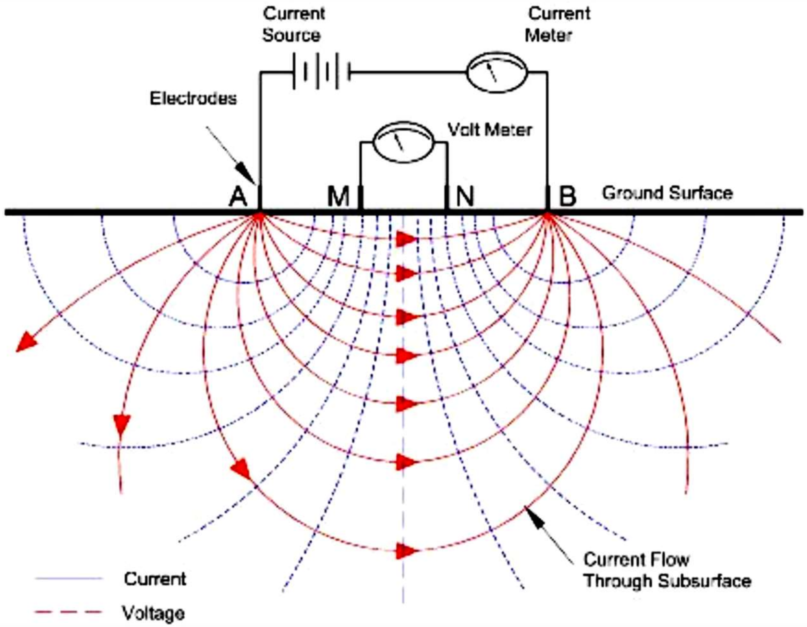

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Figure 5-6: Diagram showing the schematic setup of Electrical Resistivity Tomography

Consequently, the variation may be more limited to confined geological areas, and variations in resistivity within a certain soil or rock type will reflect variations in physical properties. For example, the lowest resistivities encountered for sandstone and limestone imply that the pore spaces in the rock are saturated with water, whereas the highest values represent strongly consolidated sedimentary rock or dry rock above the groundwater surface. Sand, gravel and sedimentary rock may also have very low resistivities, provided that the pore spaces are saturated with saline water.

Fresh crystalline rock is highly resistive, even though it may contain certain conductive ore minerals; however, weathering commonly produces highly conductive clay-rich saprolite. Variation in characteristics within one geological material type necessitates calibration of resistivity data against geological documentation, from, for example, surface mapping, test pit exposures or drilling. Such calibration, however, applies to all geophysical methods.

The degree of saturation, affects the resistivity and the resistivity above the groundwater level will be higher than that below this level, assuming the material has similar properties. Consequently, this method can be used to determine the depth to the water table, particularly where a distinct water table exists. However, if the content of fine-grained material is significant, the water content above the groundwater surface, held by hygroscopic and capillary forces, may be sufficient to dominate the electrical behaviour of the material. The resistivity of the pore water is determined by concentrations of ions in solution, the type of ions and temperature. The presence of clay minerals strongly affects the resistivity of sediments and weathered rock. The clay minerals may be regarded as electrically conductive particles, which can absorb and release ions and water molecules on their surface through an ion exchange process.

5.4.2 ERT Survey Results

Two ERT surveys were conducted at the site using the Wenner measuring protocol and 10 m electrode spacing. The 2-D profiles are shown in Figure 5-7 and the positions of these ERT surveys and resulting 2D geo-electric profiles are shown in Figure 5-8. Potential lineaments were mapped for the site and two ERT surveys were carried out across the location of these lineaments. ERT-1 is oriented NNE to SSW and ERT-2 is oriented SW to NE. The purpose of these ERT surveys was to pick up possible sympathetic fault zones crossing the site beneath the overburden.

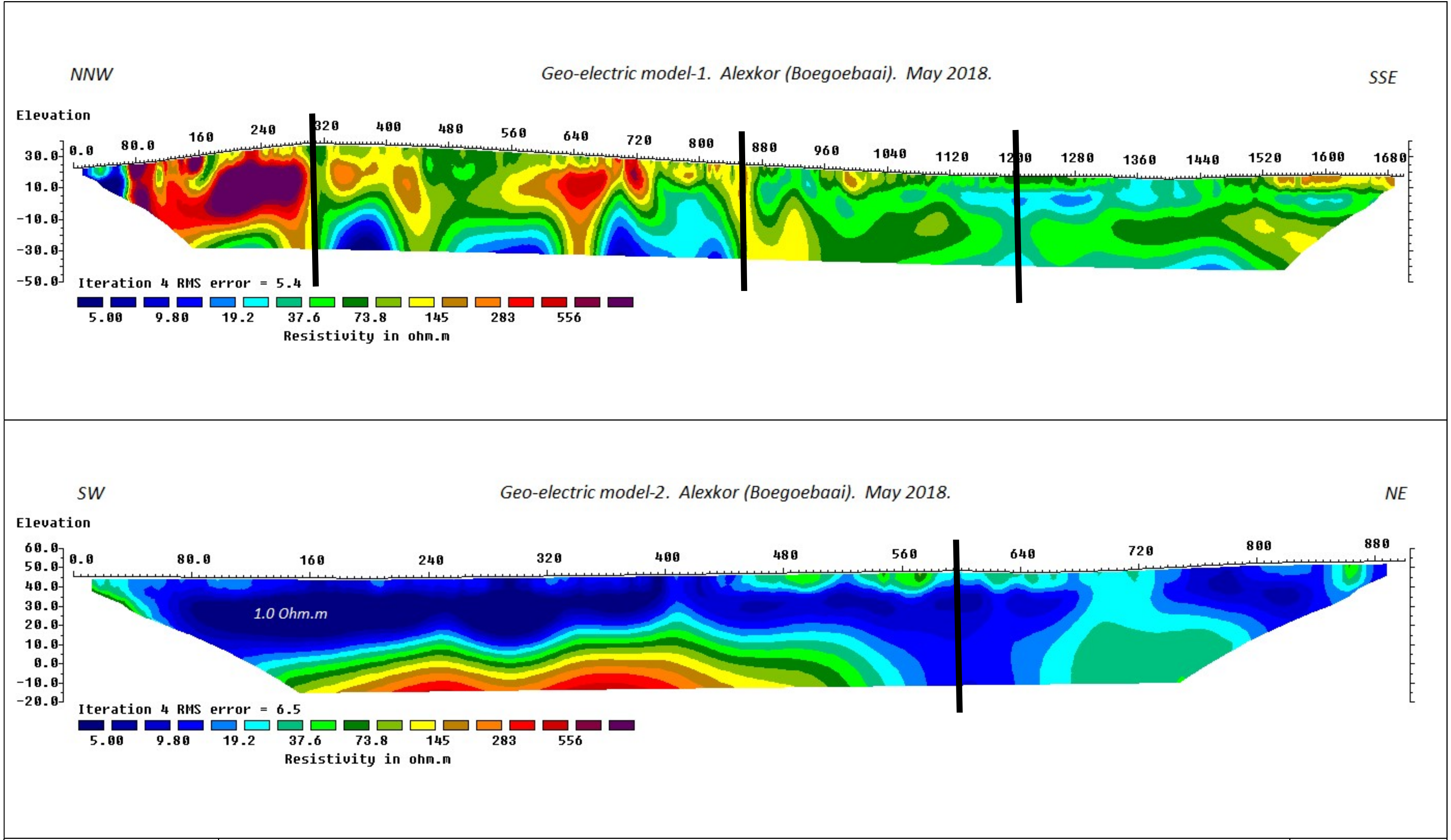
The ERT surveys indicate the following:

- Overburden consisting of a thin (<2 m) layer of transported soils mainly consisting of fine to medium sand;
- The weathering zone is on average *c.*40 m thick, and is represented by the lighter (blue to light-brown) colours on the ERT profiles;
- Fresh bedrock consists of schist, conglomerates, hornfels and limestone of the Holgat Formation. These rocks are represented by the more resistive orange to purple colours on the ERT profiles;
- Potential drill targets (shown by the black lines on Figure 5-7) are sited at linear features (potential preferential pathways for groundwater) in profile ERT-1, and at the zone with potential deepest weathering on profile ERT-2. This deeper weathering may be associated with fracturing which would therefore form a target for drilling a water borehole.

The coordinates and position of these new boreholes and drill targets are summarised in Table 5-1.

Table 5-1: Coordinates for potential drill targets at the site

Drill Target Number	**Coordinates (WGS84)**		**ERT Traverse No**	**Position on ERT**	**Comments**
	Latitude	**Longitude**			
DS1	S28.764539°	E16.570211°	ERT-1	300 m	Linear feature along interface with potential fresh bedrock. Inferred to indicate a fault / lineament.
DS2	S28.767290°	E16.571576°	ERT-1	650 m	Linear feature of high resistivity. Inferred to indicate a fault / lineament.
DS3	S28.772034°	E16.573953°	ERT-1	1210 m	Linear feature of lower resistivity. Inferred to indicate a fault / lineament.
DS4	S28.763528°	E16.583371°	ERT-2	600 m	Resistivity low indicating deeper weathering in the bedrock.



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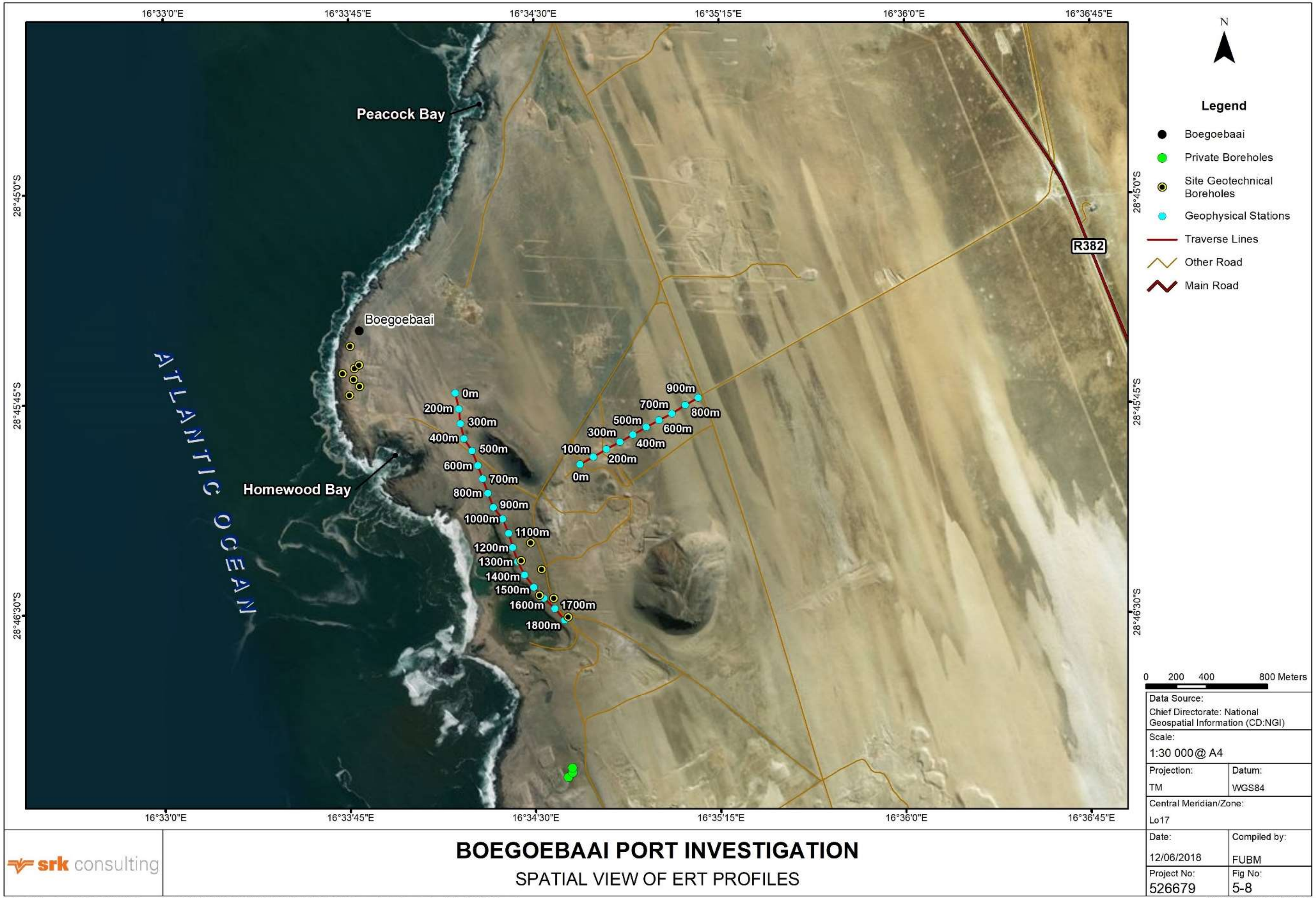
BOEGOEBAAI PORT HYDROGEOLOGICAL INVESTIGATION
ERT Profiles 1 and 2

Project No.
526679

Figure 5-7: ERT Profiles 1 and 2



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Projection: TM

Datum: WGS84

Central Meridian/Zone: Lo17

Date: 12/06/2018

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Fig No: 5-8

BOEGOEBAAI PORT INVESTIGATION

SPATIAL VIEW OF ERT PROFILES

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5.5 Groundwater Supply Feasibility Conclusions

Due to the expected low yields, deep groundwater levels and poor quality of groundwater at the site, and thus the low probability of successfully harvesting groundwater as a sustainable supply, it is recommended that Phase 2 work, including the drilling of deep water supply boreholes, is not undertaken.

However, if drilling were to take place, it should be 75 to 100 m deep at the recommended drill sites (see Table 5-1), and should include a water quality treatment plan depending on the usage and quality requirements of the water.

6 Conclusions and Recommendations

Based on the above findings, the following conclusions are drawn:

- Geology:
  - The dominant geology at the project site consists of schistose quarzites of the Holgat Formation (metacalcturbites and metasiliciclastic rocks). In the localised project area, these rocks present as jointed, extremely hard quartzite outcrops adjacent to the sea in the port area (Quarry Site 2) and the southern Quarry Site 1 area. A softer schistose band/bands striking ~north-south (and dipping towards the sea at ~40°) landward (at Quarry Site 2) and seaward (at Quarry Site 1) is noted as shown in the Leapfrog™ model.
- Quarry Potential:
  - Quarry Site 2 (in the Port area) has been screened out as a good potential quarry site because of the softer schistose band intersected in the drilling in that area – this however does not preclude using quartzite material that may be won in excavations made in the area for the Port Development, provided a reliable segregation programme can be put in place to screen out unfavourable schistose materials;
  - Quarry Site 1, however, presents as a good potential quarry site, with both mapping and drilling data indicating competent quartzite in abundance;
  - Estimates of quarry production in Quarry Site 1 indicates that the required block size distribution can largely be met, but it is possible that practicalities (blasting and handling) in the actual production could result in larger block sizes being a challenge to produce reliably – a second concern in this regard is that there appear to be well developed micro-fractures in the site rocks as was exposed by the worse than expected UCS test results and this may skew block sizes to the smaller end;
  - Quarrying conditions are not deemed to be over challenging, but blasting effects could result in local instability in the quarry highwall, and as such, it will be necessary to construct a catch bench in this highwall for HES reasons;
  - To more reliably assess the block size distribution from the proposed quarry, a pilot quarrying exercise will provide invaluable information.
- Rock Quality for use in constructing a breakwater:
  - Laboratory testing indicates that there is no reason to suspect that the quality of rock generated in Quarry Site 1 will be suspect, even though a number of UCS test results fell short of PRDW's requirements;
  - Similarly, and provided that the competent quartzite can be reliably segregated from the poor quality schistose material in the port area (Quarry Site 2), there is no reason why material won from this area cannot be used in construction of the breakwater.
- Rock Quality for use as concrete aggregate:
  - Laboratory testing indicates that there is no reason to suspect that the quality of rock generated in Quarry Site 1 will be suspect;
  - Some (long-term) test results relating to Shrinkage/Expansion of proposed aggregate are pending (due end July 2018).
- Onshore Founding:
  - Disturbance by mining and natural wind deposition of Aeolian soils across the site has resulted in an average 1.3 m depth of poorly consolidated materials that are not suitable to found in;
  - Engineering of these materials will be necessary to found even lightly loaded structures in, but re-compaction of these materials should not present a challenge;
  - Because of the lateral variability encountered on the site (primarily influenced by historical mining), it will be necessary to carry out individual geotechnical investigations for more heavily loaded structures as the founding of such structures will be site specific (particularly settlement sensitive structures) – lateral variability in the site rock geotechnical profile (alternating competent and incompetent bands that have been overturned to dip towards the sea) add emphasis in this regard should heavily loaded structure need to be founded on rock.
- Offshore Founding:

  - The obvious lateral variability in the site rock geotechnical profile (alternating competent and incompetent bands that have been overturned to dip towards the sea) annul the ability to extrapolate founding conditions offshore - the offshore geotechnical profile therefore remains an area of uncertainty.
  - Both offshore piled and gravity foundations carry risks with associated costs and design/construction complexities. The choice of founding solution should therefore be evaluated holistically within the project context before a specific founding type is selected. Choice of foundation type may be sensitive to construction programme and/or cost, and it is possible that the more complex the founding solution is, the more likely that claims could arise during the construction thereof;
  - Geotechnical investigations during construction may will provide useful data to reduce certainty.
- Groundwater Potential:
  - Due to the expected low yields, deep groundwater levels and poor quality of groundwater at the site, and thus the low probability of successfully harvesting groundwater as a sustainable supply, it is recommended that Phase 2 work, including the drilling of deep water supply boreholes, is not undertaken;
  - However, if drilling were to take place, it should be 75 to 100 m deep at the recommended drill sites and should include a water quality treatment plan depending on the usage and quality requirements of the water.

Based on the above conclusions, the following recommendations are made:

- Groundwater potential: it is recommended that alternative sources of water be investigated as there is a low probability that the project can reliably be supplied with groundwater of adequate quality;
- Quarrying: it is important that a trial quarry (or pilot quarrying exercise) be considered in the planning for this project to assess the actual block size production influenced by blasting effects;
- Onshore Founding: once the proposed layout is known, founding conditions for settlement sensitive structures should be explored on a localised site scale to provide adequate founding detail;
- Offshore Founding: it should be considered in the construction programme to carry out geotechnical investigations to reduce uncertainty.

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Appendices

Appendix A: Test Pit Logs and Photographs

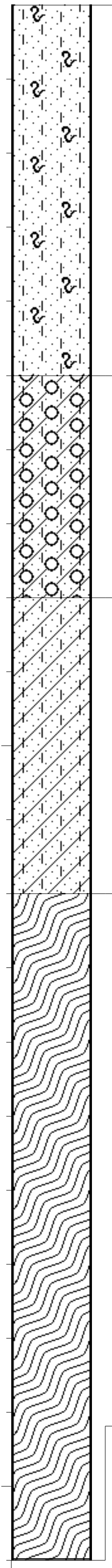
srk consulting

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: TP 1
Sheet 1 of 1

JOB NUMBER: 526679

Scale
1:10



0.00	Dry, beige, very loose, silty, fine SAND with minor angular to sub-rounded gravel and abundant fine rootlets. Aeolian.
0.50	Dry, orangey beige, stiff, sandy, silty, CLAY with abundant angular to sub-rounded gravel. Transported.
0.80	Dry, orangey brown, grey and off-white, stiff to very stiff, thinly laminated, relic jointed, poorly calcretized, sandy, silty, CLAY. Residual Schist.
1.20	Orangey brown and grey, highly weathered, steeply inclined, thinly laminated, closely jointed, very soft rock to soft rock, SCHIST. Gariep Supergroup. Joints: Sub-horizontal, sub-vertical, smooth planar and undulating, narrow to wide, iron stained, and calcretized.
2.10	

NOTES

1) No water seepage.

2) Not to refusal (possibly near refusal).

3) Easily excavatable.

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

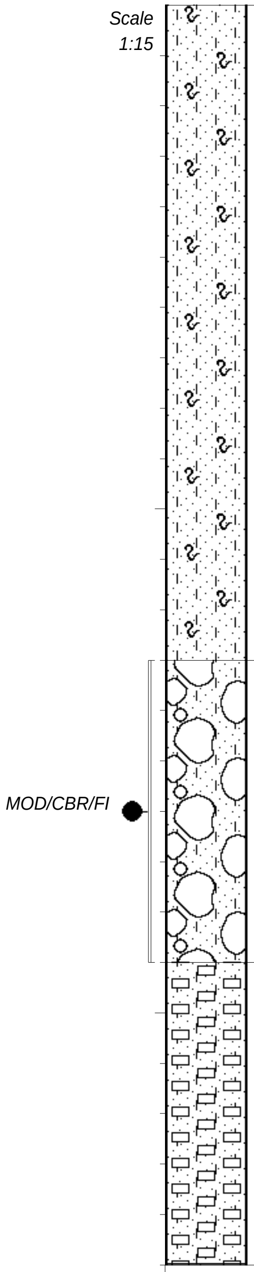
ELEVATION : 24 m
X-COORD : 3182544
Y-COORD : 0042495

HOLE No: TP 1

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: TP 2
Sheet 1 of 1

JOB NUMBER: 526679



0.00	Slightly moist, whitish beige, very loose to loose, homogeneous, silty, fine SAND with minor shell fragments and rootlets. Aeolian.
1.30	Slightly moist, olive green to beige, loose, homogeneous, silty, fine SAND with minor angular quartzite cobbles, gravel, and shell fragments. Aeolian.
1.90	Dry, orangey beige, very dense, silty, sandy, CALCRETE with some quartzite cobbles and gravel. Pedocrete.
2.50	

NOTES

1) Gradual colour change to base.

2) No water seepage.

3) Not to refusal.

4) Easily excavatable to 1.90 m.

5) MOD/CBR/FI sample taken at 1.30--1.90 m.

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

ELEVATION : 24 m
X-COORD : 3182701
Y-COORD : 0042495

HOLE No: TP 2

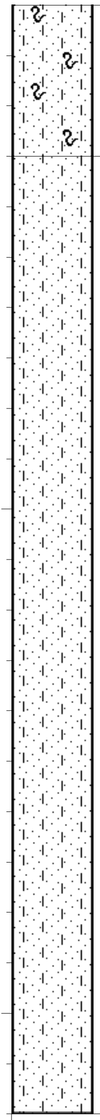
srk consulting

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: TP 3
Sheet 1 of 1

JOB NUMBER: 526679

Scale
1:15



0.00	Dry, beige, <u>very loose</u>, homogeneous, silty, fine SAND with abundant fine rootlets and minor shell fragments. Aeolian.
0.30	Slightly moist, whitish beige, <u>very loose to loose</u>, homogeneous, silty, fine SAND with minor shell fragments and rootlets. Aeolian.
2.20	

NOTES

1) Sides collapse.

2) No water seepage.

3) Not to refusal.

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

ELEVATION : 24 m
X-COORD : 3182891
Y-COORD : 0042494

HOLE No: TP 3

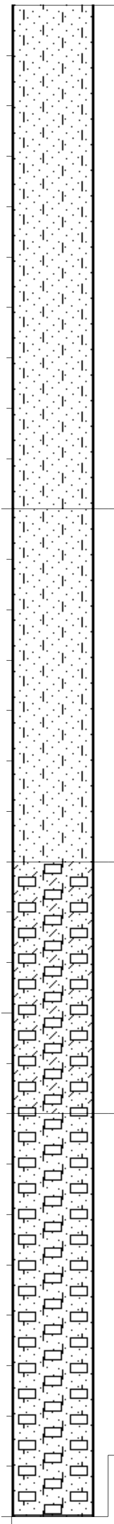
srk consulting

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: TP 4
Sheet 1 of 1

JOB NUMBER: 526679

Scale
1:15



0.00	Dry, whitish beige, <u>very loose</u>, homogeneous, silty, fine SAND with abundant fine rootlets and minor shell fragments. Aeolian.
1.00	Slightly moist, whitish beige, <u>very loose to loose</u>, homogeneous, silty, fine SAND with minor shell fragments. Aeolian.
1.70	Dry, off-white to beige, <u>dense to very dense</u>, poorly calcretized, silty, clayey, fine SAND with abundant calcrete cobbles and gravel. Aeolian/Pedocrete.
2.20	Dry, off-white, <u>very dense</u>, silty, sandy, CALCRETE with abundant quartzite and schist cobbles and gravel. Pedocrete.
3.00	

NOTES

1) No water seepage.

2) Near refusal.

3) Excavate with difficulty after 2.20 m.

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

ELEVATION : 21 m
X-COORD : 3183021
Y-COORD : 0042487

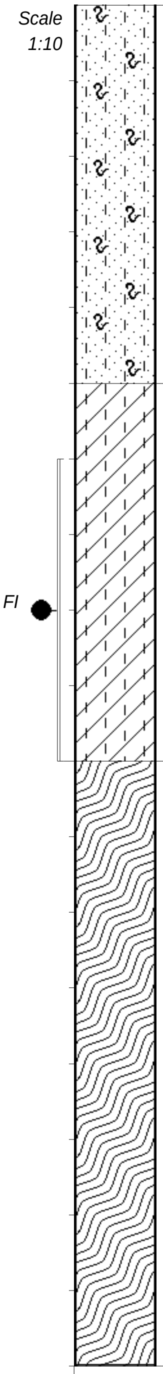
HOLE No: TP 4

srk consulting

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: TP 5
Sheet 1 of 1

JOB NUMBER: 526679



0.00	Dry, brownish beige, very loose to loose, silty, fine SAND with minor cobbles, gravel and shell fragments, and abundant fine rootlets. Aeolian.
0.50	Dry, off-white, stiff to very stiff, powdery, sandy, silty, kaolinite CLAY with minor schist gravel. Transported.
1.00	Brownish grey, highly weathered, thinly laminated, very closely jointed, medium hard rock. SCHIST with off-white kaolinite coating and infill. Gariep Supergroup. Joints: Sub-vertical, smooth planar, undulating, narrow, iron stained, and kaolinite coating/infill.
1.80	

NOTES

1) No water seepage.

2) Near refusal.

3) Excavate with difficulty after 1.80 m.

4) Disturbed FI sample taken at 0.60--1.00 m.

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

ELEVATION : 24 m
X-COORD : 3182292
Y-COORD : 0042340

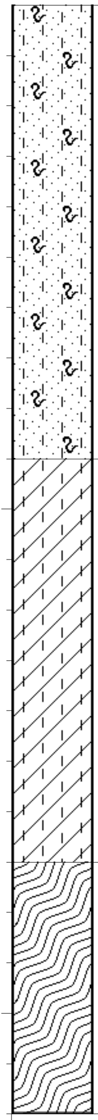
HOLE No: TP 5

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: TP 6
Sheet 1 of 1

JOB NUMBER: 526679

Scale
1:15



0.00	Dry, yellowish beige, very loose, silty, fine SAND with minor gravel and shell fragments, and abundant fine rootlets. Aeolian.
0.90	Dry, off-white and grey, stiff to very stiff, steeply inclined, thinly laminated, poorly calcretized, silty, CLAY. Residual Schist.
1.70	Brownish grey, moderately to highly weathered, steeply inclined, thinly laminated, closely jointed, medium hard rock. SCHIST with off-white kaolinite coating and infill. Gariep Supergroup. Joints: Sub-vertical, smooth planar, undulating, narrow to wide, iron stained, and kaolinite coating/infill.
2.20	

NOTES

1) No water seepage.

2) Not to refusal.

3) Easily to moderately excavatable.

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

ELEVATION : 23 m
X-COORD : 3182543
Y-COORD : 0042307

HOLE No: TP 6

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

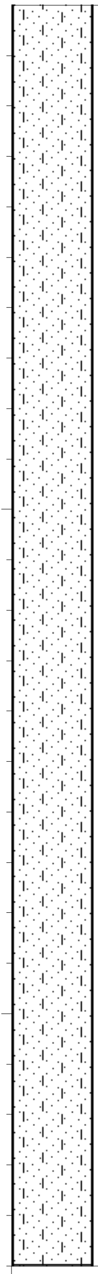
DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: TP 7
Sheet 1 of 1

JOB NUMBER: 526679

Scale
1:15



0.00

Dry, whitish beige, very loose, homogeneous, silty, fine SAND with minor gravel, shell fragments and abundant fine rootlets. Aeolian.

2.50

NOTES

1) No water seepage.

2) Not to refusal.

3) Sides collapse.

4) Easily excavatable.

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

ELEVATION : 24 m
X-COORD : 3182737
Y-COORD : 0042295

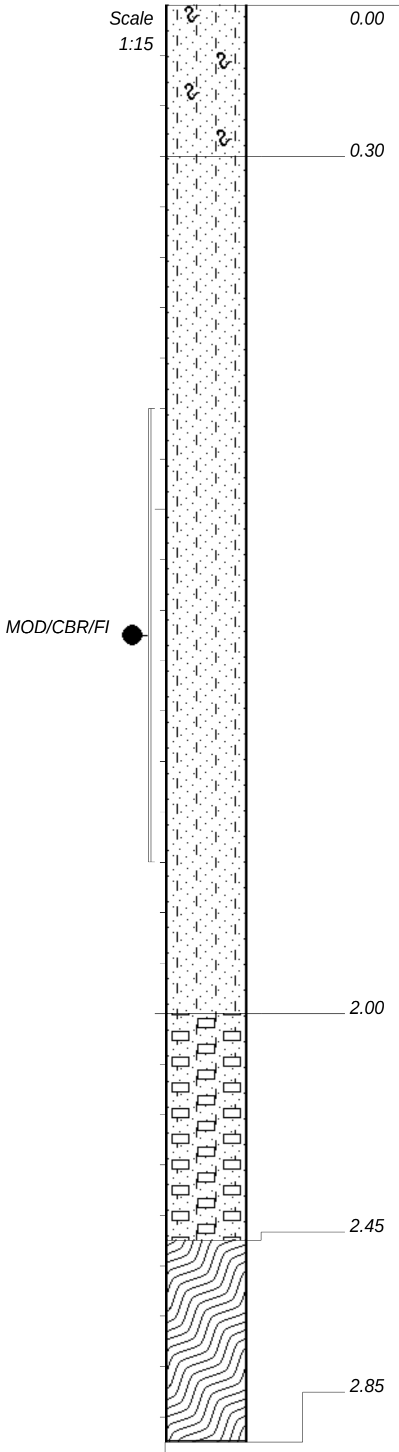
HOLE No: TP 7

srk consulting

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: **TP 7A**
Sheet 1 of 1

JOB NUMBER: 526679



Depth (m)	Description
0.00 – 0.30	Dry, whitish beige, very loose, silty, fine SAND with minor gravel and shell fragments, and abundant fine rootlets. Aeolian.
0.30 – 2.00	Slightly moist, olive green to beige, very loose to loose, homogeneous, silty, fine SAND with minor shell fragments. Aeolian.
2.00 – 2.45	Dry, off-white and grey, very dense, silty, sandy, CALCRETE with abundant schist gravel and cobbles. Pedocrete.
2.45 – 2.85	Olive green and grey, highly weathered, steeply inclined, thinly laminated, very closely jointed, medium hard rock to hard rock. SCHIST with silty, sand infill. Gariep Supergroup.

NOTES

1) No water seepage.

2) Near refusal.

3) Excavate with difficulty after 2.45 m.

4) MOD/CBR/FI sample taken at 0.80--1.70 m.

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

ELEVATION : 24 m
X-COORD : 3182735
Y-COORD : 0042264

HOLE No: **TP 7A**

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

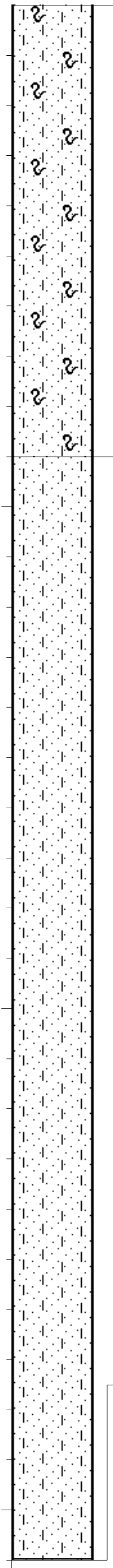
DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: TP 8
Sheet 1 of 1

JOB NUMBER: 526679

Scale
1:15



0.00	Dry, whitish beige, very loose, homogeneous, silty, fine SAND with minor gravel and shell fragments, and abundant fine rootlets. Aeolian.
0.90	Slightly moist, olive green to beige, very loose to loose, homogeneous, silty, fine SAND with minor shell fragments. Aeolian.
3.10	

NOTES

1) No water seepage.

2) Not to refusal.

3) Sides collapse.

4) Easily excavatable.

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

ELEVATION : 23 m
X-COORD : 3182903
Y-COORD : 0042292

HOLE No: TP 8

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

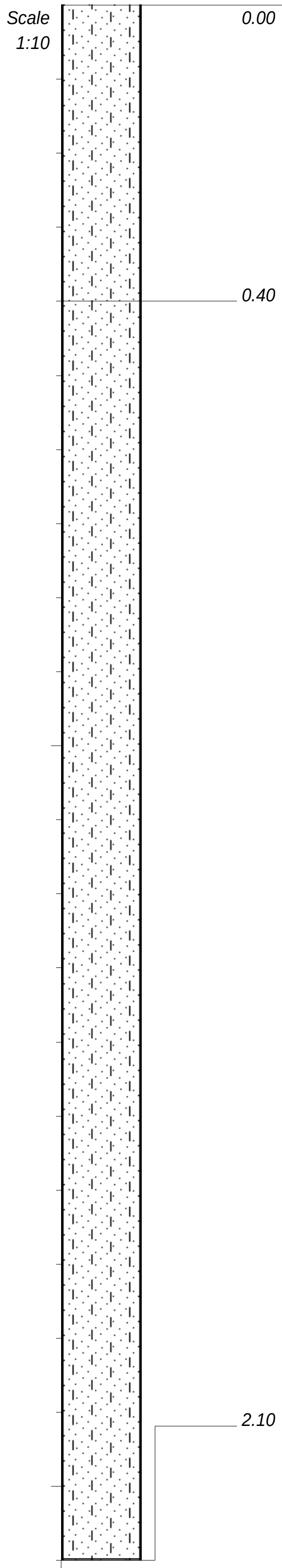
DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

srk consulting

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: TP 9
Sheet 1 of 1

JOB NUMBER: 526679



Dry, whitish beige, medium dense, poorly calcretized, silty, fine SAND with some gravel, cobbles, shell fragments and abundant fine rootlets. Gravel Road fill/Aeolian.

Dry, whitish beige, very loose to loose, sandy, homogeneous, silty, fine SAND with minor gravel and shell fragments. Aeolian.

NOTES

1) Not to refusal.

2) No water seepage.

3) Sides collapse.

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

ELEVATION : 24 m
X-COORD : 3183113
Y-COORD : 0042307

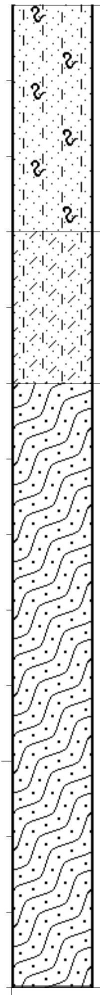
HOLE No: TP 9

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: TP 10
Sheet 1 of 1

JOB NUMBER: 526679

Scale
1:10



0.00	Dry, brownish beige, very loose to loose, silty, fine SAND with some gravel and shell fragments, and abundant fine rootlets. Aeolian.
0.30	Slightly moist, whitish beige to orangey brown, dense, poorly calcretized, silty, clayey, fine SAND. Pedocrete.
0.50	Brownish grey, highly to moderately weathered, sub-verical, closely jointed, medium hard rock, QUARTZITE with off-white, interbedded, thinly laminated, stiff to very stiff, kaolin, silty, clay layers, Gariep Supergroup. Joints: Sub-vertical, undulating, narrow, and iron stained.
1.30	

NOTES

1) Not to refusal.

2) No water seepage.

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

ELEVATION : 22 m
X-COORD : 3182335
Y-COORD : 0042109

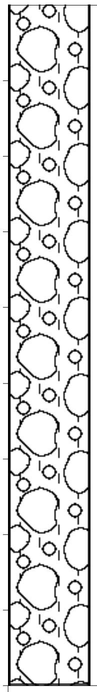
HOLE No: TP 10

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: TP 11
Sheet 1 of 1

JOB NUMBER: 526679

Scale
1:10



0.00

Dry, brownish grey, closely packed, angular, boulders, cobbles, GRAVEL with beige to off-white, poorly calcretized, silty, fine SAND matrix. Overall consistency is very dense to rock quality. Residual Quartzite.

0.90

NOTES

1) No water seepage.

2) Refusal reached at boulders and cobbles.

3) Excavate with difficulty.

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

ELEVATION : 21 m
X-COORD : 3182571
Y-COORD : 0042056

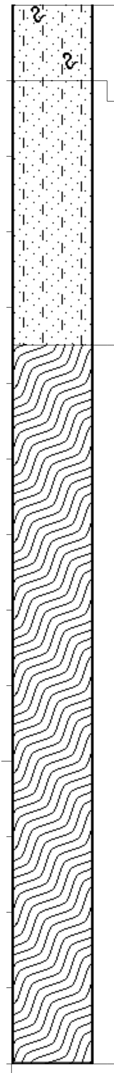
HOLE No: TP 11

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: **TP 12**
Sheet 1 of 1

JOB NUMBER: **526679**

Scale
1:10



0.00	Dry, brownish beige, very loose to loose, silty, fine SAND with gravel, and abundant fine rootlets. Aeolian.
0.10	Dry, off-white to beige, medium dense to dense, kaolinized, silty, fine SAND with brownish grey, highly weathered, interbedded, thinly laminated, soft rock to medium hard rock, quartz SCHIST layer. Residual schist.
0.45	Dry, Grey and orangey brown, highly weathered, closely jointed, thinly laminated, blocky, medium hard rock, quartz SCHIST. Gariep Supergroup. Joints: Sub-vertical, smooth planar and undulating, narrow to wide, iron stained and kaolin, silty, clay infill.
1.40	

NOTES

1) No water seepage.

2) Not to refusal.

3) Easily excavatable.

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

ELEVATION : 21 m
X-COORD : 3182744
Y-COORD : 0042063

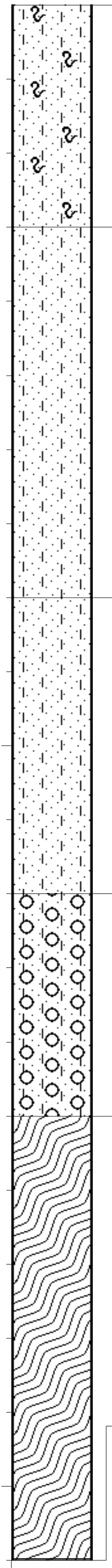
HOLE No: **TP 12**

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: TP 13
Sheet 1 of 1

JOB NUMBER: 526679

Scale
1:10



0.00

Dry, brownish beige, <u>very loose</u>, silty, fine SAND with minor shell fragments, and abundant fine rootlets. Aeolian.

0.30

Dry, beige, <u>loose</u>, sandy, silty, fine SAND with some gravel and shell fragments. Aeolian.

0.80

Slightly moist, beige, <u>medium dense to dense</u>, silty, fine SAND with some angular gravel. Aeolian.

1.20

Slightly moist, beige, <u>dense to very dense</u>, kaolinized, silty, fine SAND with abundant angular quartz schist gravel. Reworked residual schist.

1.50

Grey and orangey brown, highly weathered, closely jointed, thinly laminated, <u>soft rock to medium hard rock</u>, quartz SCHIST with off-white, kaolin, silty, clay infill. Gariep Supergroup.

2.10

NOTES

1) Not to refusal.

2) No water seepage.

3) Easily excavatable.

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

ELEVATION : 23 m
X-COORD : 3182930
Y-COORD : 0042072

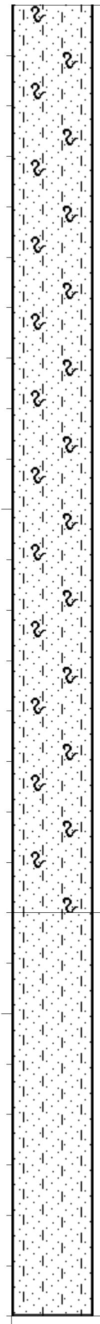
HOLE No: TP 13

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: **TP 14**
Sheet 1 of 1

JOB NUMBER: **526679**

Scale
1:15



0.00	Dry, whitish beige, <u>very loose</u>, silty, fine SAND with minor shell fragments, and abundant fine rootlets. Aeolian.
1.80	Slightly moist, olive green and beige, <u>very loose to loose</u>, silty, fine SAND with minor shell fragments. Aeolian.
2.60	

NOTES

1) No water seepage.

2) Not to refusal.

3) Sides collapse.

4) Easily excavatable.

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

ELEVATION : 30 m
X-COORD : 3183103
Y-COORD : 0042030

HOLE No: **TP 14**

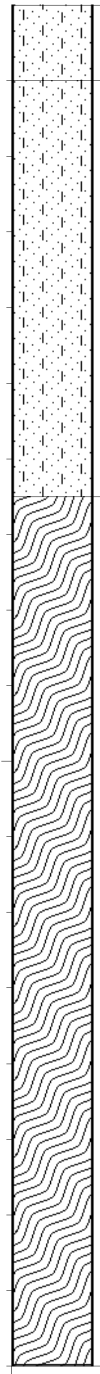
srk consulting

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: **TP 15**
Sheet 1 of 1

JOB NUMBER: 526679

Scale
1:10



0.00	Dry, brownish beige, very loose to loose, silty, fine SAND with gravel, and abundant fine rootlets. Aeolian.
0.10	Dry, off-white to beige, medium dense to dense, kaolinized, silty, fine SAND with brownish grey, highly weathered, interbedded, thinly laminated, soft rock to medium hard rock, quartz SCHIST layers. Residual schist.
0.65	Dry, grey and orangey brown, highly weathered, closely jointed, thinly laminated, blocky, medium hard rock, quartz SCHIST. Gariep Supergroup. Joints: Sub-vertical, smooth planar and undulating, narrow to wide, iron stained, and kaolin, silty, clay infill.
1.80	

NOTES

1) No water seepage.

2) Not to refusal.

3) Easily excavatable.

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

ELEVATION : 18 m
X-COORD : 3182794
Y-COORD : 0041860

HOLE No: **TP 15**

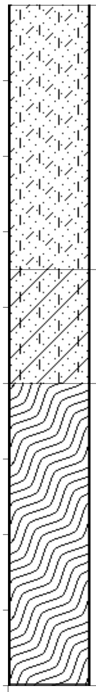
srk consulting

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: **TP 16**
Sheet 1 of 1

JOB NUMBER: **526679**

Scale
1:10



0.00	Slightly moist, brownish beige, very loose to loose, clayey, silty, fine SAND with some cobbles and gravel, and abundant fine rootlets. Aeolian.
0.35	Slightly moist, off-white to beige, firm to stiff, sandy, silty, CLAY with schist gravel. Residual schist.
0.50	Grey and orangey brown, highly weathered, closely jointed, thinly laminated, soft rock to medium hard rock, quartz SCHIST with off-white, highly weathered, interbedded, kaolin, silty, clay layers. Gariep Supergroup. Joints: Sub-horizontal, Sub-vertical, smooth planar and undulating, narrow to wide, and iron stained.
0.90	

NOTES

1) No water seepage.

2) Near refusal.

3) Excavate with difficulty at 0.90 m.

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

ELEVATION : 20 m
X-COORD : 3183011
Y-COORD : 0041824

HOLE No: **TP 16**

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

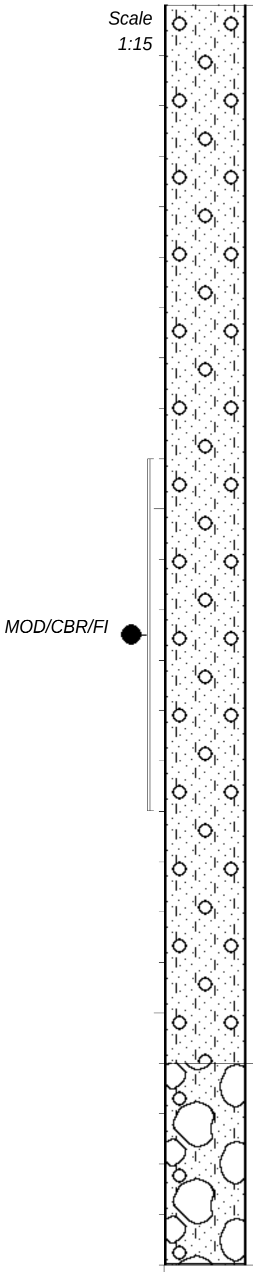
DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: TP 17
Sheet 1 of 1

JOB NUMBER: 526679

Scale
1:15



0.00	Dry, beige, very loose, silty, fine SAND with some angular gravel, minor shell fragments, and abundant fine rootlets at the top 0.35 m. Aeolian.
2.10	Slightly moist, brownish beige, dense, silty, fine SAND with abundant highly weathered, thinly laminated, quartz schist cobbles and gravel. Residual schist.
2.50	

NOTES

1) Not to refusal.

2) No water seepage.

3) Sides collapse.

4) Easily excavatable.

5) MOD/CBR/FI sample taken at 0.90--1.60 m.

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

ELEVATION : 27 m
X-COORD : 3182873
Y-COORD : 0041505

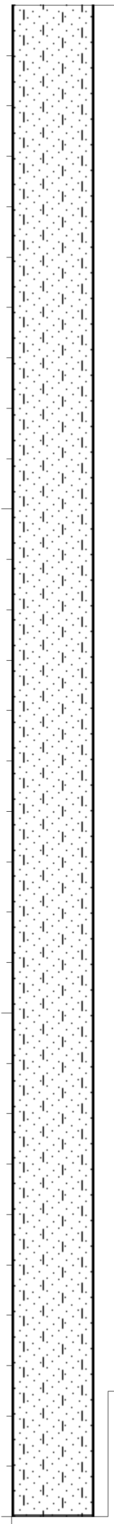
HOLE No: TP 17

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: **TP 18**
Sheet 1 of 1

JOB NUMBER: 526679

Scale
1:15



0.00

Dry, olive green to beige, very loose, silty, fine SAND with minor shell fragments, and abundant fine rootlets at the top 0.40 m. Aeolian.

3.00

NOTES

1) Not to refusal.

2) No water seepage.

3) Sides collapse.

4) Easily excavatable.

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

ELEVATION : 35 m
X-COORD : 3183126
Y-COORD : 0041497

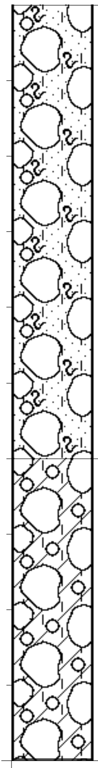
HOLE No: **TP 18**

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: TP 19
Sheet 1 of 1

JOB NUMBER: 526679

Scale
1:10



Depth	Description
0.00	Dry, brownish beige, dense, silty, fine SAND with abundant closely packed, angular boulders, cobbles and gravel, and abundant fine rootlets. Reworked (mined).
0.60	Dry, brownish grey, highly weathered, closely packed, hard rock, quartzite BOULDERS, COBBLES and GRAVEL with off-white and beige, very stiff, kaolin, silty, clay infill. Residual quartzite.
1.00	

NOTES

1) Refusal reached at 1.00 m.

2) No water seepage.

3) Excavate with difficulty.

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

ELEVATION : 34 m
X-COORD : 3182978
Y-COORD : 0041161

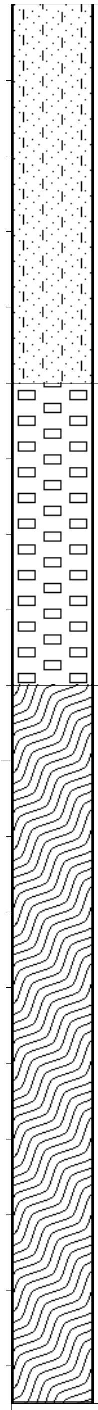
HOLE No: TP 19

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: TP 20
Sheet 1 of 1

JOB NUMBER: 526679

Scale
1:10



0.00

Dry, beige, medium dense to dense, poorly calcretized silty, fine SAND with quartz and calcrete cobbles and gravel. Aeolian/Pedocrete.

0.50

Dry, off-white, very dense, CALCRETE with cobbles and gravel. Pedocrete.

0.90

Orangey brown, highly weathered, thinly laminated, soft rock to medium hard rock, SCHIST with kaolin clay infill and calcrete coating. Gariep Supergroup.

1.85

NOTES

1) Near refusal.

2) No water seepage.

3) Excavate with difficulty at 1.85 m..

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

ELEVATION : 49 m
X-COORD : 3183146
Y-COORD : 0040724

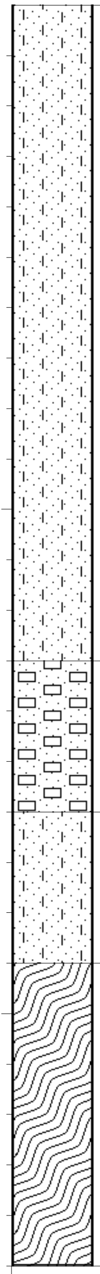
HOLE No: TP 20

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: TP 21
Sheet 1 of 1

JOB NUMBER: 526679

Scale
1:15



0.00

Dry to slightly moist, beige, very loose to loose, silty, fine SAND with minor gravel and shell fragments, and abundant fine rootlets at the top 0.35 m. Aeolian.

1.30

Dry, off-white, dense to very dense, sandy, CALCRETE with abundant angular gravel. Pedocrete.

1.60

Dry, dark brown and grey, medium dense to dense, silty, fine SAND with abundant schist gravel. Reworked residual schist.

1.90

Dark brown and grey, highly weathered, thinly laminated, soft rock to medium hard rock, SCHIST with minor calcrete coating. Gariep Supergroup.

2.50

NOTES

1) Not to refusal.

2) No water seepage.

3) Easily excavatable.

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

ELEVATION : 56 m
X-COORD : 3182915
Y-COORD : 0040348

HOLE No: TP 21

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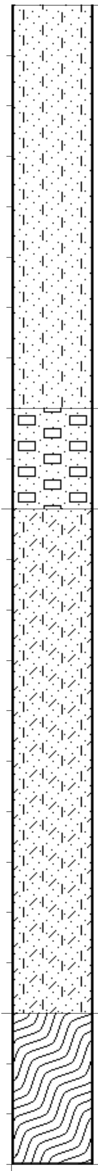
PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: TP 22
Sheet 1 of 1

JOB NUMBER: 526679

Scale
1:15



0.00	Dry, beige, very loose to loose, silty, fine SAND with minor angular gravel and shell fragments, and abundant fine rootlets. Aeolian.
0.80	Dry, off-white, dense to very dense, sandy, CALCRETE with abundant gravel and cobbles. Pedocrete.
1.00	Dry, orangey brown, dense to very dense, calcretized, silty, clayey, SAND with abundant calcrete coated gravel and cobbles. Aeolian/Pedocrete.
2.00	Olive green to brown, highly weathered, thinly laminated, medium hard rock, SCHIST with minor calcretized coating and infill. Gariep Supergroup.
2.30	

NOTES

1) Not to refusal (Possibly near).

2) No water seepage.

3) Easily excavatable (Excavate with difficulty at calcrete layers).

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

ELEVATION : 66 m
X-COORD : 3182720
Y-COORD : 0039948

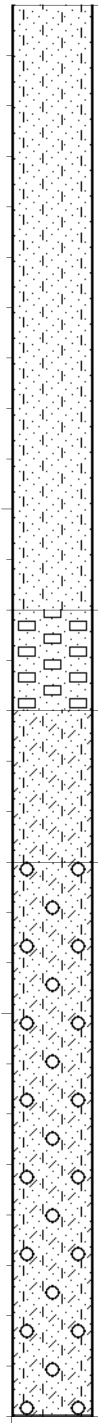
HOLE No: TP 22

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: **TP 23**
Sheet 1 of 1

JOB NUMBER: 526679

Scale
1:15



0.00	Dry, beige, very loose to loose, silty, fine SAND with minor angular gravel and shell fragments, and abundant fine rootlets. Aeolian.
1.20	Dry, off-white, dense to very dense, sandy, CALCRETE with abundant gravel. Pedocrete.
1.40	Dry, orangey brown, dense to very dense, calcretized, silty, clayey, SAND with abundant calcrete coated gravel. Aeolian/Pedocrete.
1.70	Dry, orange and off-white, dense to very dense, calcretized, silty, clayey, SAND with abundant calcrete coated gravel. Aeolian/Pedocrete.
2.80	

NOTES

1) Not to refusal.

2) No water seepage.

3) Easily excavatable.

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

ELEVATION : 65 m
X-COORD : 3182535
Y-COORD : 0039666

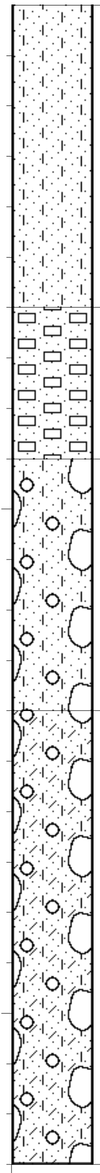
HOLE No: **TP 23**

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: TP 24
Sheet 1 of 1

JOB NUMBER: 526679

Scale
1:15



0.00	Dry, beige, very loose to loose, silty, fine SAND with minor angular gravel and shell fragments, and abundant fine rootlets. Aeolian.
0.60	Dry, off-white, dense, sandy, CALCRETE with abundant gravel. Pedocrete.
0.90	Dry, off-white and beige, medium dense to dense, calcretized, silty, fine SAND with cobbles and gravel. Aeolian/Pedocrete.
1.40	Dry, orangey brown, dense to very dense, calcretized, silty, clayey, SAND with abundant calcrete coated gravel and cobbles. Aeolian/Pedocrete.
2.30	

NOTES

1) Not to refusal.

2) No water seepage.

3) Easily excavatable.

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

ELEVATION : 70 m
X-COORD : 3182402
Y-COORD : 0039378

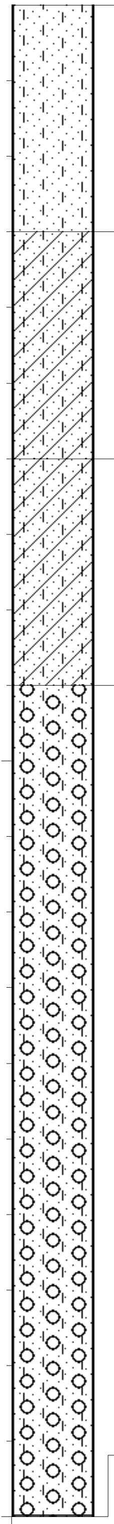
HOLE No: TP 24

PRDW
BOEGOEBAAI PORT
ALEXANDER BAAI
GEOTECHNICAL INVESTIGATION

HOLE No: TP 25
Sheet 1 of 1

JOB NUMBER: 526679

Scale
1:10



0.00	Dry, beige, very loose, silty, fine SAND with minor angular to sub-rounded gravel, and abundant fine rootlets. Aeolian.
0.30	Dry, orangey beige, stiff, sandy, silty, CLAY with abundant angular to sub-rounded gravel. Transported.
0.60	Dry, orangey brown, grey and off-white, dense to very dense, relic jointed, very thinly laminated, highly to completely weathered, poorly calcretized, sandy, silty, CLAY. Residual Phyllite.
0.90	Slightly moist, brownish orange, medium dense, silty, sandy, GRAVEL. Alluvial/Aeolian.
2.00	

NOTES

1) Not to refusal.

2) No water seepage.

3) Easily excavatable.

CONTRACTOR : BABUSISEKILE (BBE)
MACHINE : JCB 3CX
DRILLED BY : THEMBA LEKHULENI
PROFILED BY : DUPD

TYPE SET BY : DUPD
SETUP FILE : STANDARD.SET

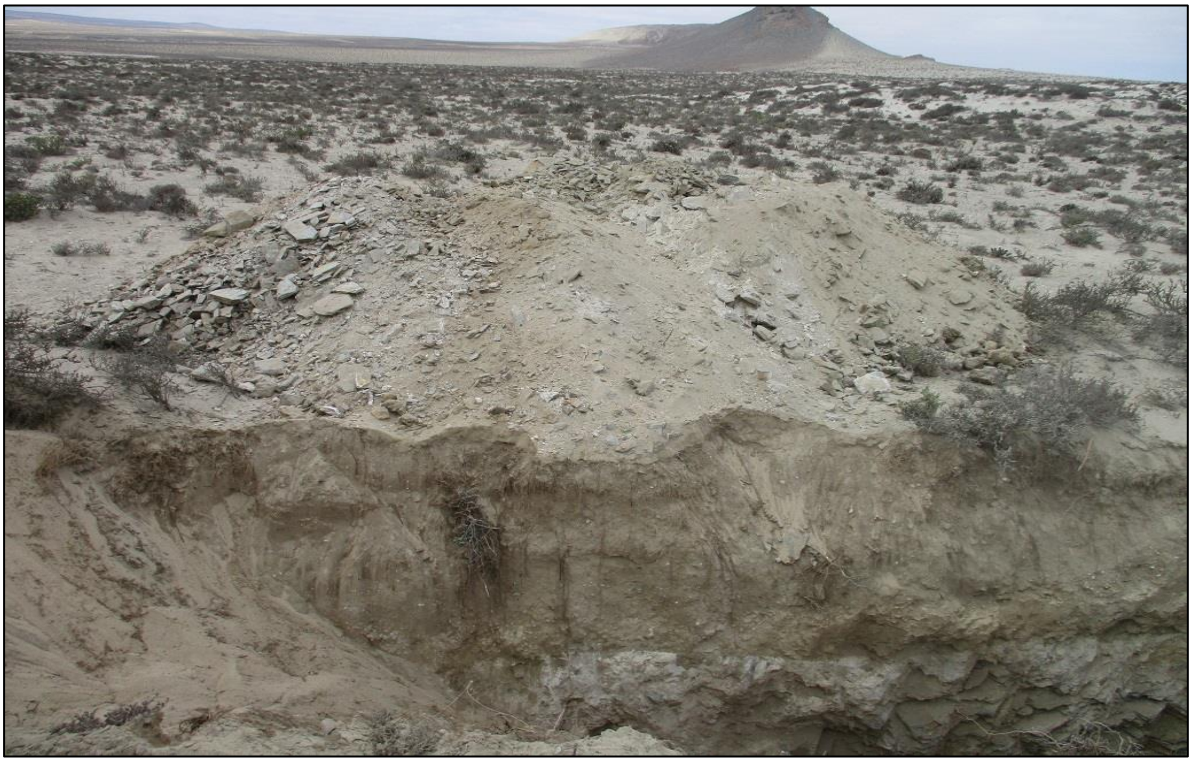
INCLINATION : VERTICAL
DIAM :
DATE : April - May 2018
DATE : April - May 2018

DATE : 20/06/2018 12:16
TEXT : ..esDotPlotsBoegoebaai.txt

ELEVATION : 73 m
X-COORD : 3182284
Y-COORD : 0039155

HOLE No: TP 25

srk consulting	**BOEGOE BAAI PORT** **TEST PIT 1**	Project No. 526679

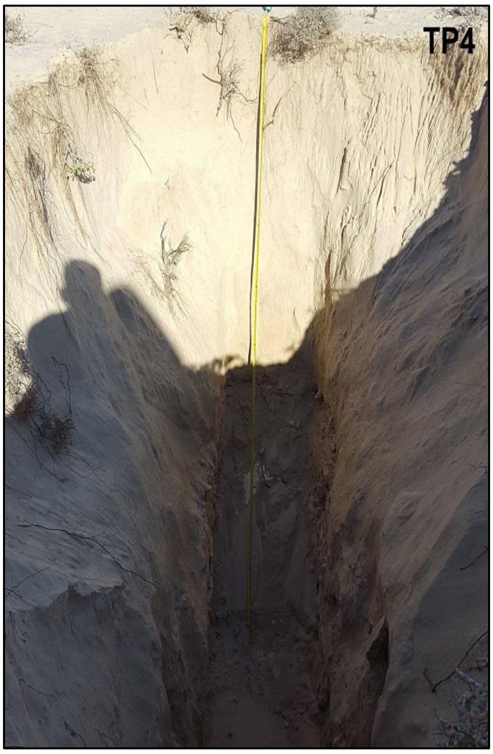


srk consulting	**BOEGOE BAAI PORT** **TEST PIT 1 - SPOIL**	Project No. 526679

srk consulting	**BOEGOE BAAI PORT** **TEST PIT 2**	Project No. 526679

srk consulting	**BOEGOE BAAI PORT TEST PIT 3**	Project No. 526679

srk consulting	**BOEGOE BAAI PORT TEST PIT 3 - SPOIL**	Project No. 526679



srk consulting	**BOEGOE BAAI PORT** **TEST PIT 4**	Project No. 526679

srk consulting	**BOEGOE BAAI PORT** **TEST PIT 4 - SPOIL**	Project No. 526679

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BOEGOE BAAI PORT
TEST PIT 5

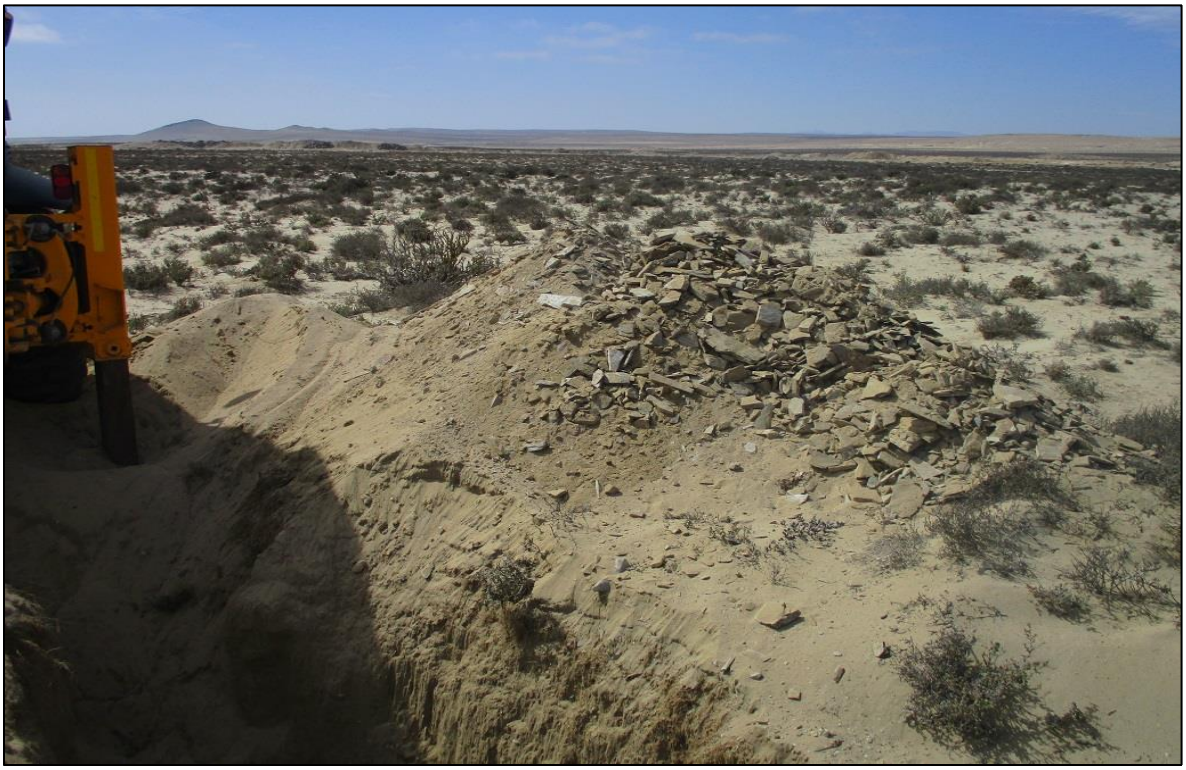
Project No.
526679

srk consulting

BOEGOE BAAI PORT
TEST PIT 5 - SPOIL

Project No.
526679

srk consulting	**BOEGOE BAAI PORT TEST PIT 6**	Project No. 526679

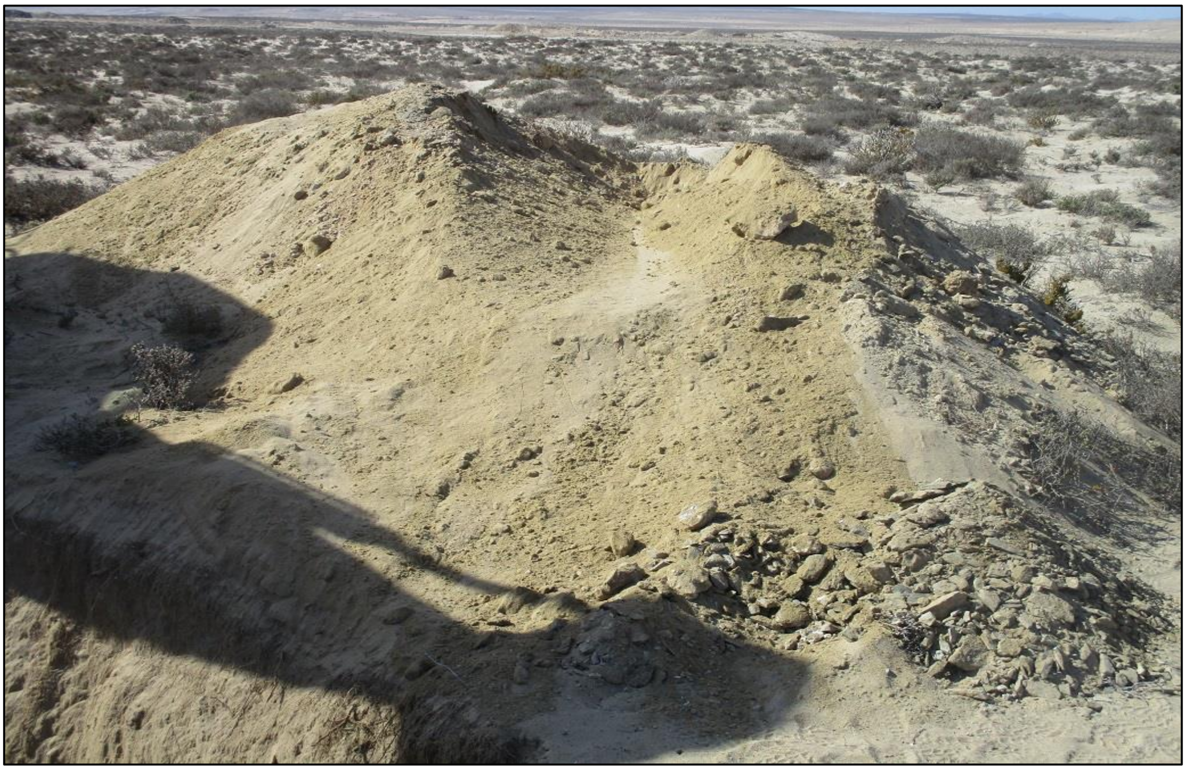


srk consulting	**BOEGOE BAAI PORT TEST PIT 6 - SPOIL**	Project No. 526679

srk consulting	**BOEGOE BAAI PORT** **TEST PIT 7**	Project No. 526679

srk consulting	**BOEGOE BAAI PORT** **TEST PIT 7 - SPOIL**	Project No. 526679

	BOEGOE BAAI PORT **TEST PIT 7A**	Project No. 526679



	BOEGOE BAAI PORT **TEST PIT 7A - SPOIL**	Project No. 526679

BOEGOE BAAI PORT
TEST PIT 8

Project No.
526679

BOEGOE BAAI PORT
TEST PIT 8 - SPOIL

Project No.
526679

srk consulting	**BOEGOE BAAI PORT** **TEST PIT 9**	Project No. 526679

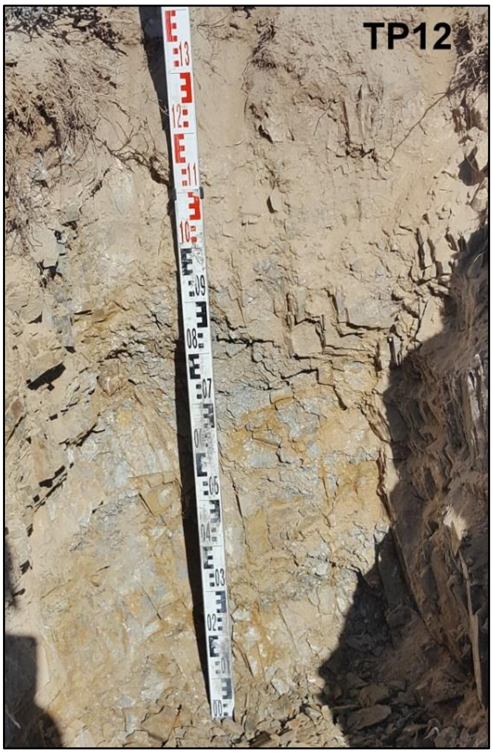
srk consulting	**BOEGOE BAAI PORT** **TEST PIT 9 - SPOIL**	Project No. 526679

srk consulting	**BOEGOE BAAI PORT** **TEST PIT 10**	Project No. 526679

srk consulting	**BOEGOE BAAI PORT** **TEST PIT 10- SPOIL**	Project No. 526679

	BOEGOE BAAI PORT **TEST PIT 11**	Project No. 526679

	BOEGOE BAAI PORT **TEST PIT 11 - SPOIL**	Project No. 526679



srk consulting	**BOEGOE BAAI PORT** **TEST PIT 12**	Project No. 526679

srk consulting	**BOEGOE BAAI PORT** **TEST PIT 13**	Project No. 526679

srk consulting	**BOEGOE BAAI PORT** **TEST PIT 13 - SPOIL**	Project No. 526679

	BOEGOE BAAI PORT **TEST PIT 14**	Project No. 526679

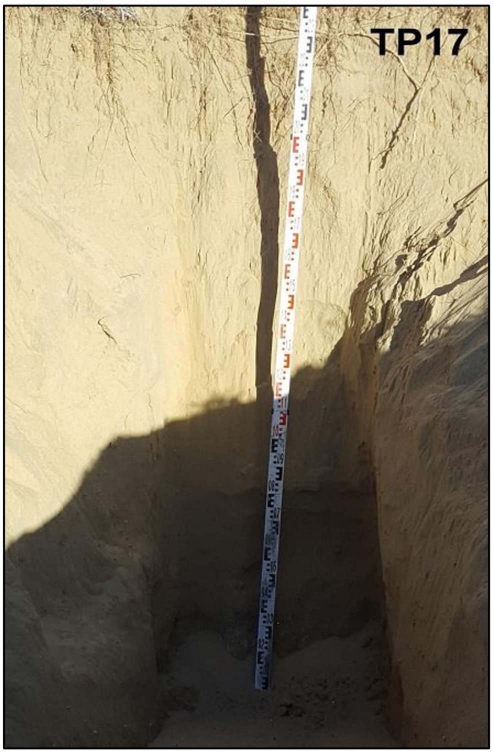
	BOEGOE BAAI PORT **TEST PIT 14 - SPOIL**	Project No. 526679

srk consulting	**BOEGOE BAAI PORT TEST PIT 15**	Project No. 526679

srk consulting	**BOEGOE BAAI PORT TEST PIT 15 - SPOIL**	Project No. 526679

	BOEGOE BAAI PORT **TEST PIT 16**	Project No. 526679

	BOEGOE BAAI PORT **TEST PIT 16 - SPOIL**	Project No. 526679



srk consulting	**BOEGOE BAAI PORT** **TEST PIT 17**	Project No. 526679

srk consulting	**BOEGOE BAAI PORT** **TEST PIT 17 - SPOIL**	Project No. 526679

srk consulting	**BOEGOE BAAI PORT** **TEST PIT 18**	Project No. 526679

srk consulting	**BOEGOE BAAI PORT** **TEST PIT 18 - SPOIL**	Project No. 526679

srk consulting

BOEGOE BAAI PORT
TEST PIT 19

Project No.
526679

srk consulting

BOEGOE BAAI PORT
TEST PIT 19 - SPOIL

Project No.
526679

srk consulting	**BOEGOE BAAI PORT** **TEST PIT 20**	Project No. 526679

srk consulting	**BOEGOE BAAI PORT** **TEST PIT 20 - SPOIL**	Project No. 526679

srk consulting	**BOEGOE BAAI PORT** **TEST PIT 21**	Project No. 526679

srk consulting	**BOEGOE BAAI PORT** **TEST PIT 21 - SPOIL**	Project No. 526679

BOEGOE BAAI PORT
TEST PIT 22

Project No.
526679

BOEGOE BAAI PORT
TEST PIT 22 - SPOIL

Project No.
526679

BOEGOE BAAI PORT
TEST PIT 23

Project No.
526679

BOEGOE BAAI PORT
TEST PIT 23 - SPOIL

Project No.
526679

BOEGOE BAAI PORT
TEST PIT 24

Project No.
526679

BOEGOE BAAI PORT
TEST PIT 24 - SPOIL

Project No.
526679

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BOEGOE BAAI PORT
TEST PIT 25

Project No.
526679

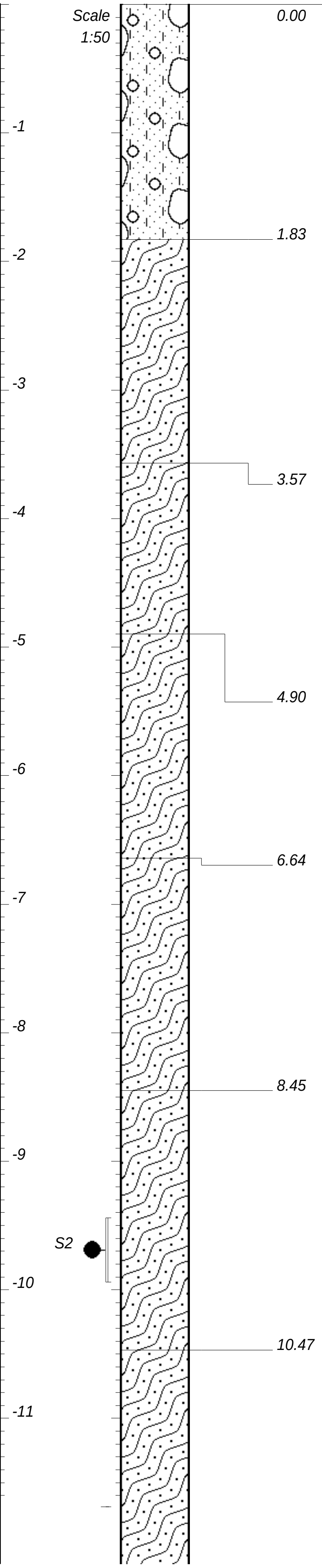
srk consulting

BOEGOE BAAI PORT
TEST PIT 25 - SPOIL

Project No.
526679

Appendix B: Borehole Logs and Core Photographs

Drill Run (m)	Drilling method	% Core Recov	SPT N-Value	% RQD	FF / (m)
0.57	NXC	81			
1.14	NXC	47		25	
1.50	NWD4	53		0	
1.61	SPT	0	Ref	0	
1.88	NWD4	41		0	11
2.85	TNW	89		35	
3.14	TNW	100		83	
3.56	TNW	100		31	
4.77	TNW	100		74	10
6.27	TNW	98		76	4
7.26	TNW	100		86	5
7.77	TNW	86		67	
9.27	TNW	100		77	6
10.47	TNW	100		72	
10.75	TNW	86		75	
10.83	TNW	100		0	
11.12	TNW	93		41	
11.38	TNW	100		77	



0.00

Purplish red blotched grey and beige, loosely packed, subangular, fine to coarse, COBBLES and GRAVEL within a silty, sandy matrix. Matrix mostly washed out, but poorly calcretised above 1.50m. Overall consistency dense. Pedocrete.

1.83

Grey, slightly unweathered, very closely to widely jointed, but mainly medium to widely jointed, very hard rock. Quartzite. Gariep Supergroup.

Joints: Subvertical and subhorizontal and occasional long vertical, planar, smooth undulating, curved, narrow to wide with some clay infill <20mm, iron-stained. Blotched colouring along joints.

3.57

Grey, slightly to unweathered, very closely to medium jointed, but mainly closely jointed, very hard rock to extremely hard rock, Quartzite.

Joints: Subvertical and subhorizontal(bedding dip 38°-38°) (joints 68°-70°), smooth planar, occasionally rough planar, narrow, calcite <1mm, iron-stained.

4.90

Grey, unweathered, closely to medium jointed, very hard rock to extremely hard rock, Quartzite.

Joints: Subvertical and subhorizontal, smooth and rough planar, narrow, iron-stained.

6.64

Grey, unweathered, very closely to widely jointed, but mainly medium to widely jointed, very hard rock to extremely hard rock, Quartzite.

Joints: Subvertical and subhorizontal, smooth and rough planar, narrow, iron-stained.

8.45

Dark grey, unweathered, very closely to widely jointed, but mainly medium to widely jointed, very hard rock to extremely hard rock, Quartzite with a quartz vein between 9.40-9.53m.

Joints: Subvertical, smooth planar, undulating, narrow, iron-stained.

10.47

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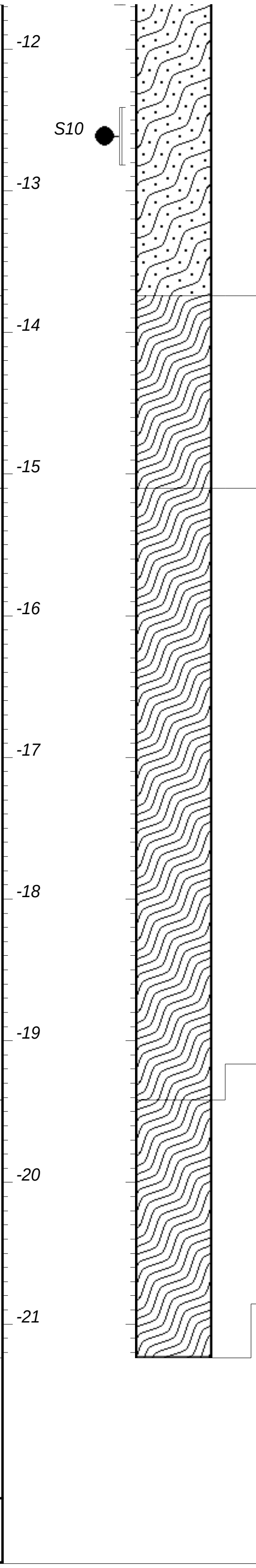
GEOTECHNICAL INVESTIGATION

HOLE No: **VBH1**
Sheet 2 of 2

JOB NUMBER: 526679

Drill Run (m)	Drilling method	% Core Recov	SPT N-Value	% RQD	FF / (m)
11.81	NWD4	100		100	
12.18	TNW	100		84	3
12.41	TNW	109		91	
12.82	TNW	100		93	
13.74	TNW	88		38	
15.10	TNW	53		0	2
16.74	TNW	100		73	5
18.24	NWD4	98		80	
19.74	NWD4	102		73	
21.24	NWD4	95		57	5



Dark grey, unweathered, closely to widely jointed, but mainly medium jointed, very hard rock to extremely hard rock, Quartzite with a quartz vein between 9.40-9.53m.

Joints: Subvertical, smooth planar, undulating, narrow, iron-stained.

13.74

Yellowish orange brown layered light grey, highly to completely weathered, very thinly laminated, very soft rock, Quartz Schist.

15.10

Orange brown layered light grey becoming grey, highly weathered, closely to widely jointed, but medium jointed, very thinly laminated, very soft rock to soft rock, Quartz Schist.

Joints: Subhorizontal and subvertical, planar, smooth and rough, undulating, narrow, iron-stained.

19.42

Yellowish orange brown and grey, highly weathered, very closely to medium jointed, very thinly laminated, very soft rock to soft rock, Quartz Schist. Gariep Supergroup.

Joints: Subhorizontal and subvertical, planar, smooth undulating, narrow, iron-stained.

21.24

End of Borehole.

NOTES

1) S2 sample taken at 9.44--9.94m.

2) S10 sample taken at 12.41--12.82m.

3) Piezometer Installed to 20.00m.

CONTRACTOR : Geomechanics CC
MACHINE : YWE D90R
DRILLED BY : ELIJA
PROFILED BY : PRIN

TYPE SET BY : LP
SETUP FILE : BH1PG-A4.SET

INCLINATION : Vertical
DIAM : 91 - 76mm
DATE : 13-04-2018
DATE : 19-04-2018

DATE : 13/06/2018 15:56
TEXT : ..oegoeBaaiDotplotsNew.txt

ELEVATION : WGS 84
X-COORD : 3182964
Y-COORD : 0042725

HOLE No: **VBH1**

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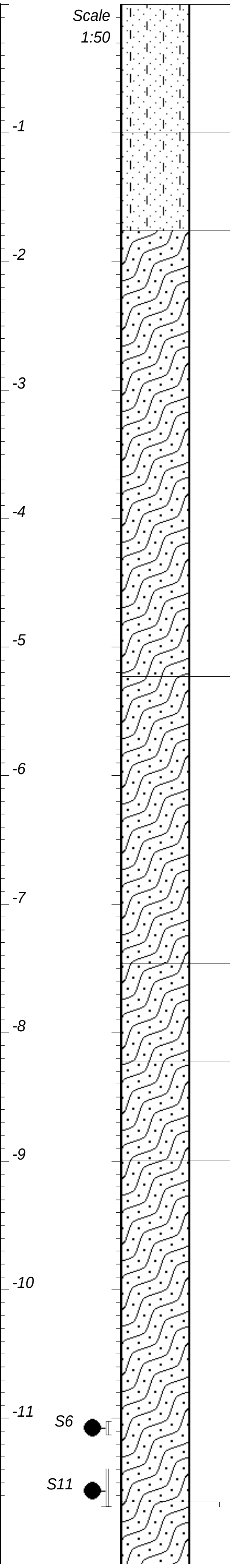
GEOTECHNICAL INVESTIGATION

HOLE No: VBH2
Sheet 1 of 2

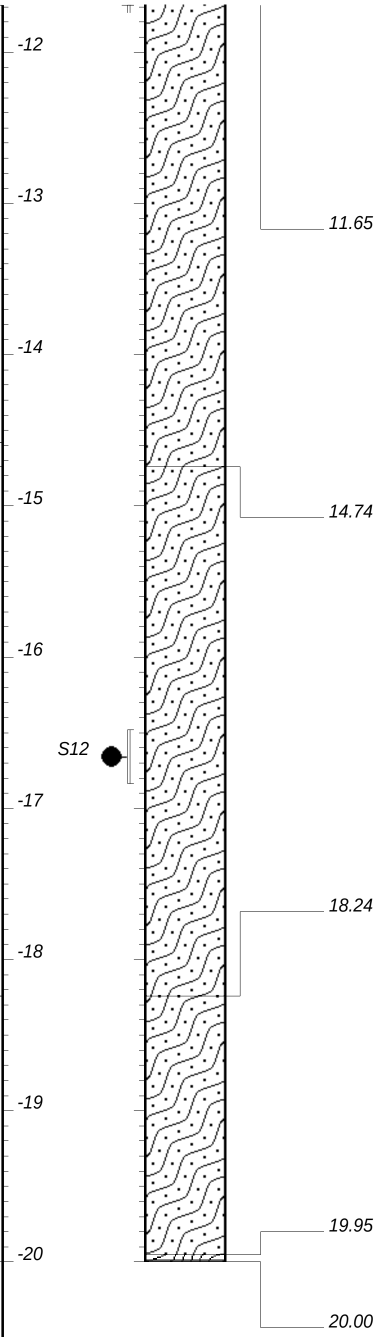
JOB NUMBER: 526679

Drill Run (m)	Drilling method	% Core Recov	SPT N-Value	% RQD	FF / (m)
0.50	NXC	100			
1.00	NXC	100			
1.50	NXC	40			
1.50	SPT	0	Ref	0	
2.10	NWD4	100		47	3
2.74	TNW	100		58	
3.24	TNW	96		94	
3.69	TNW	100		100	
4.54	TNW	88		35	19 5
4.87	TNW	85		30	
5.62	TNW	100		47	15
6.12	TNW	100		76	
6.80	TNW	88		38	
7.42	TNW	100		16	
8.38	TNW	100		74	3 14
8.74	TNW	97		28	
8.99	TNW	100		40	
9.74	TNW	100		92	3
10.74	TNW	95		81	
11.39	TNW	92		83	



0.00	Brown, medium dense to dense, silty, fine to medium SAND with minor, fine gravel. Aeolian/Alluvium??
1.00	Beige brown, dense to very dense, poorly calcretised(cemented), silty, fine SAND with occasional quartzitic sandstone gravel. Pedocrete.
1.76	Grey, slightly to unweathered, very closely to widely jointed, but mainly medium to widely jointed, very hard rock to extremely hard rock, Quartzite. Gariep Supergroup. Joints: Subvertical and subhorizontal(bedding dip 47°), smooth undulating, smooth stepped and irregular, narrow to wide, occasionally clayey, sand infill and iron-stained.
5.23	Grey, slightly to unweathered, very closely to medium jointed, but mainly closely jointed, very hard rock to extremely hard rock, Quartzite. Joints: Subvertical and subhorizontal(bedding dip 60°), smooth planar, undulating and irregular, narrow to wide, some clayey infill(5-15mm), iron-stained and calcite <1mm.
7.46	Grey, slightly to unweathered, very closely to widely jointed, but mainly medium jointed, very hard rock to extremely hard rock, Quartzite. Joints: Subvertical and subhorizontal, smooth planar, narrow, iron-stained.
8.22	Grey, slightly to unweathered, very closely to closely jointed, very hard rock to extremely hard rock, Quartzite. Joints: Subvertical and subhorizontal(steep dipping 75°), smooth planar, narrow, iron-stained and calcite powder<1mm.
8.99	

Drill Run (m)	*Drilling method*	*% Core Recov*	*SPT N-Value*	*% RQD*	*FF / (m)*
12.09	TNW	100		56	11
12.89	TNW	100		58	
13.34	TNW	96		0	
13.54	TNW	100		50	7
14.29	TNW	85		68	
14.72	TNW	100		91	>20
15.34	TNW	97		68	7
16.17	TNW	90		35	
16.84	TNW	100		100	
17.34	TNW	90		80	
18.24	TNW	91		80	
18.99	TNW	100		21	15
19.24	TNW	100		0	
20.00	TNW	100		38	



Grey blotched reddish brown, unweathered, closely to widely jointed, but mainly medium jointed, very hard rock to extremely hard rock, Quartzite.

Joints: Subvertical, smooth planar, undulating, narrow, iron-stained. Calcite <1mm and occasional clayey infill.

Grey blotched purplish red, slightly to unweathered, very closely to widely jointed, but mainly closely to medium jointed, (drilling fractured at 14.58-14.74m), very hard rock to extremely hard rock, Quartzite.

Joints: Subvertical and subhorizontal, smooth and rough planar, irregular, narrow to occasionally wide, clayey infill(<10mm), iron-stained.

Grey blotched purplish red, unweathered, closely to widely jointed, but mainly medium jointed, very hard rock to extremely hard rock, Quartzite.

Joints: Subvertical and subhorizontal, smooth and rough planar, undulating, narrow to medium, calcite <2mm and iron-stained.

Grey blotched purplish red, slightly to unweathered, very closely to medium jointed, but mainly closely jointed, very hard rock to extremely hard rock, Quartzite.

Joints: Subvertical and subhorizontal, rough planar, undulating and irregular, narrow to wide with occasional quartz gravel and clayey infill and iron-stained.

Brown, highly weathered, closely jointed, medium hard rock, Quartz Schist. Gariep Supergroup.

End of Borehole.

NOTES

1) S6 sample taken at 11.02--11.13m.

2) S11 sample taken at 11.39--11.74m.

3) S12 sample taken at 16.48--16.84m.

4) Piezometer Installed to 20.00m.

CONTRACTOR : Geomechanics CC
MACHINE : YWE D90R
DRILLED BY : ELIJA
PROFILED BY : PRIN

TYPE SET BY : LP
SETUP FILE : BH1PG-A4.SET

INCLINATION : Vertical
DIAM : 91 - 76mm
DATE : 13-04-2018
DATE : 19-04-2018

DATE : 13/06/2018 15:56
TEXT : ..oegoeBaaiDotplotsNew.txt

ELEVATION : WGS 84
X-COORD : 3182859
Y-COORD : 0042697

HOLE No: VBH2

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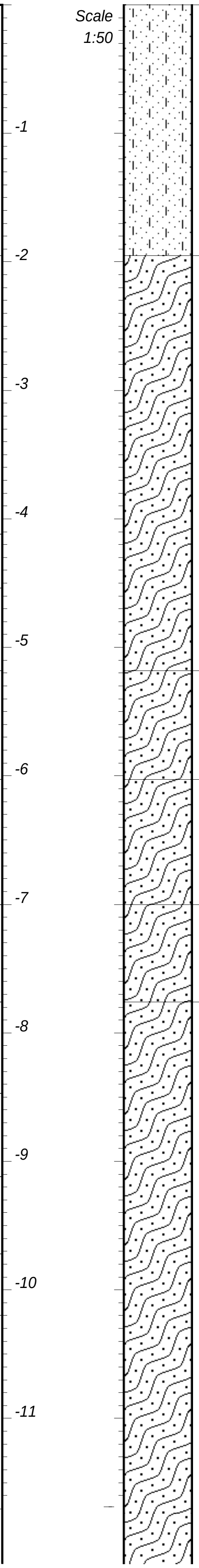
GEOTECHNICAL INVESTIGATION

HOLE No: **VBH3**
Sheet 1 of 2

JOB NUMBER: 526679

Drill Run (m)	*Drilling method*	*% Core Recov*	*SPT N-Value*	*% RQD*	*FF / (m)*
0.76	NXC	70		0	
1.50	NXC	54		0	
1.95	SPT	100	29	0	
3.00	NWD4	38		0	5
3.52	NWD4	100		19	
4.12	NWD4	83		20	
4.54	NWD4	100		69	10
4.86	TNW	100		31	17
5.18	TNW	94		0	
5.62	TNW	100		100	5
6.22	TNW	93		63	
6.92	TNW	97		20	11
7.37	TNW	100		51	5
7.89	TNW	100		52	
8.09	TNW	100		0	10
8.47	TNW	100		32	
8.77	TNW	100		0	6
9.27	TNW	100		66	
9.57	TNW	100		50	13
10.20	TNW	100		35	8
10.78	TNW	93		81	8
11.04	TNW	100		46	
11.56	TNW	100		38	



0.00

Brown, medium dense, silty, fine to medium SAND with minor, fine gravel. Aeolian/Alluvium??

1.95

Dark grey and light grey, unweathered, very closely to medium jointed, but closely jointed, occasionally very thinly spaced healed fractures(some drilling induced fractures), very hard rock, Quartzite with occasional quartz veins. Gariep Supergroup.

Joints: Subvertical and subhorizontal, smooth undulating, smooth stepped, narrow to medium, clayey, sand infill <5mm.

5.18

Dark grey, unweathered, closely to medium jointed, very hard rock, Quartzite with a quartz veins(<5mm) before 5.62m.

Joints: Subvertical and subhorizontal, smooth planar and undulating, narrow to medium, clayey and iron-stained.

6.03

Dark grey and light grey, unweathered, very closely to medium jointed, but closely jointed, occasionally very thinly spaced healed fractures(some drilling induced fractures), very hard rock, Quartzite.

Joints: Subvertical and subhorizontal, smooth undulating, smooth stepped, narrow to medium, clayey, sand infill <5mm.

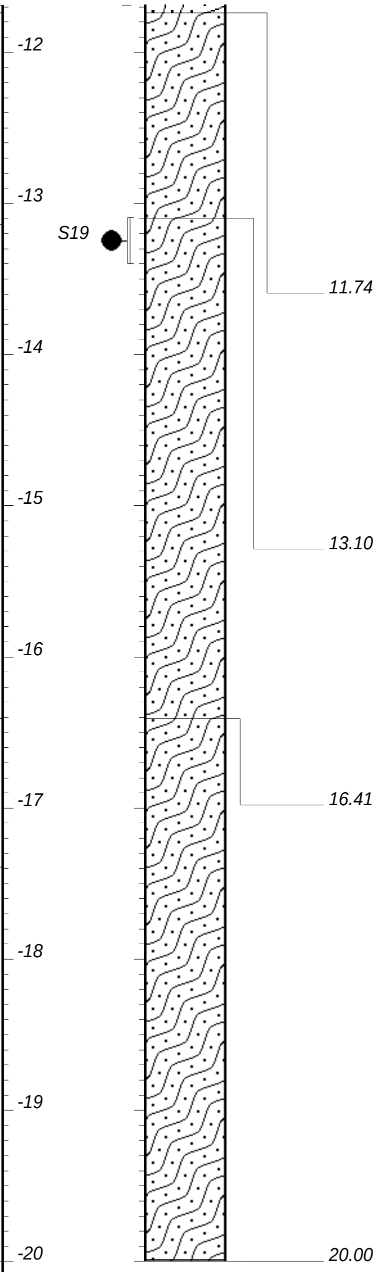
7.00

Dark grey and reddish brown, stained, slightly weathered to unweathered, medium jointed, some healed fractures, very hard rock, Quartzite with a quartz vein between 7.29 - 7.39m.

Joints: Subvertical, rough, undulating, narrow, iron-stained.

7.76

Drill Run (m)	Drilling method	% Core Recov	SPT N-Value	% RQD	FF / (m)
11.74	TNW	100		100	
12.39	TNW	100		0	18
12.74	TNW	100		0	
13.04	TNW	100		0	
13.89	TNW	98		72	4
14.22	TNW	100		100	
15.39	TNW	91		76	
15.89	TNW	100		100	
16.08	TNW	100		74	
16.41	TNW	97		91	
16.84	TNW	100		47	8
17.39	TNW	100		56	
17.92	TNW	98		98	3
18.75	TNW	100		92	
20.00	TNW	94		94	



Dark grey and light grey blotched reddish brown, unweathered, very closely to medium jointed (drilling induced fractures at end of runs), very hard rock, Quartzite with some healed fractures.

Joints: Subvertical, planar, smooth, narrow, occasionally iron-stained and a 15mm calcite vein at 11.74m.

Dark grey and light grey, slightly to unweathered, very closely to closely jointed, highly fractured (drilling??), hard rock to very hard rock, Quartzite with occasional quartz veins and abundant healed fractures,

Joints: Subhorizontal and subvertical, planar, smooth, narrow to medium, calcite <10mm, iron-stained.

Dark grey and light grey blotched reddish brown, unweathered, very closely to widely jointed, but mainly medium jointed, very hard rock, Quartzite with some healed fractures and occasional quartz vein.

Joints: Subvertical and subhorizontal, planar, smooth, smooth stepped and undulating, narrow, iron-stained.

Dark grey and light grey becoming blotched reddish brown, slightly weathered to unweathered, very closely to widely jointed, but mainly medium jointed, very hard rock, Quartzite with abundant healed fractures. Gariep Supergroup.

Joints: Subvertical and subhorizontal, planar, smooth, smooth stepped and undulating, narrow to medium, clay infill <5mm at 16.84m, calcite <1mm and iron-stained.

End of Borehole.

NOTES

1) S19 sample taken at 13.09--13.40m.

2) Piezometer Installed to 20.00m.

CONTRACTOR : Geomechanics CC
MACHINE : YWE D90R
DRILLED BY : ELIJA
PROFILED BY : PRIN

INCLINATION : Vertical
DIAM : 91 - 76mm
DATE : 19-04-2018
DATE : 23-04-2018

ELEVATION : WGS 84
X-COORD : 3182822
Y-COORD : 0042769

HOLE No: VBH3

TYPE SET BY : LP
SETUP FILE : BH1PG-A4.SET

DATE : 13/06/2018 15:56
TEXT : ..oegoeBaaiDotplotsNew.txt

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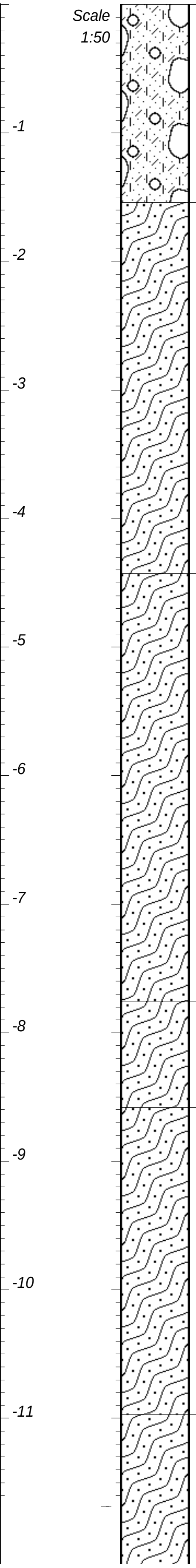
GEOTECHNICAL INVESTIGATION

HOLE No: **VBH4**
Sheet 1 of 2

JOB NUMBER: **526679**

Drill Run (m)	Drilling method	% Core Recov	SPT N-Value	% RQD	FF / (m)
0.57	NXC	56		0	>20
1.14	NXC	88		0	
1.50	NXC	100		0	
1.54	SPT	100	Ref	0	14
1.91	NWD4	100		0	
2.48	NWD4	93		56	5
3.22	TNW	100		86	
4.75	TNW	100		58	
5.83	TNW	93		41	11
6.26	TNW	100		30	
7.21	TNW	95		45	
7.76	TNW	69		0	
8.41	TNW	98		62	12
9.22	TNW	100		78	3
9.65	TNW	88		58	
9.77	TNW	100		0	
10.47	TNW	94		63	
11.33	TNW	85		67	
11.80	TNW	96		83	7



0.00

Beige orange brown, medium dense to dense, poorly calcretised, clayey, silty, fine to medium SAND with some quartzite cobbles and abundant fine gravel. Transported?

1.54

Grey stained brown, slightly to moderately weathered, very closely to widely jointed, but mainly medium to widely jointed(intensely healed fractured), very hard rock, Quartzite. Gariep Supergroup.

Joints: Subvertical and subhorizontal(bedding dip 40°)(Joints 68°-78°), smooth undulating and planar, rough stepped, narrow to wide, clayey, sand infill <10mm, iron-stained.

4.43

Greyish and orange brown, moderately to highly weathered, very closely to medium jointed(intensely healed fractured and mostly drilling fractured), very hard rock, Quartzite with some quartz veins.

Joints: Subvertical, smooth stepped, irregular, narrow to medium, iron-stained.

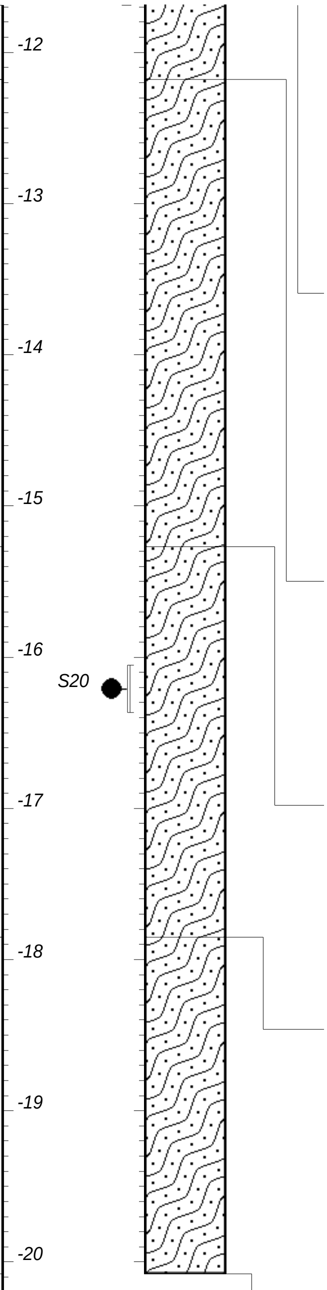
7.76

Light grey blotched orangey and reddish brown, moderately to slightly weathered, very closely to widely jointed, but mainly closely to medium jointed(mostly drilling fractured at end and begining of drill run), very hard rock, Quartzite.

Joints: Subhorizontal and subvertical, rough planar, undulating and stepped, narrow to medium, clayey infill <5mm, iron-stained.

8.58

Drill Run (m)	Drilling method	% Core Recov	SPT N-Value	% RQD	FF / (m)
12.18	TNW	100		0	
12.58	TNW	100		95	3
13.76	TNW	99		98	
14.13	TNW	100		100	
14.61	TNW	94		56	
14.91	NWD4	100		100	
15.11	TNW	100		100	
15.86	TNW	100		73	6
16.37	TNW	100		78	
16.75	TNW	100		97	
17.70	TNW	92		25	
17.85	NWD4	100		67	
18.78	TNW	100		87	4
18.89	TNW	100		0	
19.68	TNW	100		85	
19.77	TNW	100		0	
20.08	TNW	100		71	



Grey blotched reddish brown, slightly weathered to unweathered, very closely to widely jointed, but mainly medium to widely jointed, occasional healed joints, very hard rock, Quartzite.

Joints: Subvertical(mainly) and subhorizontal, smooth undulating, occasionally smooth planar, narrow to medium <5mm, clayey, sand infill at base, iron-stained.

10.97

Reddish brown blotched grey, slightly weathered to unweathered, very closely to medium jointed, but mainly closely jointed, occasional healed joints(drilling fractured at end of drill run), very hard rock, Quartzite.

Joints: Subvertical and subhorizontal, smooth planar and rough irregular, narrow to medium <5mm, clayey, sand and kaolinised, iron-stained.

12.18

Grey occasionally blotched reddish brown, slightly weathered to unweathered, closely to widely jointed, but mainly medium jointed, very hard rock, Quartzite.

Joints: Subvertical and subhorizontal, smooth undulating, narrow, iron-stained.

15.27

Reddish brown blotched grey, slightly weathered to unweathered, very closely to medium jointed, but mainly medium jointed, very hard rock, Quartzite.

Joints: Subhorizontal and subvertical, smooth planar, narrow to medium, clayey infill at 15.80m, iron-stained.

17.85

Grey becoming reddish brown from 18.78m, unweathered to slightly weathered, closely to widely jointed, but mainly medium jointed(intense healed fractures below 18.78m), very hard rock, Quartzite occasionally pitted. Gariep Supergroup.

Joints: Subvertical, smooth undulating, planar, narrow, kaolinised and iron-stained.

20.08

End of Borehole.

NOTES

1) S20 sample taken at 16.05--16.37m.

2) Piezometer Installed to 20.08m.

CONTRACTOR : Geomechanics CC
MACHINE : YWE D90R
DRILLED BY : ELIJA
PROFILED BY : PRIN

TYPE SET BY : LP
SETUP FILE : BH1PG-A4.SET

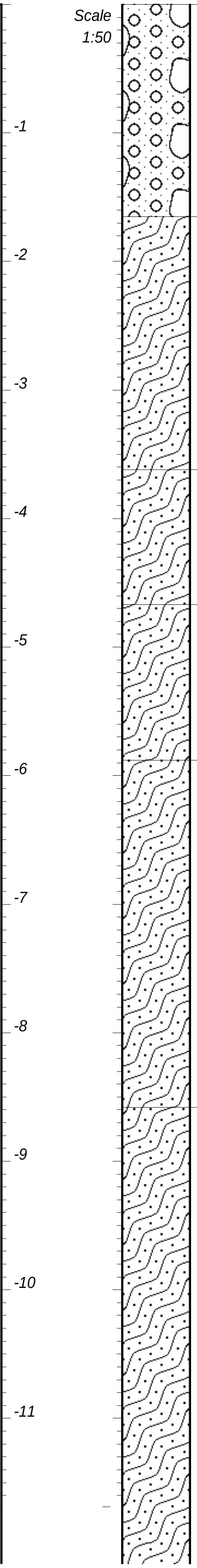
INCLINATION : Vertical
DIAM : 91 - 76mm
DATE : 20-04-2018
DATE : 04-05-2018

DATE : 13/06/2018 15:56
TEXT : ..oegoeBaaiDotplotsNew.txt

ELEVATION : WGS 84
X-COORD : 3182787
Y-COORD : 0042692

HOLE No: **VBH4**

Drill Run (m)	*Drilling method*	*% Core Recov*	*SPT N-Value*	*% RQD*	*FF / (m)*
0.76	NXC	62		0	>20
1.50	NXC	76		0	
2.07	NWD4	91		61	4
2.63	TNW	100		100	
3.74	TNW	100		87	>20
4.44	TNW	100		60	3 13
4.67	TNW	100		0	
5.21	TNW	76		39	3
5.59	TNW	100		100	
6.02	TNW	100		67	8
6.99	TNW	100		68	10
7.68	TNW	100		67	
8.58	TNW	100		40	
9.10	TNW	100		98	
10.28	TNW	100		86	
11.80	TNW	100		96	



0.00

Greyish and brown stained, loosely packed, COBBLES and GRAVEL within a sandy matrix. Matrix washed out. Overall consistency dense. Transported?

1.65

Grey, unweathered to slightly weathered at joints, closely to widely jointed, but mainly medium jointed, very hard rock, Quartzite. Gariep Supergroup.

Joints: Subvertical and subhorizontal, smooth planar and undulating, narrow to medium, clayey infill and iron-stained.

3.62

Light grey, slightly weathered to unweathered, very closely to medium jointed(occasionally intense drilling fractured), very hard rock, Quartzite.

Joints: Subhorizontal and subvertical, smooth planar, narrow, slightly clean and iron-stained.

4.67

Dark grey blotched reddish brown, unweathered, closely to widely jointed(occasional healed joints), very hard rock, Quartzite.

Joints: Subvertical and subhorizontal, smooth planar, undulating, narrow, slightly iron-stained.

5.88

Dark grey and reddish brown, unweathered, very closely to medium jointed, but mainly medium jointed(occasional drilling fractured), very hard rock, Quartzite with a quartz vein between 8.06-8.24m.

Joints: Subhorizontal, smooth planar, undulating, irregular, narrow, iron-stained.

8.58

Dark grey blotched reddish brown on joints, slightly weathered to unweathered, very closely to widely jointed, but mainly medium jointed, very hard rock, Quartzite.

Joints: Bedding subvertical and subhorizontal, smooth planar and rough, narrow to medium, clayey <5mm and iron-stained.

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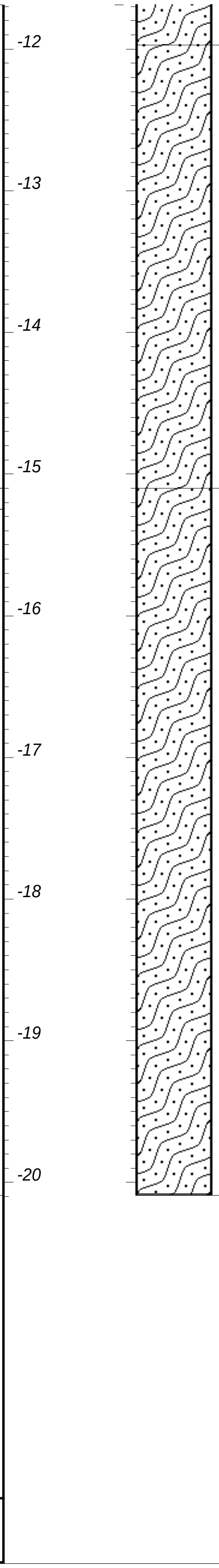
HOLE No: **VBH5**
Sheet 2 of 2

JOB NUMBER: 526679

Drill Run (m)	Drilling method	% Core Recov	SPT N-Value	% RQD	FF / (m)
13.10	TNW	100		98	3
14.57	TNW	100		99	
15.95	TNW	100		79	13
16.39	TNW	91		89	
17.83	TNW	100		82	4
19.00	TNW	100		86	
19.27	TNW	100		74	
19.72	TNW	100		82	
20.09	TNW	100		81	



11.97

Reddish brown blotched grey becoming light grey, unweathered, closely to widely jointed, but mainly medium jointed, very hard rock, Quartzite.

Joints: Subhorizontal and subvertical, smooth planar, undulating, narrow, calcite <1mm and iron-stained.

15.10

Reddish brown blotched light grey, slightly weathered to unweathered, very closely to widely jointed, but mainly medium jointed(occasional drilling fractures), very hard rock, Quartzite with intensly healed fractures and quartz veining between 17.47-19.00m. Gariep Supergroup.

Joints: Bedding subvertical(steep dipping 62-72) and subhorizontal, smooth planar, undulating, narrow to medium, iron-stained.

20.09

End of Borehole.

NOTES

1) Piezometer Installed to 20.09m.

CONTRACTOR : Geomechanics CC
MACHINE : YWE D90R
DRILLED BY : ELIJA
PROFILED BY : PRIN

TYPE SET BY : LP
SETUP FILE : BH1PG-A4.SET

INCLINATION : Vertical
DIAM : 91 - 76mm
DATE : 24-04-2018
DATE : 07-05-2018

DATE : 13/06/2018 15:56
TEXT : ..oegoeBaaiDotplotsNew.txt

ELEVATION : WGS 84
X-COORD : 3182641
Y-COORD : 0042721

HOLE No: **VBH5**

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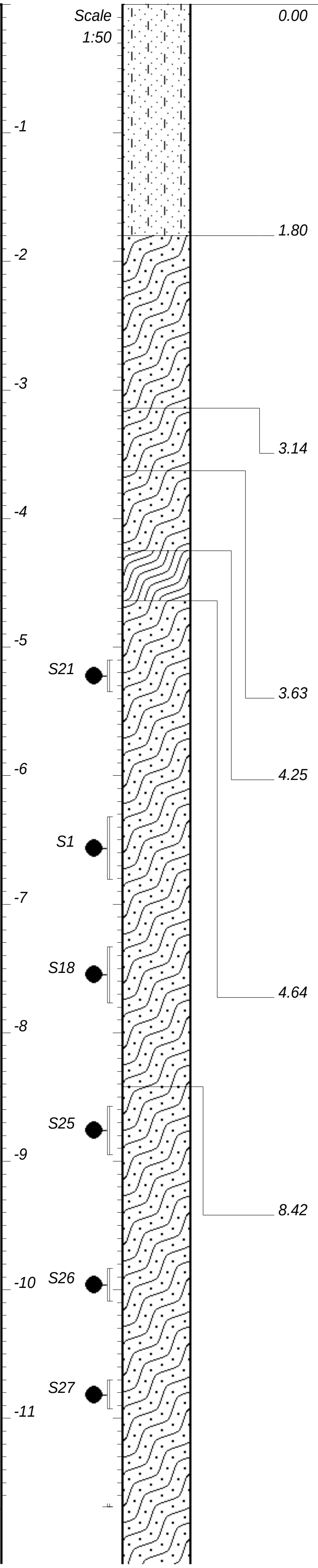
BOEGOE BAAI - ALEXKOR
GEOTECHNICAL INVESTIGATION

HOLE No: VBH6
Sheet 1 of 2

JOB NUMBER: 526679

Drill Run (m)	*Drilling method*	*% Core Recov*	*SPT N-Value*	*% RQD*	*FF / (m)*
0.90	NXC	100		0	
1.50	NXC	83		0	
1.70	SPT	100	Ref	0	
2.84	NWD4	87		48	4
3.14	TNW	100		93	
3.95	TNW	100		41	16
4.86	TNW	100		69	3 15
6.32	TNW	100		85	4
7.82	TNW	99		89	
8.38	TNW	95		79	
8.42	TNW	100		0	
9.29	TNW	97		68	5
10.70	TNW	100		88	
11.27	TNW	96		42	



Beige brown, medium dense to dense becoming very dense, silty, fine to coarse, gritty SAND. Reworked/Alluvium.

Light greyish and brown, slightly to unweathered, closely to medium jointed, very hard rock, Quartzite. Gariep Supergroup.

Joints: Subhorizontal and subvertical (steeply dipping 14°), smooth planar and undulating, narrow to very wide, calcretize sand and gravel infill <15mm.

Grey and light, slightly weathered, vey closely to closely jointed, intensly drilling fractured, slightly laminated, hard rock, Quartzite interbedded Quart Schist.

Joints: Subhorizontal and subvertical, smooth undulating, curved, narrow to medium clayey sand infill.

Orangey brown blotched grey, slightly to unweathered, medium jointed, very hard rock, Quartzite.

Cream and light grey, slightly weathered, very closely to medium jointed, very thinly to thinly laminated, medium hard rock to hard rock, Quartz Schist with a calcrete shear of 0,05m at 4,25m depth.

Joints: Subhorizontal, smooth undulating, curved, narrow to medium, clayey infill.

Dark grey blotched orangey brown, unweathered, medium jointed, very hard rock, Quartzite with two sheared contacts and occasional quartz veins.

Joints: Subhorizontal and subvertical (steeply dipping 14°), planar, smooth undulating, narrow, calcite infill <1mm.

Light grey blotched orange brown, unweathered, closely to widely jointed, but mainly medium jointed, (some healed fractures), very hard rock, Quartzite with some lenses of quartz veins.

Joints: Subhorizontal and subvertical (steeply dipping 14°), planar, smooth undulating, narrow, clean.

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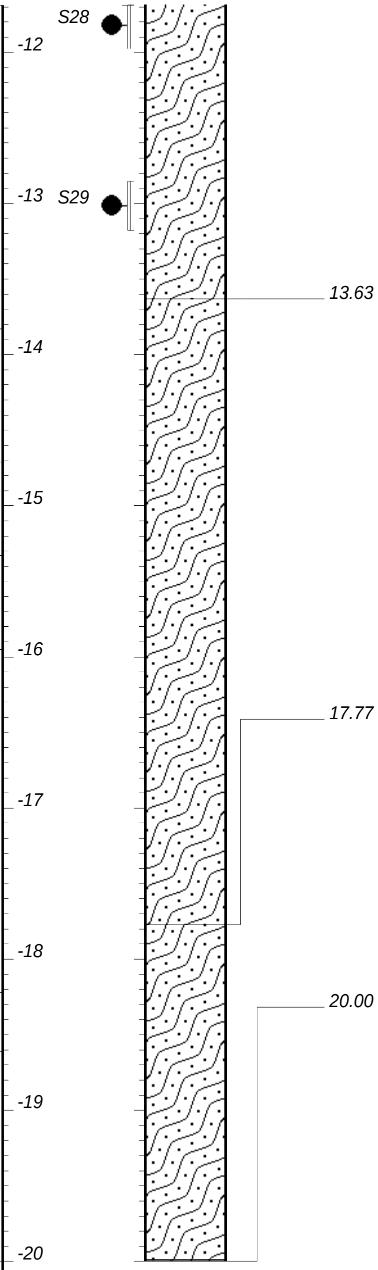
GEOTECHNICAL INVESTIGATION

HOLE No: **VBH6**
Sheet 2 of 2

JOB NUMBER: **526679**

Drill Run (m)	Drilling method	% Core Recov	SPT N-Value	% RQD	FF / (m)
12.30	TNW	100		100	
13.18	TNW	90		90	
13.83	TNW	100		97	
14.71	TNW	67		33	3
15.33	TNW	100		90	3
15.95	TNW	61		19	6
16.39	TNW	100		89	5
17.42	TNW	87		74	
18.05	TNW	90		89	
18.61	TNW	79		29	>20
18.74	TNW	92		92	6
20.00	TNW	95		66	



Dark and light grey blotched orangey brown, unweathered, very closely to widely jointed, but mainly medium jointed (some drilling induced fractures), very hard rock, Quartzite with some quartz veins and healed fractures.

Joints: Subhorizontal and subvertical (steeply dipping), planar, smooth undulating, curved, narrow, calcite <1mm infill.

Light grey and off-white blotched orangey brown, unweathered, medium jointed (some drilling induced fractures 18,22-18,61m), very hard rock, Quartzite some vertical healed fractures.Gariep Supergroup.

Joints: Subhorizontal and subvertical (steep dipping), planar, smooth undulating, curved, narrow, calcite <1mm infill.

End of Borehole.

NOTES

1) S21 sample taken at 5.10--5.35m.

2) S1 sample taken at 6.32--6.81m.

3) S18 sample taken at 7.33--7.77m.

4) S25 sample taken at 8.57--8.95m.

5) S26 sample taken at 9.83--10.09m.

6) S27 sample taken at 10.70--10.93m.

7) S28 sample taken at 11.66--11.98m.

8) S29 sample taken at 12.85--13.18m.

9) Piezometer Installed to 20.00m.

CONTRACTOR : Geomechanics CC
MACHINE : YWE D90R
DRILLED BY : ELIJA
PROFILED BY : PRIN

INCLINATION : Vertical
DIAM : 91 - 76mm
DATE : 15-05-2018
DATE : 17-05-2018

ELEVATION : WGS 84
X-COORD : 3183938
Y-COORD : 0041531

HOLE No: **VBH6**

TYPE SET BY : LP
SETUP FILE : BH1PG-A4.SET

DATE : 13/06/2018 15:56
TEXT : ..oegoeBaaiDotplotsNew.txt

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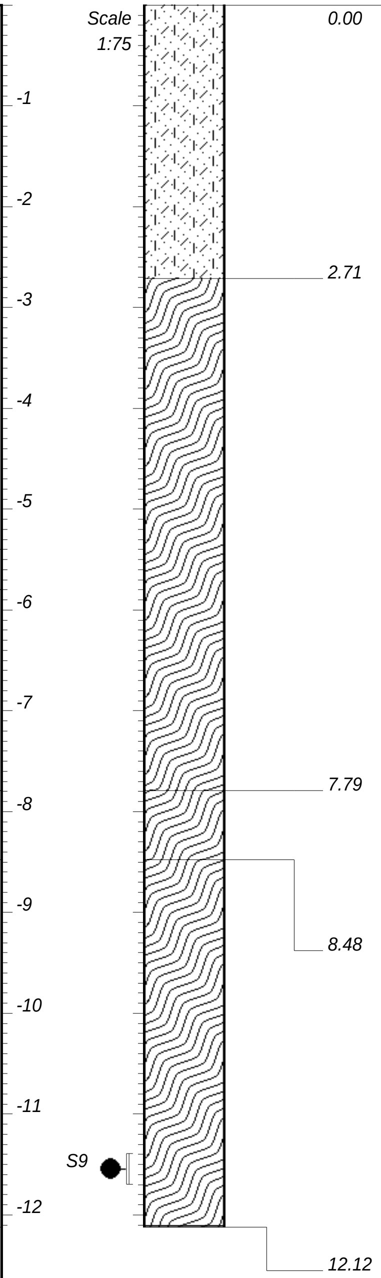
BOEGOE BAAI - ALEXKOR
GEOTECHNICAL INVESTIGATION

HOLE No: IBH1A
Sheet 1 of 1

JOB NUMBER: 526679

Drill Run (m)	*Drilling method*	*% Core Recov*	*SPT N-Value*	*% RQD*	*FF / (m)*
0.90	NXC	62		0	
1.50	NXC	67		0	>20
3.00	NWD4	23		7	
4.50	NWD4	97		46	8
6.00	NWD4	100		55	3
7.50	NWD4	70		23	7
8.48	NWD4	100		0	0
9.12	NWD4	94		45	
10.62	NWD4	98		66	5
12.12	NWD4	100		83	



Beige brown, <u>medium dense</u>, poorly calcretised, clayey, silty, fine to medium SAND withsome subrounded and subangular, fine to coarse gravel, some very fine shell fragments. Sandy core loss at 1.15m. Aeolian/Reworked?

Olive green layered grey and orange brown, highly weathered to moderately weathered, very closely to widely jointed, but mainly closely to medium jointed, very thinly to thinly laminated, <u>very soft rock to soft rock</u> with some lenses quartzite. Quartz Schist. Gariep Supergroup.

Joints: Subhorizontal, planar, smooth, undulating and curved, narrow to wide, clayey and iron-stained.

Olive green speckled orange brown, highly weathered to completely weathered, very closely to closely jointed, very thinly laminated, <u>very soft rock to soft rock</u>, Quartz Schist.

Olive green layered orange brown, highly weathered, very closely to widely jointed, but mainly closely to medium jointed, very thinly laminated, <u>very soft rock to soft rock</u> with a 5mm quartz vein at 10.82m. Quartz Schist. Gariep Supergroup.

Joints: Subhorizontal and subvertical, planar, smooth, undulating and curved, narrow, iron-stained.

End of Borehole.

NOTES

1) S9 sample taken at 11.39--11.70m.

CONTRACTOR : Geomechanics CC
MACHINE : YWE D90R
DRILLED BY : ELIJA
PROFILED BY : PRIN

TYPE SET BY : LP
SETUP FILE : BH1PG-A4.SET

INCLINATION : INCLINE 60°
DIAM : 91 - 76mm
DATE : 04-05-2018
DATE : 07-05-2018

DATE : 13/06/2018 15:56
TEXT : ..oegoeBaaiDotplotsNew.txt

ELEVATION : WGS 84
X-COORD : 3182764
Y-COORD : 0042662

HOLE No: IBH1A

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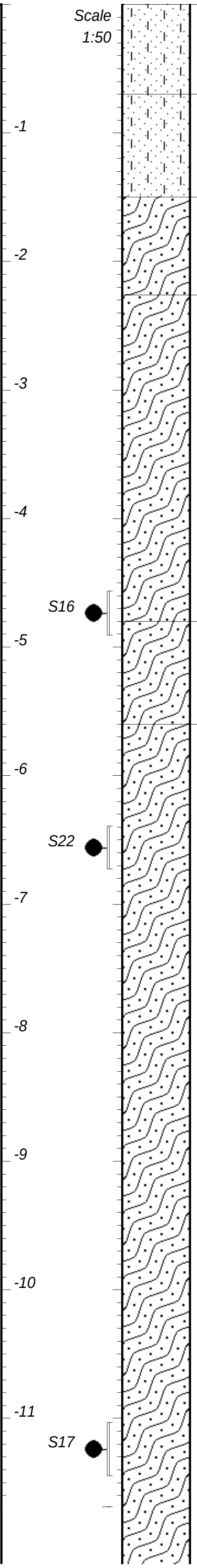
GEOTECHNICAL INVESTIGATION

HOLE No: IBH3A
Sheet 1 of 2

JOB NUMBER: 526679

Drill Run (m)	Drilling method	% Core Recov	SPT N-Value	% RQD	FF / (m)
0.90	NXC	89		0	
1.50	NXC	83		0	
2.61	NWD4	92		68	7
2.70	TNW	100		0	
3.01	TNW	100		94	2
3.52	TNW	100		100	
4.00	TNW	98		48	7
4.56	TNW	88		52	
5.05	TNW	100		71	
6.01	TNW	84		72	
7.54	TNW	93		73	4
8.60	TNW	100		96	
9.03	TNW	100		93	
9.73	TNW	100		73	
10.53	TNW	95		93	
11.03	TNW	100		94	
11.55	TNW	100		88	



0.00	Brown, medium dense to dense, silty, fine to medium SAND. Aeolian? Reworked.
0.70	Beige brown, dense, poorly calcretized, silty, fine to coarse SAND with calcretized nodules. Pedocrete?
1.50	Off-white, slightly weathered to unweathered, closely to medium jointed, hard rock to very hard rock, Quartzite. Gariep Supergroup. Joints: Steep subvertical and subhorizontal, smooth planar, undulating and rough irregular, narrow to wide with sand infill <10mm, calcite <10mm.
2.26	Brown streaked (blotched) grey, unweathered, closely to medium jointed, hard rock to very hard rock, Quartzite. Joints: Steep subvertical and subhorizontal, planar, smooth undulating, narrow to medium, kaolinized infill <1mm.
4.80	As above but medium jointed. Quartzite.
5.60	Light brown blotched light grey, unweathered, closely to widely jointed but mainly medium jointed, very hard rock, Quartzite with some off-white thinly laminated healed fractures. Joints: Subhorizontal and steep dipping 14° subvertical, smooth undulating, narrow and medium, occasional kaolinized infill <3mm infill, occasional iron-stained.
12.36	

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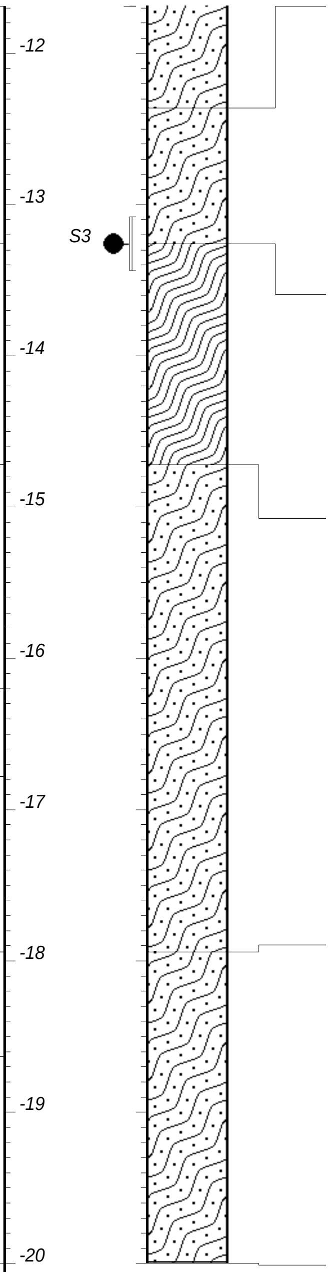
GEOTECHNICAL INVESTIGATION

HOLE No: IBH3A
Sheet 2 of 2

JOB NUMBER: 526679

Drill Run (m)	Drilling method	% Core Recov	SPT N-Value	% RQD	FF / (m)
12.04	TNW	100		98	
13.00	TNW	84		72	
13.54	TNW	100		78	
15.04	TNW	33		20	2
15.68	TNW	92		59	3
16.20	TNW	100		60	
16.78	TNW	91		26	10
17.94	TNW	47		22	2
18.80	TNW	93		60	1
20.00	TNW	42		8	4



12.36

Grey and off-white (light grey), unweathered, closely jointed but mainly to widely jointed, very hard rock, Quartzite.

Joints: Subhorizontal and steep dipping 14° subvertical, smooth undulating, narrow and medium, occasional kaolinized infill.

13.26

Light grey, unweathered, very closely to closely jointed, (very thinly laminated), medium hard rock to hard rock, Quartz Schist - Noticeable void of 1,00m.

Joints: Subhorizontal, smooth planar, narrow, kaolinized stained.

14.72

Grey streaked dark grey blotched brown, unweathered, very closely to medium jointed, intensively drilling fractured at end of runs, very hard rock, Quartzite.

Joints: Subhorizontal and steeply dipping 14° subvertical, planar, smooth undulating, narrow, occasional calcite <1mm and iron-stained.

17.94

Light grey and light brown, unweathered, very closely to medium jointed, mainly closely fractured because of drilling fractured, hard rock to very hard rock, Quartzite with a shear zone at 18,38m. Gariep Supergroup.

Joints: Subvertical and subhorizontal, smooth undulating, planar, narrow to widely, clay infill sheared zone.

20.00

End of Borehole.

NOTES

1) S16 sample taken at 4.56--4.91m.

2) S22 sample taken at 6.39--6.73m.

3) S17 sample taken at 11.03--11.45m.

4) S3 sample taken at 13.08--13.44m.

5) Standpipe Installed.

CONTRACTOR : Geomechanics CC
MACHINE : YWE D90R
DRILLED BY : ELIJA
PROFILED BY : PRIN

INCLINATION : INCLINE 60°
DIAM : 91 - 76mm
DATE : 07-05-2018
DATE : 10-05-2018

ELEVATION : WGS 84
X-COORD : 3184054
Y-COORD : 0041594

HOLE No: IBH3A

TYPE SET BY : LP
SETUP FILE : BH1PG-A4.SET

DATE : 13/06/2018 15:56
TEXT : ..oegoeBaaiDotplotsNew.txt

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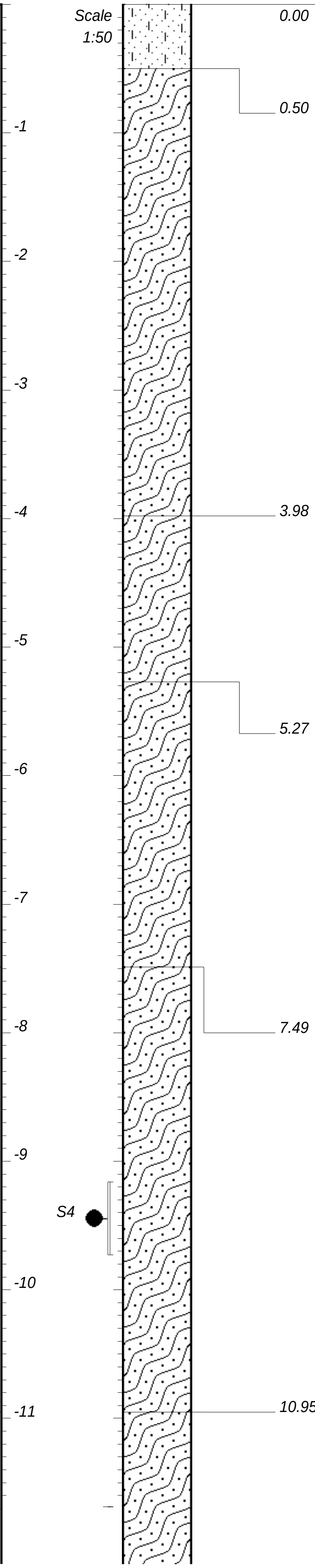
BOEGOE BAAI - ALEXKOR
GEOTECHNICAL INVESTIGATION

HOLE No: IBH4A
Sheet 1 of 2

JOB NUMBER: 526679

Drill Run (m)	*Drilling method*	*% Core Recov*	*SPT N-Value*	*% RQD*	*FF / (m)*
0.50	NXC	60		0	
1.00	NXC	50		0	5
1.50	NXC	40		0	
3.00	NWD4	77		32	
3.98	TNW	41		0	
4.49	NWD4	100		65	9
5.24	TNW	73		0	
5.99	NWD4	100		64	9
7.49	NWD4	93		0	14
8.65	NWD4	71		54	5
9.73	TNW	100		62	
10.17	TNW	100		70	
10.89	TNW	100		68	
11.19	TNW	100		53	
11.80	TNW	100		41	



Beige brown, medium dense to dense, silty, fine to coarse SAND with occasional fine gravel. Aeolian? Reworked.

Light brownish grey with occasional very thin grey lenses, slightly weathered to unweathered, very closely to medium jointed (some drilling fractured), hard rock to very hard rock, Quartzite. Gariep Supergroup.

Joints: Subvertical to subhorizontal, smooth planar, smooth stepped and undulating, narrow, slight iron-stained.

Light brownish grey, unweathered, very closely to medium jointed, hard rock to very hard rock, Quartzite with a kaolinized layer between between 4,67 - 4,73m. (Shear???)

Joints: Subvertical to subhorizontal, smooth undulating, narrow to wide, slight iron-stained.

Light grey layered dark grey and light brown, slightly weathered to unweathered, very closely to medium jointed, but mainly closely jointed, (intensly drilling fractured and healed fractures with layers of kaolinized clay) medium hard rock to hard rock occasional very hard rock, Quartzite. Possible Shear Zones???

Joints: Subhorizontal and subvertical, smooth planar, undulating and irregular, narrow to wide, kaolinized clay infilling.

Brown blotched dark grey and dark grey lenses, unweathered, closely to medium jointed, very hard rock, Quartzite with some healed fractures.(some drilling fractures)

Joints: Subvertical, smooth planar, undulating, narrow, clean.

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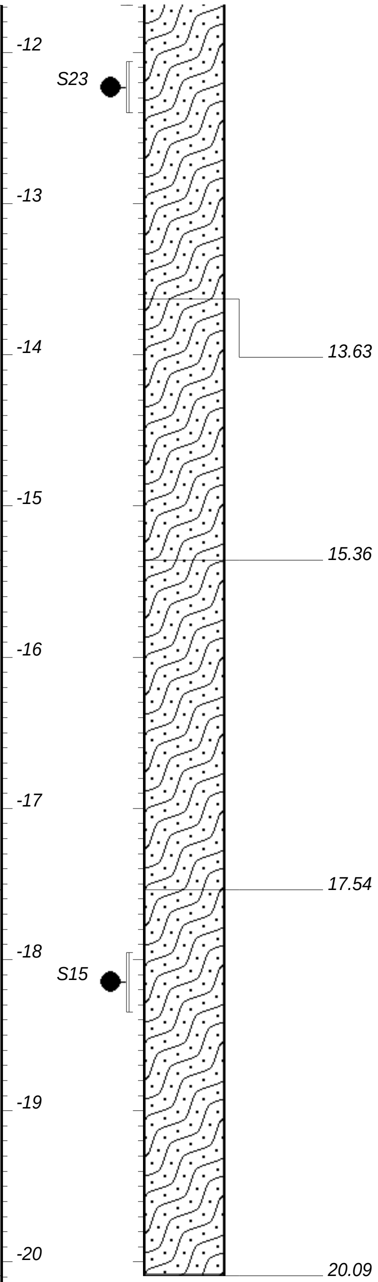
GEOTECHNICAL INVESTIGATION

HOLE No: **IBH4A**
Sheet 2 of 2

JOB NUMBER: 526679

Drill Run (m)	Drilling method	% Core Recov	SPT N-Value	% RQD	FF / (m)
12.06	TNW	100		96	8
12.83	TNW	100		70	14
13.63	TNW	100		46	
14.11	TNW	100		96	9
14.98	TNW	100		47	
15.98	TNW	100		29	16
16.71	TNW	100		0	
16.86	TNW	100		0	
17.19	TNW	100		0	
17.54	TNW	100		0	
18.58	TNW	100		86	5
18.96	TNW	100		45	
19.75	TNW	97		62	
20.09	TNW	100		29	



Grey blotch light brown and light grey, unweathered, very closely jointed to closely jointed, but mainly medium jointed, <u>very hard rock</u>, Quartzite with occasional thinly laminated quartz schist layer at (11,27-11,48m) and two clayey layers at 13,39 and 13,58m.

Joints: Subvertical and subhorizontal, smooth planar, undulating, narrow to medium, kaolinized clay infill.

Light brownish grey, unweathered, closely to medium jointed, <u>very hard rock</u>, Quartzite.

Joints: Subhorizontal, smooth undulatuing, curved, narrow, clean.

Light grey, unweathered to slightly weathered, very closely to closely jointed,(intensively drilling fractured and some intensly very thinly laminated healed fractures), <u>hard rock to very hard rock</u>, Quartzite with occasional quartz veins.

Joints: Subhorizontal, smooth undulating, irregular, narrow, orange brown and kaolinized staining /infill.

Light greyish streaked and brown, unweathered, closely to medium jointed, <u>very hard rock</u>, Quartzite with some healed fractures. Gariep Supergroup.

Joints: Long subvertical and subhorizontal, smooth planar, undulating, narrow to medium, calcite <2mm, occasional iron-stained.

End of Borehole.

NOTES

1) S4 sample taken at 9.16--9.73m.

2) S23 sample taken at 12.06--12.40m.

3) S15 sample taken at 17.95--18.35m.

4) Standpipe Installed.

CONTRACTOR : Geomechanics CC
MACHINE : YWE D90R
DRILLED BY : ELIJA
PROFILED BY : PRIN

INCLINATION : INCLINE 60°
DIAM : 91 - 76mm
DATE : 07-05-2018
DATE : 15-05-2018

ELEVATION : WGS 84
X-COORD : 3184283
Y-COORD : 0041471

HOLE No: **IBH4A**

TYPE SET BY : LP
SETUP FILE : BH1PG-A4.SET

DATE : 13/06/2018 15:56
TEXT : ..oegoeBaaiDotplotsNew.txt

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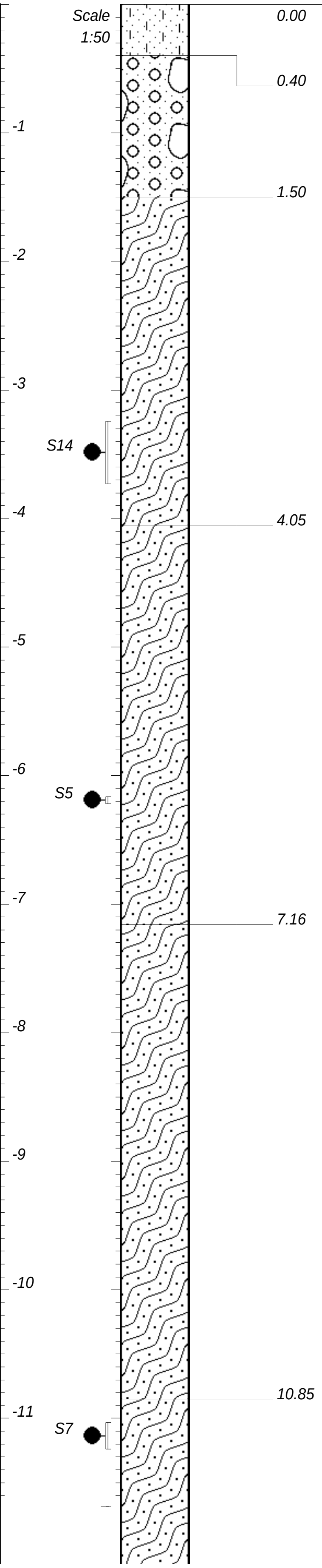
BOEGOE BAAI - ALEXKOR
GEOTECHNICAL INVESTIGATION

HOLE No: IBH5A
Sheet 1 of 2

JOB NUMBER: 526679

Drill Run (m)	*Drilling method*	*% Core Recov*	*SPT N-Value*	*% RQD*	*FF / (m)*
0.90	NXC	92		23	1
1.50	NXC	57		0	
1.96	TNW	100		50	
2.06	TNW	100		0	
2.84	TNW	100		67	6
4.33	TNW	95		22	
5.76	TNW	100		31	5
6.16	TNW	100		60	
7.37	TNW	83		41	
7.84	TNW	100		30	
8.78	TNW	99		99	
9.35	TNW	100		100	4
10.36	TNW	100		61	
11.03	TNW	101		81	
11.74	TNW	100		100	



Brown, <u>medium dense to dense</u>, silty, fine to coarse SAND with occasional gravel. Reworked Aeolian.

Grey and off-white cream, loosely packed, quartzite and calcrete COBBLES and GRAVEl within a silty sandy matrix. Matrix washed out. Reworked Colluvium.

Dark grey, unweathered, closely to widely jointed, but mainly medium jointed, (intensly healed fractures), <u>hard rock to very hard rock</u>, Quartzite with occasional quartz veins. Gariep Supergroup.

Joints: Subhorizontal, smooth undulating, narrow, kaolinized coatings.

As above but closely to medium jointed (very intensely healed fractures), <u>hard rock to very hard rock,</u> Quartzite with abundant quartz veins and drilling fractures at end of zone.

Joints: Subhorizontal and subvertical (steeply dipping 14°), smooth planar and undulating, narrow, calc <2mm and kaolinized coatings.

Dark grey, unweathered, closely to widely jointed but mainly medium jointed, (intensely healed fractures), <u>hard rock to very hard rock</u>, Quartzite with occasional kaolinized sheared zones at (7,48-7,57m) and (9,95-10,04m).

Joints: Subhorizontal, smooth planar and undulating, narrow to wide, kaolinized infill and coatings.

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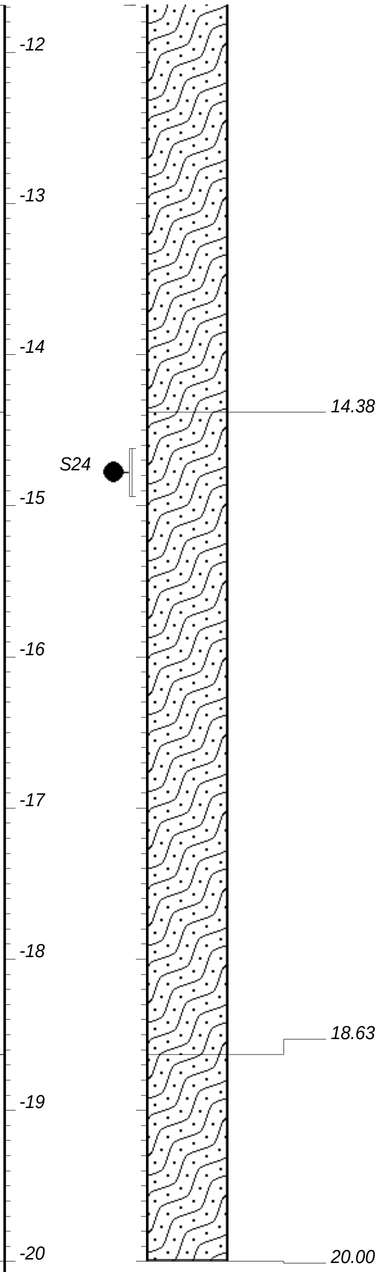
GEOTECHNICAL INVESTIGATION

HOLE No: **IBH5A**
Sheet 2 of 2

JOB NUMBER: **526679**

Drill Run (m)	*Drilling method*	*% Core Recov*	*SPT N-Value*	*% RQD*	*FF / (m)*
11.92	TNW	100		78	5
12.55	TNW	95		0	
13.16	TNW	92		16	
13.72	TNW	82		55	
14.38	TNW	100		77	
15.19	TNW	84		64	2
16.36	TNW	109		100	
17.51	TNW	100		91	
18.96	TNW	100		69	
19.55	TNW	90		58	4
20.00	TNW	100		40	



Dark and light grey, unweathered, closely to medium jointed, <u>hard rock to very hard rock</u>, Quartzite with some quartz veining and a minor sheared lense at (13,94-13,96). Some long healed subvertical fractures.

Joints: Subhorizontal and long subvertical (steeply dipping 11-14°), smooth planar, undulating, narrow to wide, kaolinized infill <5mm and coatings.

Brown and greyt, unweathered, vey closely to widely jointed, but mainly medium to widely jointed, <u>hard rock to very hard rock</u>, Quartzite with som quartz veins and subvertical healed fractures.

Joints: Subhorizontal, smooth undulating, curved, narrow with kaolinized coatings.

Light grey and brown, unweathered, closely to medium jointed, <u>hard rock to very hard rock</u>, Quartzite with occasional quartz veins. Gariep Supergroup.

Joints: Subhorizontal, smooth planar, undulating, narrow to medium with kaolinized infill <2mm.

End of Borehole.

NOTES

1) S14 sample taken at 3.24--3.73m.

2) S5 sample taken at 6.16--6.22m.

3) S7 sample taken at 11.03--11.24m.

4) S24 sample taken at 14.62--14.94m.

5) Standpipe Installed.

CONTRACTOR : Geomechanics CC
MACHINE : YWE D90R
DRILLED BY : ELIJA
PROFILED BY : PRIN

INCLINATION : INCLINE 60°
DIAM : 91 - 76mm
DATE : 11-05-2018
DATE : 15-04-2018

ELEVATION : WGS 84
X-COORD : 3184112
Y-COORD : 0041457

HOLE No: **IBH5A**

TYPE SET BY : LP
SETUP FILE : BH1PG-A4.SET

DATE : 13/06/2018 15:56
TEXT : ..oegoeBaaiDotplotsNew.txt

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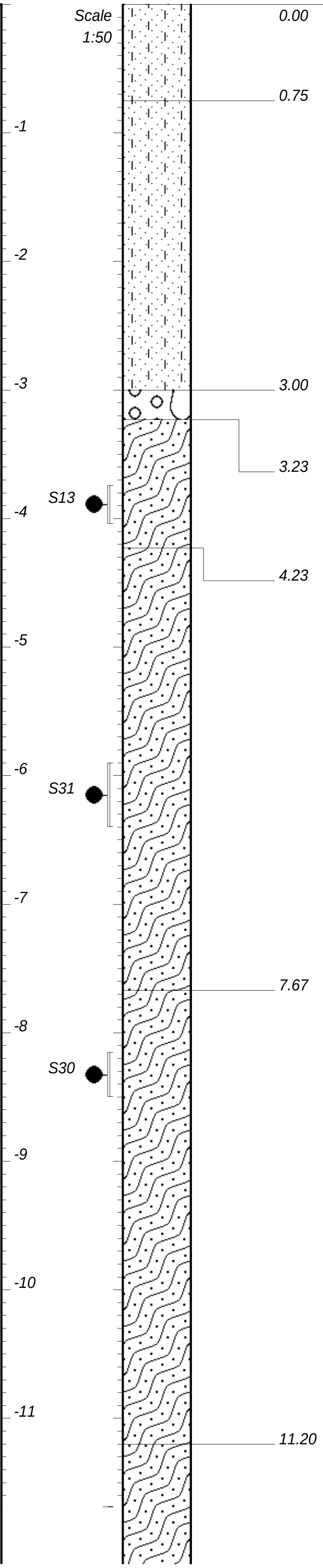
PRDW
BOEGOE BAAI - ALEXKOR
GEOTECHNICAL INVESTIGATION

HOLE No: IBH6A
Sheet 1 of 2

JOB NUMBER: 526679

Drill Run (m)	Drilling method	% Core Recov	SPT N-Value	% RQD	FF / (m)
0.75	NXC	73		0	
1.50	NXC	60		0	
3.00	NWD4	50		0	
4.09	NWD4	89		72	0
4.54	TNW	100		89	4
4.79	TNW	100		0	
5.18	TNW	95		44	
5.90	TNW	100		56	
7.00	TNW	98		68	
7.50	TNW	100		64	
8.50	TNW	100		79	5
9.40	TNW	100		57	
10.35	TNW	99		67	
11.20	TNW	100		31	
12.00	TNW	100		33	



Greyish brown, dense, silty, fine to coarse SAND. Reworked/Aeolian? Alluvium.

Brown, dense, silty, fine to coarse, gritty SAND. Reworked/Alluvium.

Beige brown, very dense, calcretized COBBLE and GRAVELS. Matrix washed out. Pedocrete.

Light grey, unweathered, medium to widely jointed, intense healed fractures, very hard rock, Quartzite with occasional quartz veins. Gariep Supergroup.

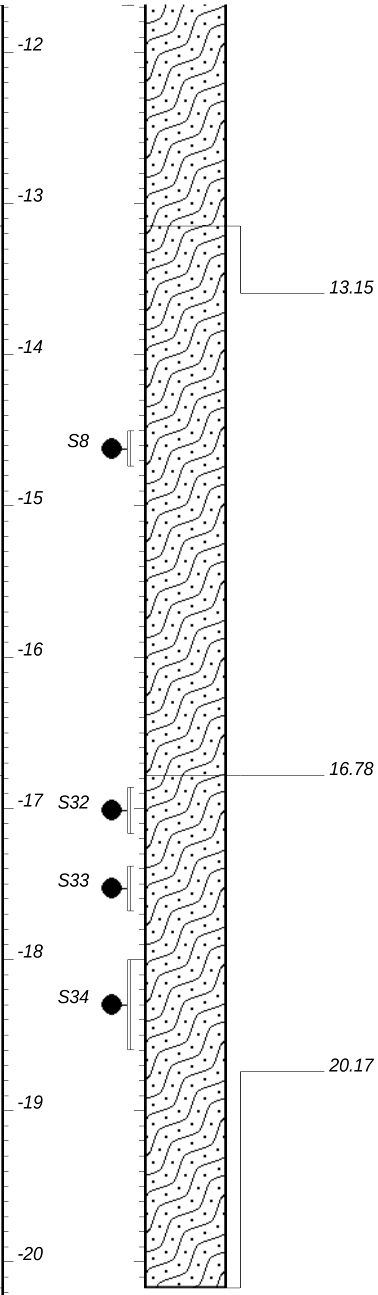
Light brown blotched grey, unweathered, closely to widely jointed, but mainly medium jointed, very hard rock, Quartzite with some healed fractures and quartz veins.

Joints: Subhorizontal and subvertical, smooth planar, rough irregular and curved, narrow to medium, kaolinized infill, calc <1mm.

Light brown blotched and layered grey, unweathered, very closely to medium jointed, but mainly closely to medium jointed, occasional laminated (wavy), intensly healed fractures, very hard rock, Quartzite with abundant quartz veining.

Joints: Subhorizontal, smooth undulating, stepped and irregular, narrow to widely, kaolinized and calcite infill <7mm.

Drill Run (m)	*Drilling method*	*% Core Recov*	*SPT N-Value*	*% RQD*	*FF / (m)*
13.15	TNW	100		73	6
13.95	TNW	100		100	3
14.50	TNW	100		65	
15.23	TNW	100		92	
15.88	TNW	100		68	
16.31	TNW	100		98	
16.86	TNW	100		96	
17.38	TNW	100		58	1
17.68	TNW	100		100	
18.00	TNW	100		100	
18.60	TNW	100		97	
19.23	TNW	100		86	
20.17	TNW	100		100	



Light orangey brown and grey, slightly weathered to unweathered, very closely to widely jointed, but mainly medium jointed, <u>very hard rock</u>, Quartzite with some quartz veins and healed fractures.

Joints: Subhorizontal and subvertical, smooth undulating,stepped and irregular, narrow, kaolinized and iron-stained.

Grey blotched orangey brown, unweathered, medium to widely jointed, <u>very hard rock</u>, Quartzite with some healed fractures and abundant quartz veining.

Joints:Subhorizontal and subvertical, smooth planar, undulating, irregular, narrow, kaolinbized and calcite infill <1mm.

Light grey occasionally blotched brown, unweathered, medium to widely jointed, <u>very hard rock</u>, Quartzite with a minor quartz vein andfine grained healed fracture. Gariep Supergroup.

Joints: Subhorizontal and occasional steep subvertical, smooth planar and undulating, narrow, occasional slight iron-stained.

End of Borehole.

NOTES

1) S13 sample taken at 3.74--4.04m.

2) S31 sample taken at 5.90--6.40m.

3) S30 sample taken at 8.15--8.50m.

4) S8 sample taken at 14.50--14.74m.

5) S32 sample taken at 16.86--17.17m.

6) S33 sample taken at 17.38--17.68m.

7) S34 sample taken at 18.00--18.60m.

8) Standpipe Installed.

CONTRACTOR : Geomechanics CC
MACHINE : YWE D90R
DRILLED BY : ELIJA
PROFILED BY : PRIN

INCLINATION : INCLINE 60°
DIAM : 91 - 76mm
DATE : 11-05-2018
DATE : 16-04-2018

ELEVATION : WGS 84
X-COORD : 3184303
Y-COORD : 0041378

HOLE No: IBH6A

TYPE SET BY : LP
SETUP FILE : BH1PG-A4.SET

DATE : 13/06/2018 15:56
TEXT : ..oegoeBaaiDotplotsNew.txt

BOREHOLE VBH1


START 13.74
VBH: NO: 1
BOX: No. 4
SITE NAME: BOEGOEBaai
DEPTH 15.10
DEPTH 16.74
DEPTH 18.24
END 18.24


START: 18.24
SITE NAME: Boegoebaai
VBH: NO: 1
BOX: NO: 5
DEPTH 19.74
DEPTH 21.24

BOREHOLE VBH2


BOEGOEBAAI
V.B.H. NO: 02
Box 4 OF 5
14.74
DEPTH 15.34
DEPTH 16.17
80°C +
DEPTH 15.84
DEPTH 17.34
DEPTH 18.24
DEPTH 18.99
DEPTH 19.24
19.88


19.88
BOEGOEBAAI
V.B.H. NO: 02
Box 5 OF 5
DEPTH 20.00

BOREHOLE VBH3


VBH no : 03
Box 4 OF
BOEGOEBAAI
15.50
DEPTH 15.89
DEPTH 16.08
DEPTH 16.41
0.43
DEPTH 17.39
DEPTH 17.92
DEPTH 18.75
DEPTH 20.00

BOREHOLE VBH4


START 14.61 VBH: NO:4 SITE:NAME: Boegoe Baai BOX: No: 4
DEPTH 14.91
DEPTH 15.11
DEPTH 15.86
DEPTH 16.37
DEPTH 16.75
DEPTH 17.70
DEPTH 17.85
DEPTH 18.78
DEPTH 18.89
VBH: NO:4
18.89


START: 18.89 VBH:No:4 SITE:NAME: BoegoeBaai BOX: NO:5
DEPTH 19.68
DEPTH 19.77
DEPTH 20.08

BOREHOLE VBH5


10.48
BOEGOEBAAI
DEPTH 11.80
DEPTH 13.30


14.03
BOEGOEBAAI
DEPTH 14.57
DEPTH 15.99
DEPTH 16.39


17.47
DEPTH 17.83
DEPTH 19.00
DEPTH 18.27
DEPTH 19.72
DEPTH 20.09

BOREHOLE VBH6


START: 10,09
SITE NAME: BoEgoEBaai
VBH: NO6
BOX: NO:4
DEPTH 10.70
DEPTH 11.27
DEPTH 12.30
DEPTH 13.18
VBH NO 6
13.42
END


START: 13.42
SITE: NAME: BoEgoEBaai
VBH: NO:6
BOX: NO5
DEPTH 13.83
DEPTH 14.7
DEPTH 15.33
DEPTH 15.95
DEPTH 16.39
DEPTH 17.47
DEPTH 18.05


START: 18.05
SITE: NAME: BoEgoEBaai
VBH: NO:6
BOX: NO:6 of 6
DEPTH 18.61
DEPTH 18.74
DEPTH 20.00

INCLINE BOREHOLE IBH1

INCLINE BOREHOLE IBH3


START 10.24
SITE: NAME: BOEGOEBAAI
IBH: NO: 3
BOX: NO: 4
DEPTH 10.53
LC
3B
DEPTH 11.03
L/D
DEPTH 11.55
DEPTH 12.04
DEPTH 13.00
DEPTH 13.54
IBH: 3


START: 13.54
SITE: NAME: BOEGOEBAAI
IBH: NO: 3
BOX: NO: 5
DEPTH 15.04
DEPTH 15.68
DEPTH 16.20
DEPTH 16.78
DEPTH 17.94
IBH: NO: 3
17.94


START: 17.94
SITE: NAME: BOEGOEBAAI
IBH: NO: 3
BOX: NO: 6 OF 6
DEPTH 18.80
DEPTH 20.00
20.00 END OF HOLE

INCLINE BOREHOLE IBH4

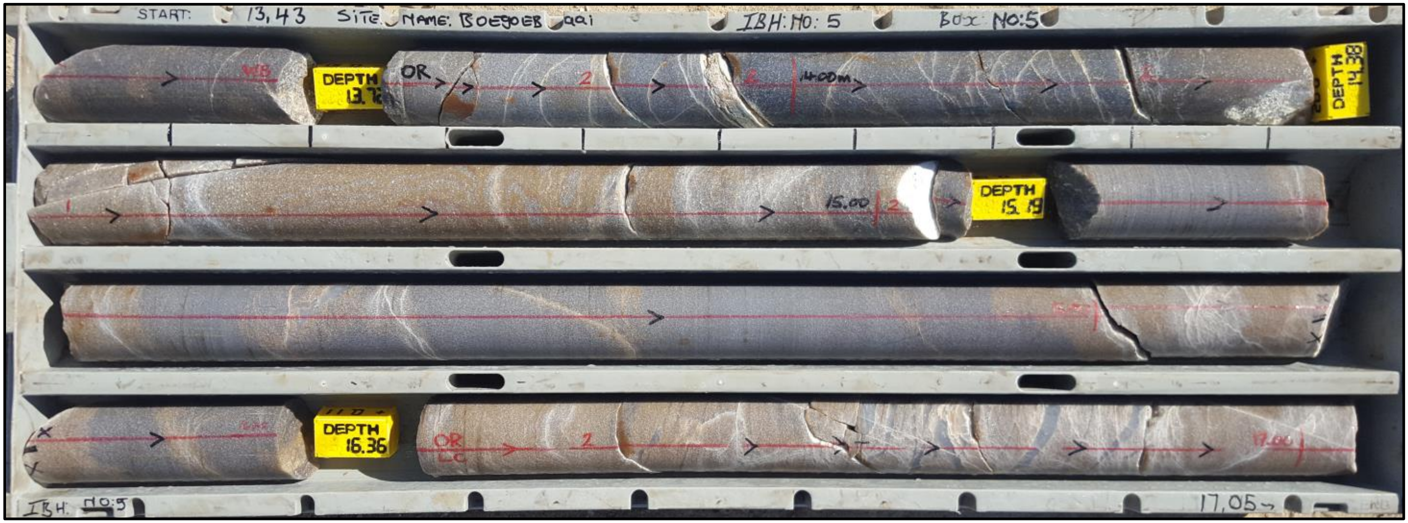

11.68
11,68
IBH 4
BOX 4-6
DEPTH 11.80
DEPTH 12.06
DEPTH 12.83
0.77
DEPTH 13.83
DEPTH
14.98


14.98
14.98
IBH 4
BOX 5-6
DEPTH 14.98
DEPTH 15.98
DEPTH 16.71
DEPTH 16.86
DEPTH 17.19
DEPTH 17.54
18.50


18.50
18.58
IBH 4
BOX 6-6
DEPTH 18.58
DEPTH 18.96
DEPTH 19.75
DEPTH 20.09
20.09
20.09 E.O.H.

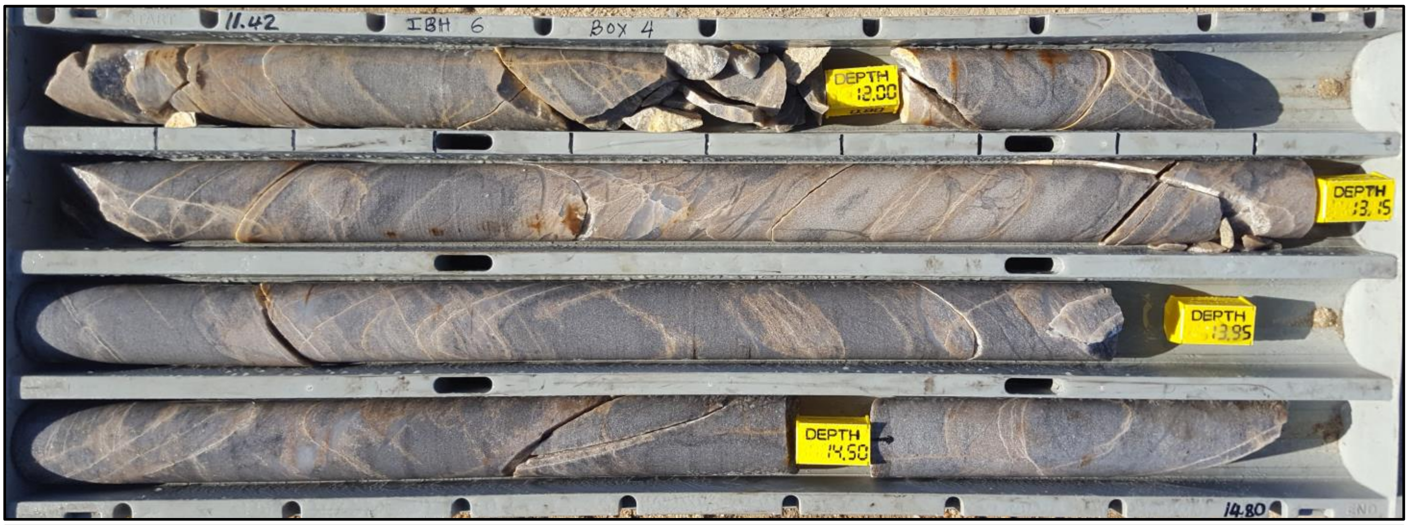
INCLINE BOREHOLE IBH5


START: 10,36
SITE:NAME: Boegoe Baai
IBH:NO:5
BOX:NO: 4
OR
DEPTH 11.03
DEPTH 11.74
DEPTH 11.92
DEPTH 12.55
DEPTH 13.16
IBH: NO:5
13,43→
END


START: 13,43
SITE NAME: BOEGOEB aai
IBH:NO: 5
BOX NO:5
DEPTH 13.72
OR
14.00m
DEPTH 14.38
15.00
DEPTH 15.19
DEPTH 16.36
OR LC
17.00
IBH: NO:5
17,05→
END


START: 17,05
SITE: NAME: BOEGOE Baai
IBH:NO:5
BOX:NO:6
DEPTH 17.51
18.00
DEPTH 18.96
DEPTH 19.55
DEPTH 20.00
END OF IBH:NO:5 AT:20.00
IBH NO:5
END

INCLINE BOREHOLE IBH6


11.42
IBH 6
Box 4
DEPTH 12.00
DEPTH 13.15
DEPTH 13.95
DEPTH 14.50
14.80


14.80m
IBH 6
Box 5
DEPTH 15.23
DEPTH 15.88
DEPTH 16.3
DEPTH 16.86
0.55
DEPTH 17.30
DEPTH 17.68
DEPTH 18.00


18.00
IBH 06
Box 6
DEPTH 18.60
DEPTH 19.23
DEPTH 20.17
E.O.H 20.17m

Appendix C: Laboratory Test Results

C1: Soils

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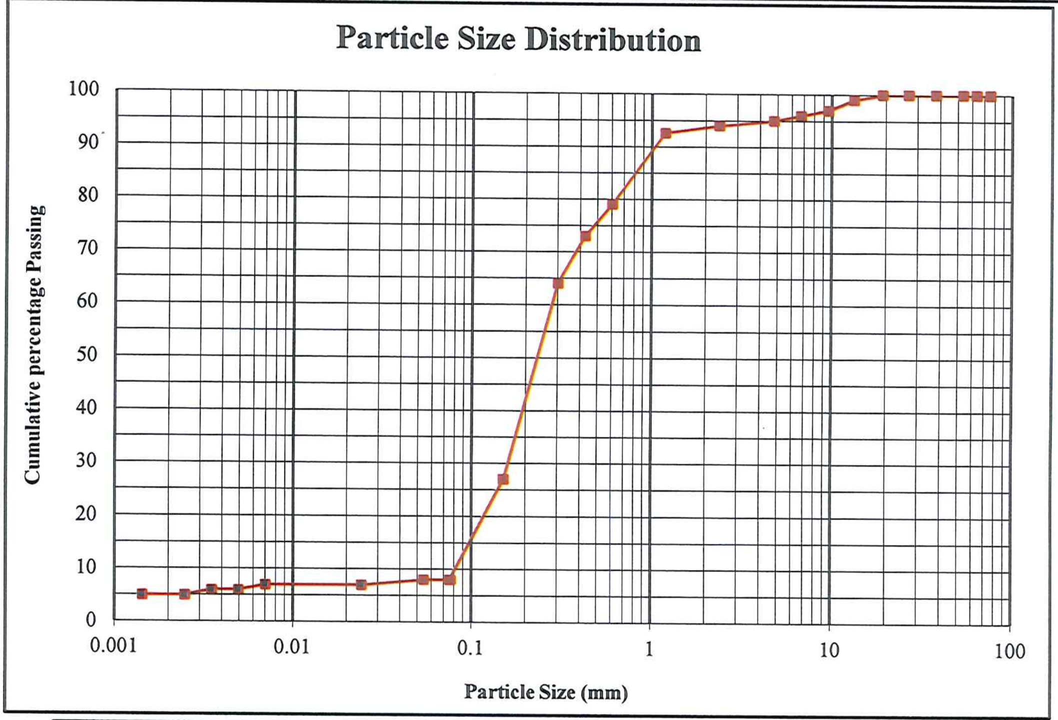
Customer :	SRK Consulting Engineers P.O.Box 55291 Northlands 2116	Project :	Boegoe Baai
		Date Received :	30.05.18
		Date Reported :	04.06.18
		Req. Number :	Q62524
Attention :	Mr.Ashley Nanton		

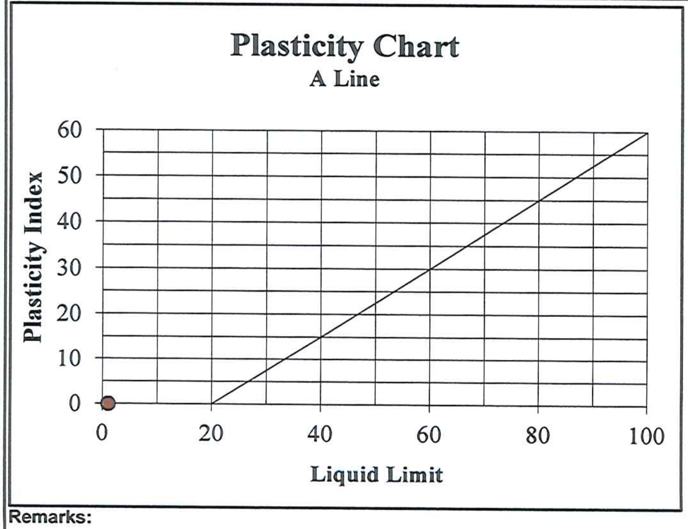
FOUNDATION INDICATOR - (TMH 1 Method A1(a),A2,A3,A4,A5) & (ASTM Method D422)

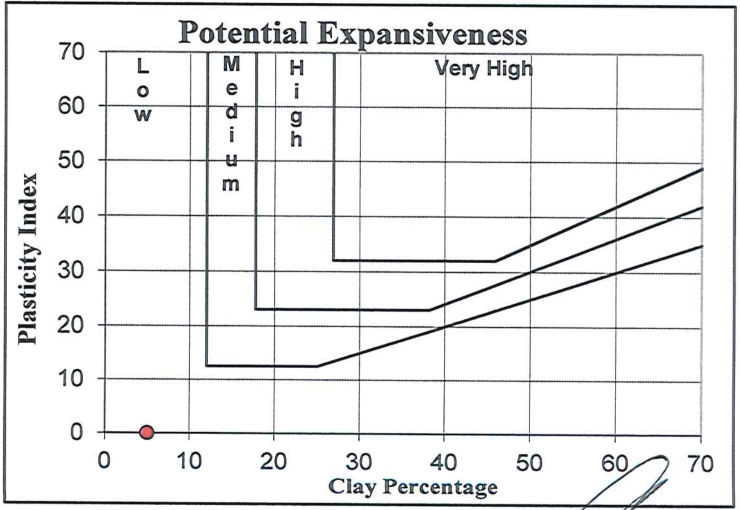
Material Description:	Light Brown Sand with Quartzitic Sandstone	Sample Number:	43990		
Position:	TP2	Liquid Limit	-	Linear Shrinkage	0.0
Depth:	1.3-1.9m	Plasticity Index	NP	Insitu M/C%	0.8

Sieve Size(mm)	% Passing
75.0	100
63.0	100
53.0	100
37.5	100
26.5	100
19.0	100
13.2	99
9.5	97
6.7	96
4.75	95
2.36	94
1.18	93
0.600	79
0.425	73
0.300	64
0.150	27
0.075	8.0
0.0761	8
0.0538	8
0.0240	7
0.0069	7
0.0049	6
0.0035	6
0.0025	5
0.0014	5



% Clay	5	% Silt	3	% Sand	86	% Gravel	6





Remarks:

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Technical Signatory

Compiled By: N. v. d. Westhuizen

Approved By: Technical Signatory

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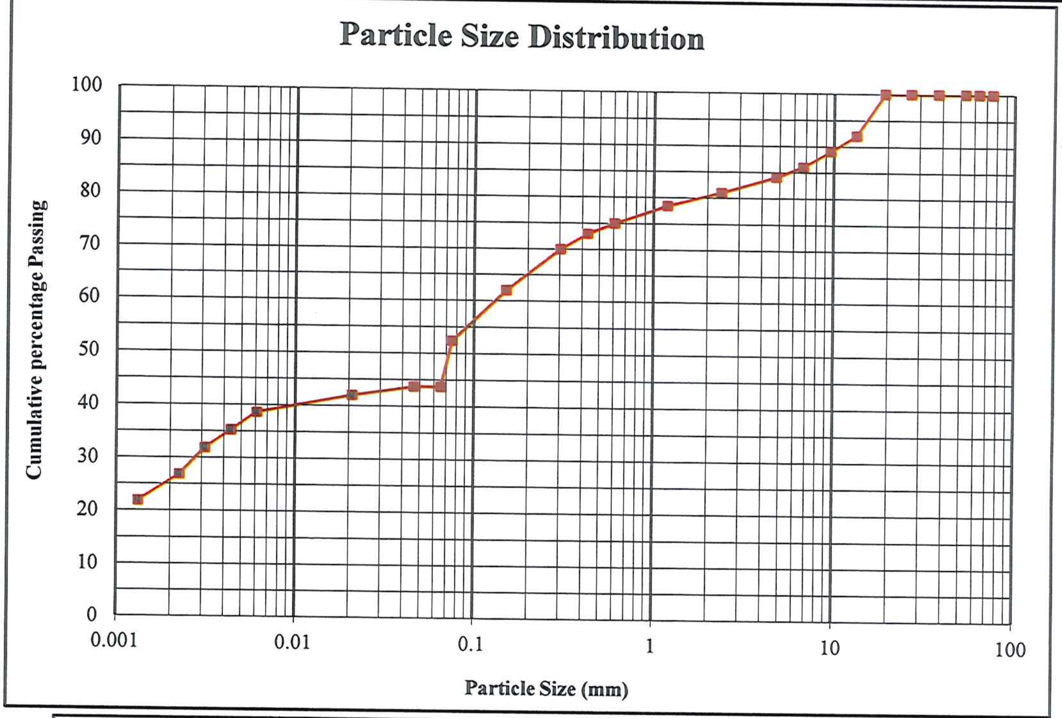
2116
Attention : Mr.Ashley Nanton

Project : Boegoe Baai
Date Received : 30.05.18
Date Reported : 05.06.18
Req. Number : Q62524

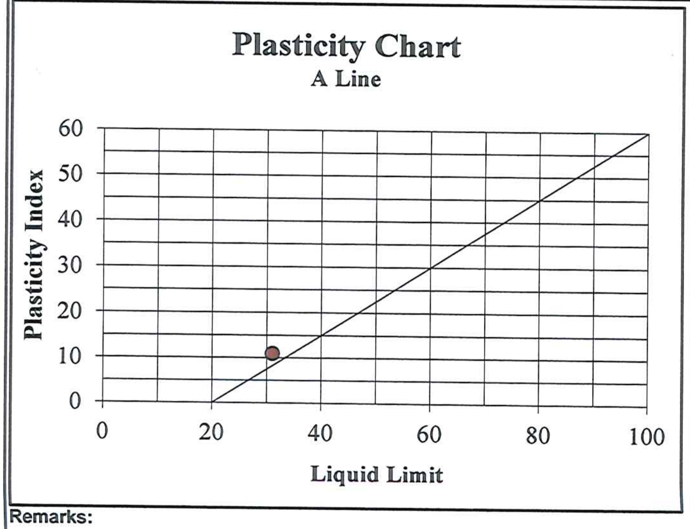
FOUNDATION INDICATOR - (TMH 1 Method A1(a),A2,A3,A4,A5) & (ASTM Method D422)

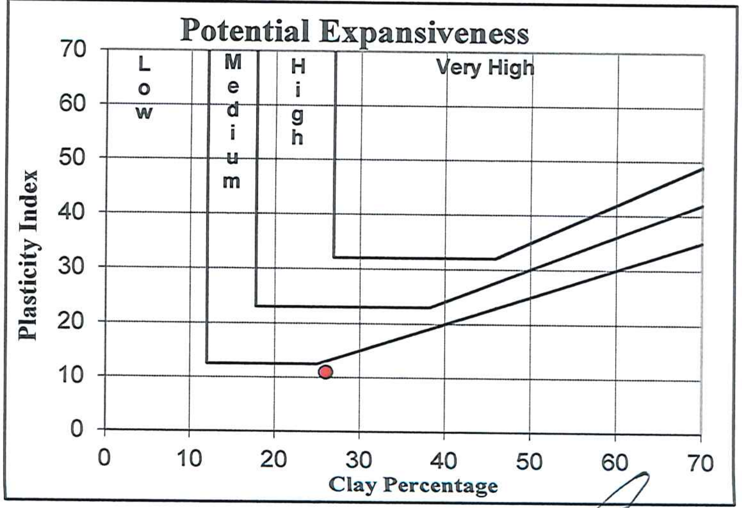
Material Description:	White Silty Clay	Sample Number:	43991		
Position:	TP5	Liquid Limit	31	Linear Shrinkage	5.4
Depth:	0.6-1.0m	Plasticity Index	11	Insitu M/C%	12.7

Sieve Size(mm)	% Passing
75.0	100
63.0	100
53.0	100
37.5	100
26.5	100
19.0	100
13.2	92
9.5	89
6.7	86
4.75	84
2.36	81
1.18	78
0.600	75
0.425	73
0.300	70
0.150	62
0.075	52.4
0.0649	44
0.0459	44
0.0207	42
0.0060	39
0.0043	35
0.0031	32
0.0022	27
0.0013	22



% Clay	26	% Silt	18	% Sand	36	% Gravel	20





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Customer : SRK Consulting Engineers
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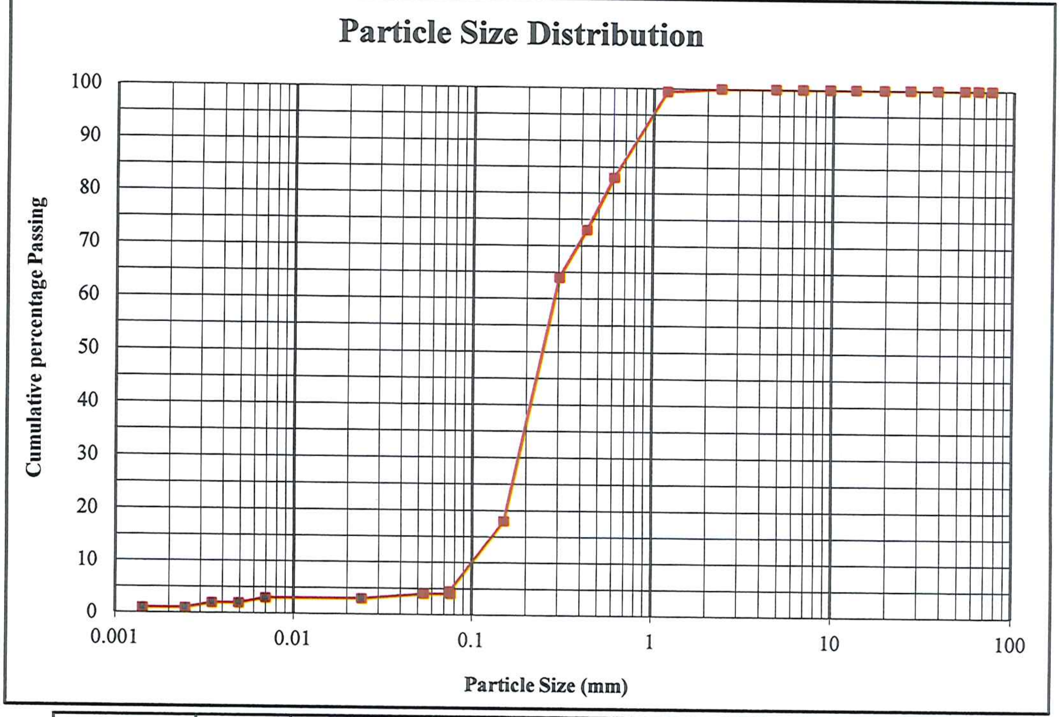
2116
Attention : Mr.Ashley Nanton

Project : Boegoe Baai
Date Received : 30.05.18
Date Reported : 05.06.18
Req. Number : Q62524

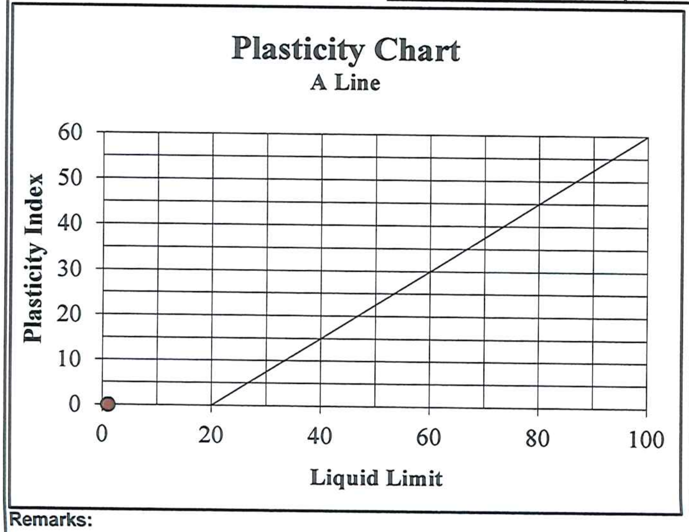
FOUNDATION INDICATOR - (TMH 1 Method A1(a),A2,A3,A4,A5) & (ASTM Method D422)

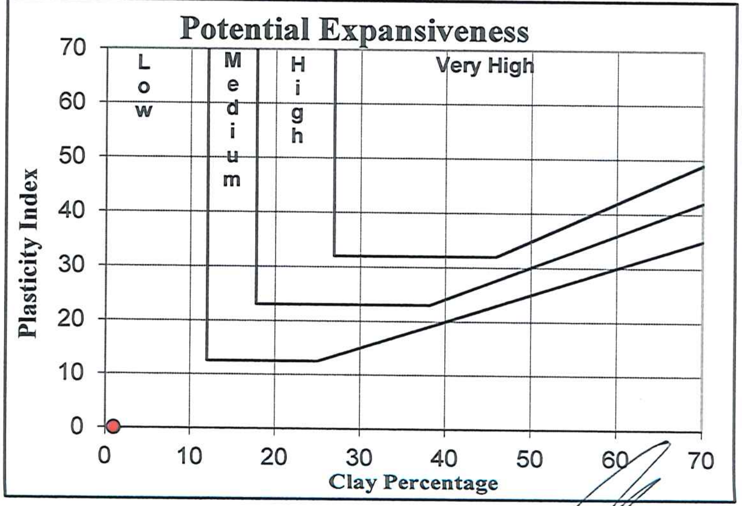
Material Description:	Light Brown Yellowish Sand	Sample Number:	43992		
Position:	TP7A	Liquid Limit	-	Linear Shrinkage	0.0
Depth:	0.8-1.7m	Plasticity Index	NP	Insitu M/C%	0.4

Sieve Size(mm)	% Passing
75.0	100
63.0	100
53.0	100
37.5	100
26.5	100
19.0	100
13.2	100
9.5	100
6.7	100
4.75	100
2.36	100
1.18	99
0.600	83
0.425	73
0.300	64
0.150	18
0.075	4.5
0.0759	4
0.0537	4
0.0240	3
0.0069	3
0.0049	2
0.0035	2
0.0025	1
0.0014	1



% Clay	1	% Silt	3	% Sand	96	% Gravel	0





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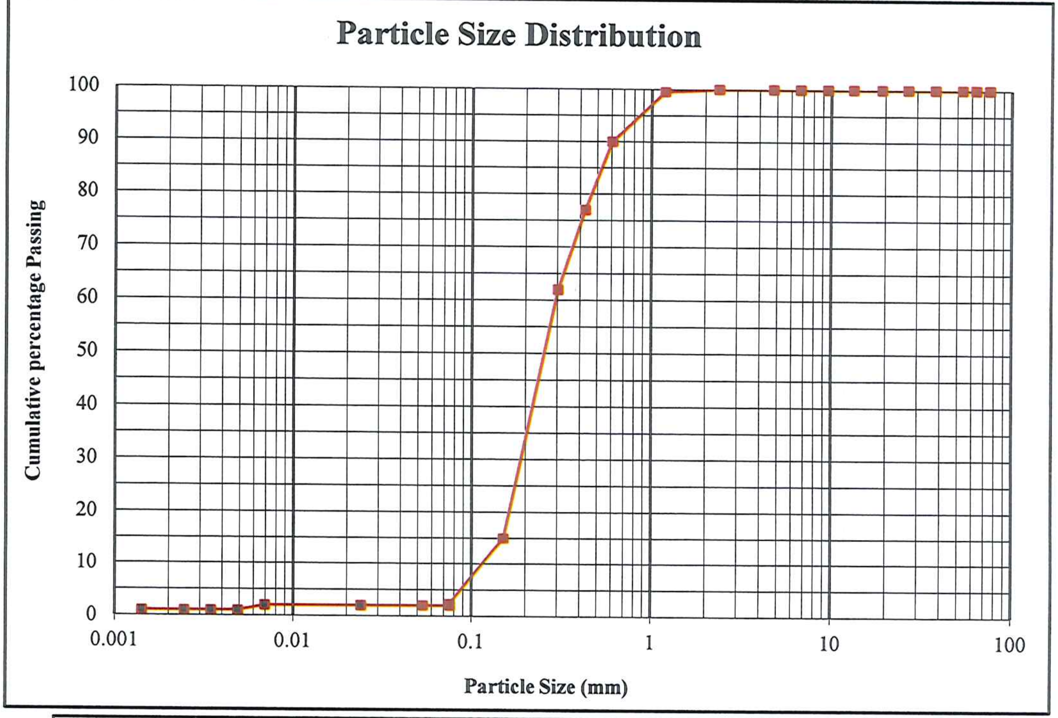
Customer :	SRK Consulting Engineers P.O.Box 55291 Northlands 2116	Project :	Boegoe Baai
		Date Received :	30.05.18
		Date Reported :	05.06.18
		Req. Number :	Q62524
Attention :	Mr.Ashley Nanton		

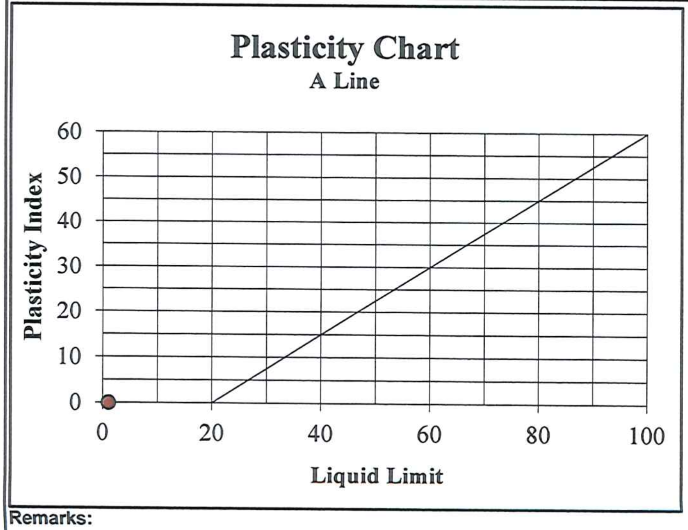
FOUNDATION INDICATOR - (TMH 1 Method A1(a),A2,A3,A4,A5) & (ASTM Method D422)

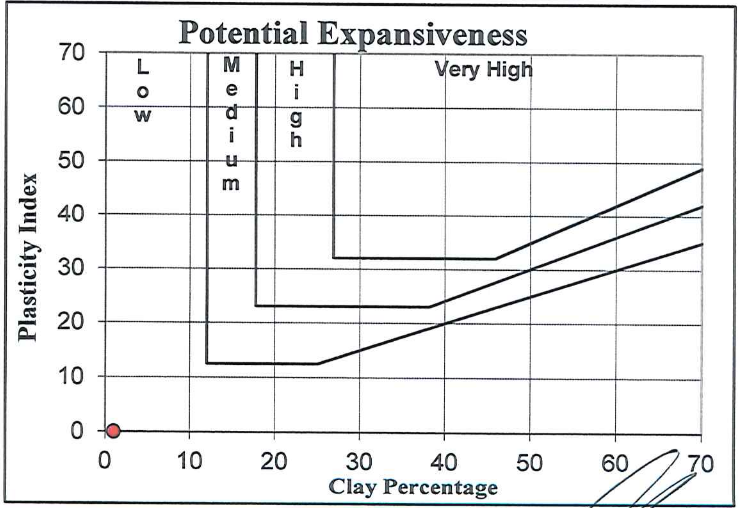
Material Description:	Light Brown Yellowish Sand	Sample Number:	43993		
Position:	TP17	Liquid Limit	-	Linear Shrinkage	0.0
Depth:	0.9-1.6m	Plasticity Index	NP	Insitu M/C%	0.5

Sieve Size(mm)	% Passing
75.0	100
63.0	100
53.0	100
37.5	100
26.5	100
19.0	100
13.2	100
9.5	100
6.7	100
4.75	100
2.36	100
1.18	100
0.600	90
0.425	77
0.300	62
0.150	15
0.075	2.3
0.0755	2
0.0534	2
0.0239	2
0.0069	2
0.0049	1
0.0034	1
0.0024	1
0.0014	1



% Clay	1	% Silt	1	% Sand	98	% Gravel	0





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JOB NO: CT5691 **Your Ref** Q62524 **Date** 05.06.18

SRK Consulting Engineers
P.O.Box 55291
Northlands
2116

PROJECT: Boegoe Baai

ATTENTION: **Mr. A. Nanton**

Dear Sir

TMH5 MD1, MD2 / SANS 3001 GR1, GR2 PR5, GR10, GR12, GR30, GR31, GR40

The unambiguous description of the sample/s as received are as follows :

			SPEC		SPEC		SPEC
SAMPLE No.		43990	G7	43992	G9	43993	G8
CONTAINER USED FOR SAMPLING		Sampling Bag		Sampling Bag		Sampling Bag	
SIZE / WEIGHT OF SAMPLE		± 80 Kg		± 80 Kg		± 80 Kg	
MOISTURE CONDITION OF SAMPLE ON ARRIVAL		Moist		Moist		Moist	
HOLE No. / Km. / CHAINAGE / SV		TP2		TP7A		TP17	
ROAD No. OR NAME / STRUCTURE		Not Specified		Not Specified		Not Specified	
LAYER TESTED / SAMPLED FROM		1.3-1.9m		0.8-1.7m		0.9-1.6m	
DATE SAMPLED		30.05.18		30.05.18		30.05.18	
DATE RECEIVED		03.05.18		03.05.18		03.05.18	
CLIENTS MARKING		None		None		None	
DESCRIPTION OF SAMPLE (COLOUR & TYPE)		Light Brown Sand with Quartzitic Sandstone		Light Brown Yellowish Sand		Light Brown Yellowish Sand	
SIEVE ANALYSIS (mm)	75.0	100		100		100	
	63.0	100		100		100	
	53.0	100		100		100	
	37.5	100	-	100	-	100	-
	28.0	100	-	100	-	100	-
	20.0	100	-	100	-	100	-
	14.0	99	-	100	-	100	-
	5.0	95	-	100	-	100	-
	2.00	92.6	-	99.4	-	99.5	-
SANS 3001 GR1	0.425	73	-	73	-	77	-
	0.075	7.8	-	4.5	-	2.3	-
ATTERBERG LIMITS **SANS 3001 GR10, GR12**	LL%	-	-	-	-	-	-
	P.I.	NP	≤ 12	NP	≤ 12	NP	≤ 12
	LS%	0.0	-	0.0	-	0.0	-
	GM	1.27	2.7≥ GM ≥ 0.75	1.23	2.7≥ GM ≥ 0.75	1.21	2.7≥ GM ≥ 0.75
SOIL-MORTAR PERCENTAGES **SANS 3001 PR5**	Coarse sand	21.2		26.6		22.6	
	Coarse fine sand	9.7		9.1		15.1	
	Fine fine sand	20.7		13.6		12.8	
	Fine sand	70.4		68.9		75.1	
	Medium fine sand	40.0		46.3		47.2	
	Silt and clay	8.4		4.5		2.3	
	Coarse sand ratio	0.2		0.3		0.2	
CLASSIFICATION	H.R.B.	A-3		A-3		A-3	
	COLTO	G7		G9		G8	
	T.R.H. 14	G7		G9		G8	
MOD AASHTO **SANS 3001 GR30 / GR31**	OMC%	7.5		9.2		9.3	
	MDD(KG/M^3)	1769		1685		1736	
C.B.R. **SANS 3001 GR40** U.C.S **SANS 3001 GR53**	COMP MC	7.3		9.0		9.1	
	% SWELL	0.00	1.50	0.00	1.50	0.00	1.50
	100%	23	-	16	-	17	-
	98%	20	-	14	-	14	-
	97%	19	-	13	-	13	-
	95%	17	-	10	-	11	-
	93%	15	15	8	7	10	10
	90%	13	-	4	-	7	-
MOD ITS : DRY (kPa) **(GR54)**							
PROCTOR ITS : DRY (kPa)							
STABILISED WITH	IN LAB						
	ON SITE						
REMARKS & NOTES							

Remarks:

1. Opinions & Interpretations are not included in our schedule of Accreditation.
2. The samples where subjected and analyzed according to SANS 3001.
3. The results reported relate only to the sample tested, Further use of the above information is not the responsibility or liability of Roadlab Laboratories Western Cape.
4. This document is the correct record of all measurements made, and may not be reproduced other than with full written approval from the Technical Manager of Roadlab Laboratories Western Cape.
5. Measuring equipment is traceable to national standards (Where applicable).
6. Test methods marked with (*) are not accredited Test methods.

sanas
Testing Laboratory
Accreditation No.: T0507

Mr. A.Swanepoel
Technical Signatory

C2: Rocks

TABLE 1 RESULTS OF UNIAXIAL COMPRESSION TESTS WITH ELASTIC MODULUS AND POISSON RATIO MEASUREMENTS BY MEANS OF STRAIN GAUGES

ROCKLAB
DIVISION OF SOILLAB (PTY) LTD
Tel: 0027 12 813 4910
E-mail: Chenj@rocklab.co.za

Client: SRK Consulting SA

Sampling Site: Boegoe Baai

06-06-2018

SPECIMEN PARTICULARS			SPECIMEN DIMENSIONS					SPECIMEN TEST RESULTS								
Rocklab Specimen No 7503-	Sample ID	Rock Type	Diameter mm	Height mm	Ratio of Height to diameter	Mass g	Density g/cm³	Failure Load kN	Strength (UCS) MPa	Tangent Elastic Modulus @ 50% UCS GPa	Secant Elastic Modulus @ 50% UCS GPa	Poisson's Ratio Tangent @ 50% UCS	Poisson's Ratio Secant @ 50% UCS	Linear Axial Strain at Failure mm/mm	Failure Code	Note
UCM-S09	S9		51.29	135.2	2.6	636.0	2.28	26.91	13.0	0.5	0.6	0.16	0.10	0.024840	6B	
UCM-S10	S10		60.32	164.2	2.7	1223.8	2.61	182.00	63.7	85.7	84.7	0.21	0.19	0.000748	3B	
UCM-S11	S11		59.98	152.8	2.5	1126.8	2.61	194.60	68.9	77.3	74.1	0.17	0.14	0.000922	3B	
UCM-S12	S12		60.05	165.8	2.8	1231.3	2.62	548.40	193.6	76.4	76.8	0.11	0.10	0.002499	4B	
UCM-S13	S13		52.05	136.5	2.6	745.3	2.57	129.90	61.0	46.5	58.9	0.09	0.10	0.001256	4B	
UCM-S14	S14		60.96	165.1	2.7	1238.4	2.57	26.78	9.2	49.3	31.8	0.14	0.11	0.000307	3B	
UCM-S15	S15		59.73	104.0	1.7	746.1	2.56	172.20	61.5	20.3	18.1	0.15	0.10	0.003647	0B	
UCM-S16	S16		60.35	166.8	2.8	1229.7	2.58	588.30	205.7	69.3	71.0	0.12	0.12	0.002977	7B	
UCM-S17	S17		60.21	166.3	2.8	1235.7	2.61	848.00	297.8	72.7	76.0	0.17	0.14	0.004114	YA	
UCM-S18	S18		60.55	165.7	2.7	1241.9	2.60	689.00	239.3	82.3	83.0	0.11	0.11	0.003065	4B	

Note: All tests were conducted according to the ISRM's Specification.

Failure codes refer to Appendix 3

TABLE 2 RESULTS OF POINT LOAD STRENGTH TESTS

ROCKLAB
Tel: 0027 12 813 4910
E-mail: Chenj@rocklab.co.za

Client: SRK Consulting Sampling Location: Boegoe Baai 28-06-2018

SPECIMEN	PARTICULARS		SPECIMEN TEST RESULTS							
ROCKLAB Specimen No 7503-	Sample ID	Rock Type	Core Diameter D (mm)	Core Height (mm)	Failue Load P (kN)	Equivalent Core Diameter (mm)	Point Load Strength I_S (MPa)	Corrected $I_{S(50)}$ (MPa)	Test Code	Note
PLT-S11	S11		60.01		39.23	60.01	10.89	11.83	1	
			60.01		38.25	60.01	10.62	11.53	1	
			60.01		34.20	60.01	9.50	10.31	1	
			60.01		27.55	60.01	7.65	8.30	1	
PLT-S12	S12		60.03		16.87	60.03	4.68	5.08	1	
			60.03		15.40	60.03	4.27	4.64	1	
			60.03		21.60	60.03	5.99	6.51	1	
			60.03		24.40	60.03	6.77	7.35	1	
			60.03		16.25	60.03	4.51	4.90	1	
			60.03		17.60	60.03	4.88	5.30	1	
PLT-S13	S13		52.25		15.75	52.25	5.77	5.88	1	
			52.25		16.73	52.25	6.13	6.25	1	
PLT-S14	S14		60.87		18.80	60.87	5.07	5.54	1	
			60.87		19.23	60.87	5.19	5.67	1	
			60.87		15.75	60.87	4.25	4.64	1	
			60.87		18.71	60.87	5.05	5.52	1	
PLT-S16	S16		60.30		15.80	60.30	4.35	4.73	1	
			60.30		17.65	60.30	4.85	5.28	1	
			60.30		15.05	60.30	4.14	4.50	1	
			60.30		18.15	60.30	4.99	5.43	1	
PLT-S17	S17		60.17		34.75	60.17	9.60	10.43	1	
			60.17	18.07	21.20	37.21	15.31	13.41	2	
			60.17	24.79	24.40	43.58	12.85	12.08	2	
PLT-S18	S18		60.52		35.60	60.52	9.72	10.59	1	
			60.52		34.30	60.52	9.36	10.21	1	
			60.52		29.20	60.52	7.97	8.69	1	
			60.56		32.65	60.56	8.90	9.70	1	
			60.56		36.30	60.56	9.90	10.79	1	
PLT-S19	S19		60.16		41.65	60.16	11.51	12.51	1	
			60.16		40.60	60.16	11.22	12.19	1	
			60.16		39.45	60.16	10.90	11.85	1	
			60.16	24.31	25.30	43.15	13.59	12.72	2	
			60.16	22.99	21.95	41.96	12.46	11.52	2	
PLT-S20	S20		60.81		31.70	60.81	8.57	9.36	1	
			60.81		32.98	60.81	8.92	9.74	1	
PLT-S21	S21		60.14		41.00	60.14	11.34	12.32	1	
			60.14		45.60	60.14	12.61	13.70	1	
			60.14		41.80	60.14	11.56	12.56	1	
			60.14	22.75	28.30	41.74	16.25	14.98	2	
			60.14	20.47	25.40	39.59	16.20	14.59	2	
			60.14	22.80	24.00	41.78	13.75	12.68	2	
PLT-S22	S22		58.65		24.75	58.65	7.20	7.73	1	
			58.65		18.10	58.65	5.26	5.65	1	
			58.65		18.25	58.65	5.31	5.70	1	
PLT-S24	S24		60.06		34.20	60.06	9.48	10.30	1	
			60.06		33.60	60.06	9.31	10.12	1	
			60.06	22.80	27.05	41.76	15.51	14.31	2	
PLT-S26	S26		60.54		25.25	60.54	6.89	7.51	1	
			60.54		24.20	60.54	6.60	7.20	1	

Note: All tests were conducted according to the ISRM's suggested method.

Loading mode: 1 - diametrial loading, 2 - Axial loading

TABLE 3 RESULTS OF ROCK WATER ABSORPTION

ROCKLAB
DIVISION OF SOILLAB (PTY) LTD
Tel: 0027 12 813 4910
E-mail: Chenj@rocklab.co.za

Client: SRK Consulting Sampling Site: 03-07-2018

SPECIMENS PARTICULARS						
ROCKLAB Specimen No 7503-	Sample ID	Rock Type	Mass of Oven-dry test specimen in Air A (g)	Mass of Saturated-surface Dry test specimen in Air B (g)	Water Absorption (B-A)/A*100 (%)	Note
DW-S10	S10		231.46	231.74	0.12	
DW-S16	S16		145.44	146.06	0.43	
DW-S17	S17		144.88	145.98	0.76	
DW-S19	S19		389.18	389.60	0.11	
DW-S20	S20		378.91	379.15	0.06	
DW-S21	S21		408.52	408.60	0.02	
DW-S22	S22		529.40	530.25	0.16	
DW-S24	S24		481.24	482.40	0.24	
DW-S26	S26		449.49	449.97	0.11	

Notes: the tests were conducted according to ASTM D 6473-15.

TABLE 4 RESULTS OF ROCK SPECIFIC GRAVITY MEASUREMENTS

ROCKLAB
Tel: 0027 12 813 4910
E-mail: Chenj@rocklab.co.za

Client: SRK Consulting SA

2018-07-02

SPECIMENS PARTICULARS						
ROCKLAB Specimen No 7503-	Sample ID	Rock Type	Mass of sample A (g)	Volume B (cm^3)	Rock Density A/B (g/cm^3)	Note
SG-S10	S10		108.3	41.4	2.61	
SG-S16	S16		81.9	31.9	2.57	
SG-S17	S17		88.0	33.8	2.60	
SG-S19	S19		90.2	34.4	2.62	
SG-S20	S20		99.3	37.5	2.64	
SG-S21	S21		96.0	36.4	2.64	
SG-S22	S22		93.1	36.7	2.54	
SG-S24	S24		92.1	35.7	2.58	
SG-S26	S26		82.8	31.8	2.60	

Notes: the tests were conducted according to ASTM D 6473-15.

TABLE 5 RESULTS OF THE MICRO-DEVAL ABRASION (MDA)TESTS

ROCKLAB
Tel: 0027 12 813 4910
E-mail: Chenj@rocklab.co.za

Client: SRK Consulting SA, Cape Town Sampling Site: Boegoe Baai 06-06-2018

SPECIMEN PARTICULARS			SPECIMEN TEST RESULTS													
Rocklab Specimen 7503-	Sample ID	Rock Type	The Micro-Deval Abrasion Tests													Note
			Test No.1			Test No.2			Test No.3			Test No.4			Aver.±Std.	
			10.0 - 14.0 mm Mass before test A gram	> 1.6 mm Mass after test B Gram	MDA (A-B)/A*100 %	10.0 - 14.0 mm Mass before test A gram	> 1.6 mm Mass after test B gram	MDA (A-B)/A*100 %	10.0 - 14.0 mm Mass before test A gram	> 1.6 mm Mass after test B gram	MDA (A-B)/A*100 %	10.0 - 14.0 mm Mass before test A gram	> 1.6 mm Mass after test B gram	MDA (A-B)/A*100 %		
MDA-S7	S7		500.8	478.5	4.5	500.6	482.6	3.6	500.4	478.7	4.3	500.6	483.5	3.4	4.6 ± 0.6	
MDA-S8	S8		500.4	476.6	4.8	500.7	473.6	5.4	500.1	479.0	4.2	500.6	483.4	3.4	4.6 ± 0.6	

Note: Tests were conducted according to French's specification.

TABLE 6 RESULTS OF MATERIAL FRACTURE TOUGHNESS TESTS BASED ON THREE-POINT CHEVRON-NOTCH METHOD

ROCKLAB
DIVISION OF SOILLAB (PTY) LTD
Tel: 0027 12 813 4910
E-mail: Chenj@rocklab.co.za

Client: SRK Consulting Sampling Site: 21-Jun-18

SPECIMEN PARTICULARS			SPECIMEN DIMENSIO		SPECIMEN TEST RESULTS		
Rocklab Specimen No 7503-	Sample ID	Rock Type	Diameter cm	Support Span cm	Failure Load kN	Fracture Toughness Kic $MN/m^{1.5}$	Note
KIC-S19	S19		6.02	19.00	4.26	2.85	
KIC-S20	S20		6.09	15.00	6.32	3.25	
KIC-S21	S21		6.03	20.07	4.21	2.96	
KIC-S22	S22		6.03	20.07	4.18	2.94	
KIC-S23	S23		6.07	16.00	5.64	3.11	
KIC-S24	S24		6.00	16.00	4.50	2.55	

Note: All tests were conducted according to the ISRM's specfications.

APPENDIX 1

STRESS VIA STRAIN CURVES FOR UCM TESTS

UNIAXIAL COMPRESSION TEST

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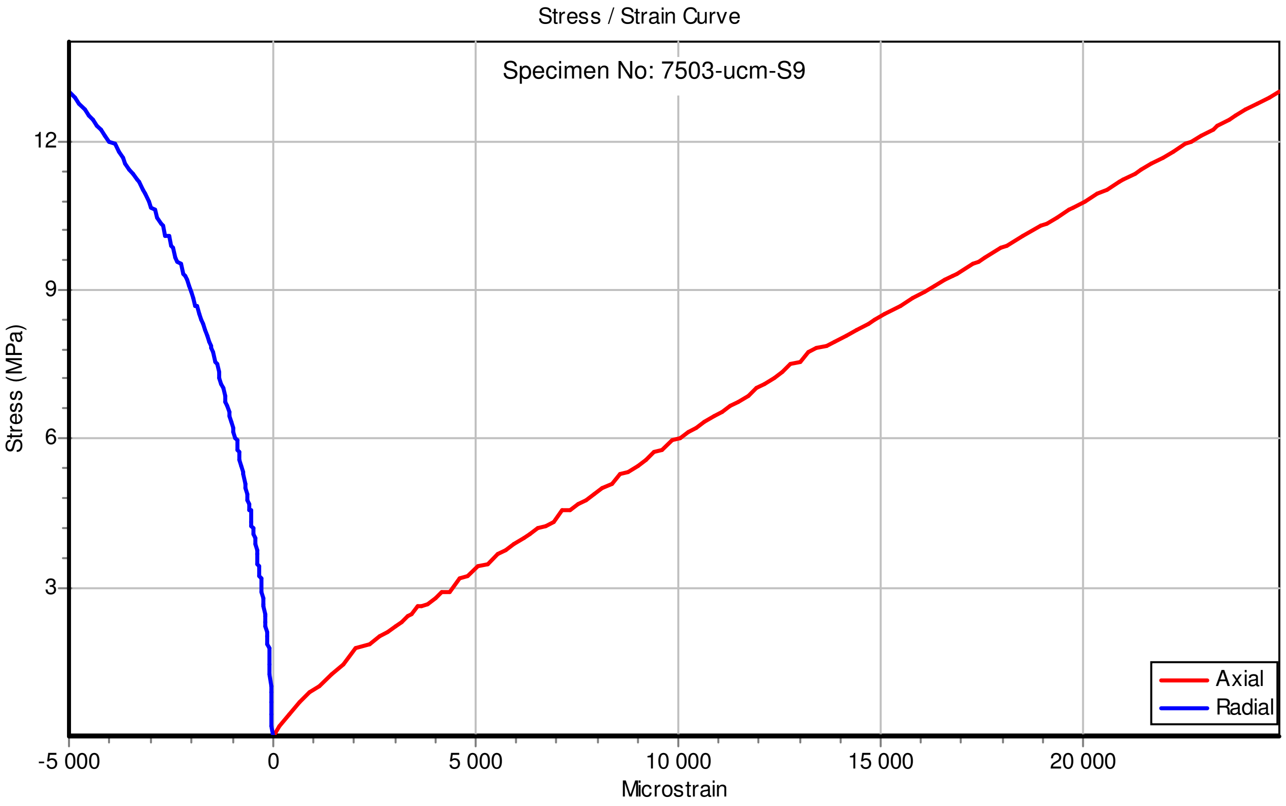
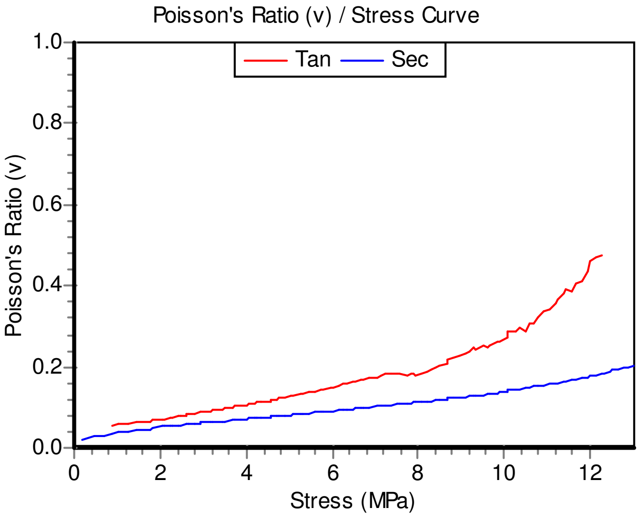
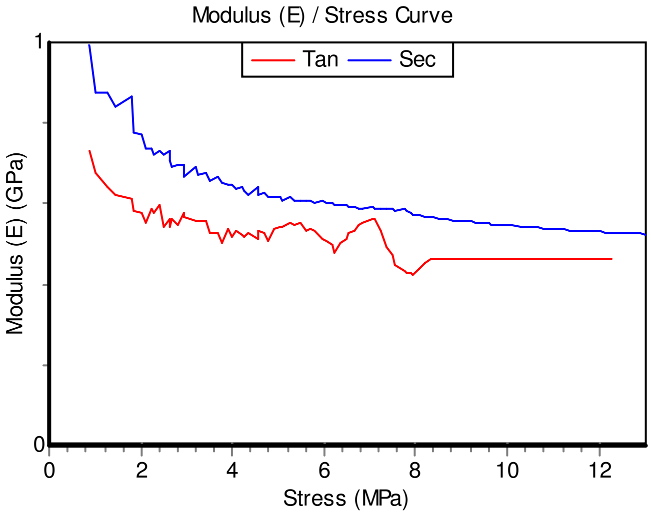
WITH ELASTIC MODULUS AND POISSON'S RATIO MEASUREMENTS BY MEANS OF STRAIN GAUGES



Stress / Strain Curve



Poisson's Ratio (v) / Stress Curve



Modulus (E) / Stress Curve

Failure Load: 26.91 kN   Peak Strength: 13.02 MPa   Axial Strain at Failure: 24840 microstrain

% Strength	Strength (MPa)	E Tan (GPa)	E Sec (GPa)	v Tan	v Sec
10	1.3	0.621	0.842	0.063	0.045
20	2.6	0.563	0.732	0.080	0.057
30	3.91	0.518	0.647	0.106	0.071
40	5.21	0.552	0.616	0.133	0.084
50	6.51	0.526	0.59	0.164	0.097
60	7.81	0.426	0.582	0.182	0.111
70	9.11	0.463	0.555	0.238	0.127
80	10.4	0.463	0.542	0.287	0.147
90	11.7	0.463	0.531	0.413	0.171

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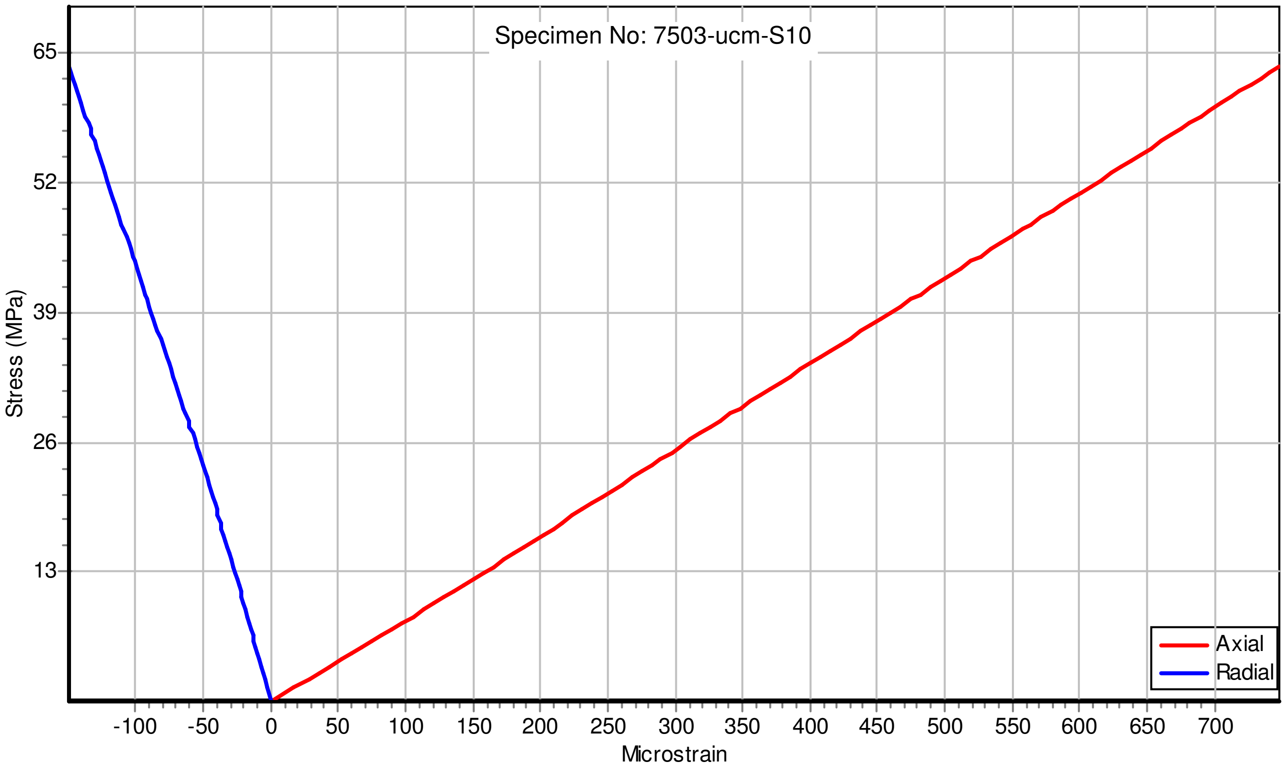
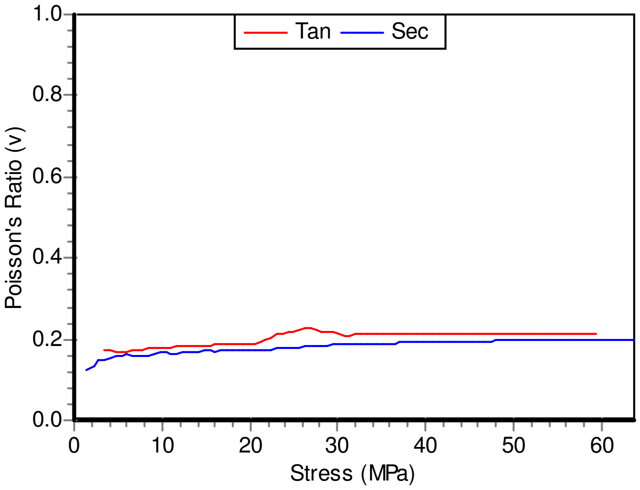
UNIAXIAL COMPRESSION TEST

WITH ELASTIC MODULUS AND POISSON'S RATIO MEASUREMENTS BY MEANS OF STRAIN GAUGES

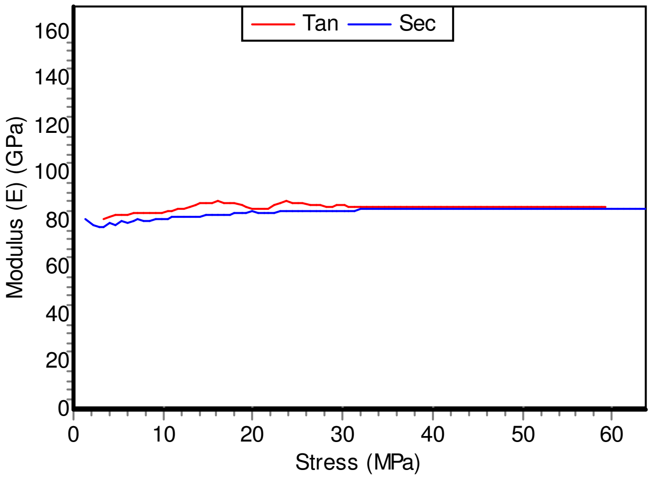
Stress / Strain Curve



Poisson's Ratio (v) / Stress Curve



Modulus (E) / Stress Curve



Failure Load: 182 kN

Peak Strength: 63.7 MPa

Axial Strain at Failure: 748 microstrain

% Strength	Strength (MPa)	E Tan (GPa)	E Sec (GPa)	v Tan	v Sec
10	6.37	83.1	80	0.172	0.160
20	12.7	86.2	81.5	0.185	0.167
30	19.1	86.1	83.5	0.187	0.173
40	25.5	87.2	84	0.224	0.179
50	31.9	85.7	84.7	0.212	0.187
60	38.2	85.8	84.8	0.213	0.191
70	44.6	85.7	85	0.212	0.194
80	51	85.7	85	0.212	0.197
90	57.3	85.7	85.1	0.213	0.198

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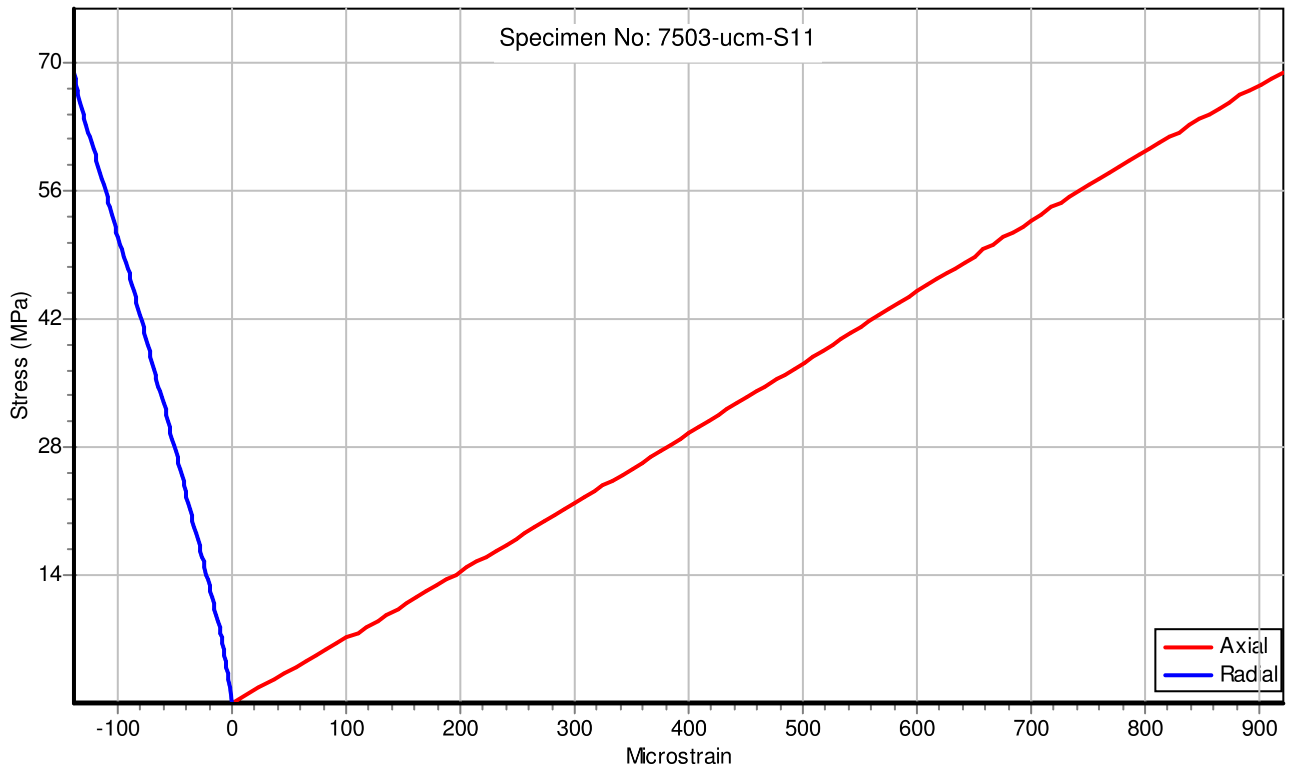
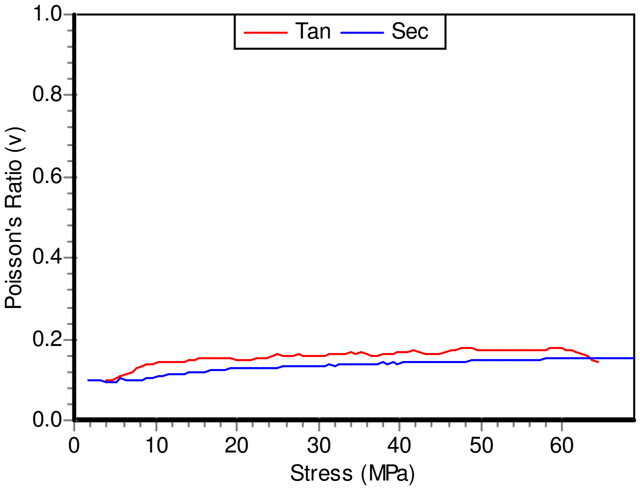
UNIAXIAL COMPRESSION TEST

WITH ELASTIC MODULUS AND POISSON'S RATIO MEASUREMENTS BY MEANS OF STRAIN GAUGES

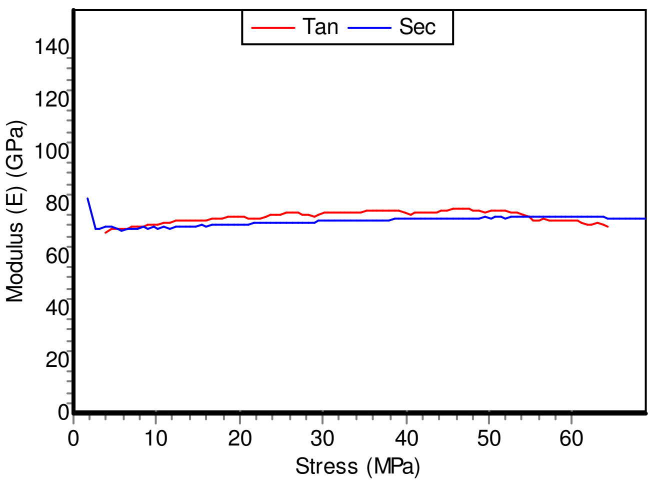
Stress / Strain Curve



Poisson's Ratio (v) / Stress Curve



Modulus (E) / Stress Curve



Failure Load: 194.6 kN Peak Strength: 68.88 MPa Axial Strain at Failure: 922 microstrain

% Strength	Strength (MPa)	E Tan (GPa)	E Sec (GPa)	v Tan	v Sec
10	6.89	71.9	71	0.121	0.098
20	13.8	73.9	71.7	0.147	0.117
30	20.7	75.1	72.7	0.147	0.127
40	27.6	76.3	73.6	0.161	0.134
50	34.4	77.3	74.1	0.165	0.139
60	41.3	77.1	74.8	0.171	0.143
70	48.2	77.7	75.1	0.176	0.147
80	55.1	74.3	75.4	0.171	0.150
90	62	72.5	75.2	0.162	0.153

UNIAXIAL COMPRESSION TEST

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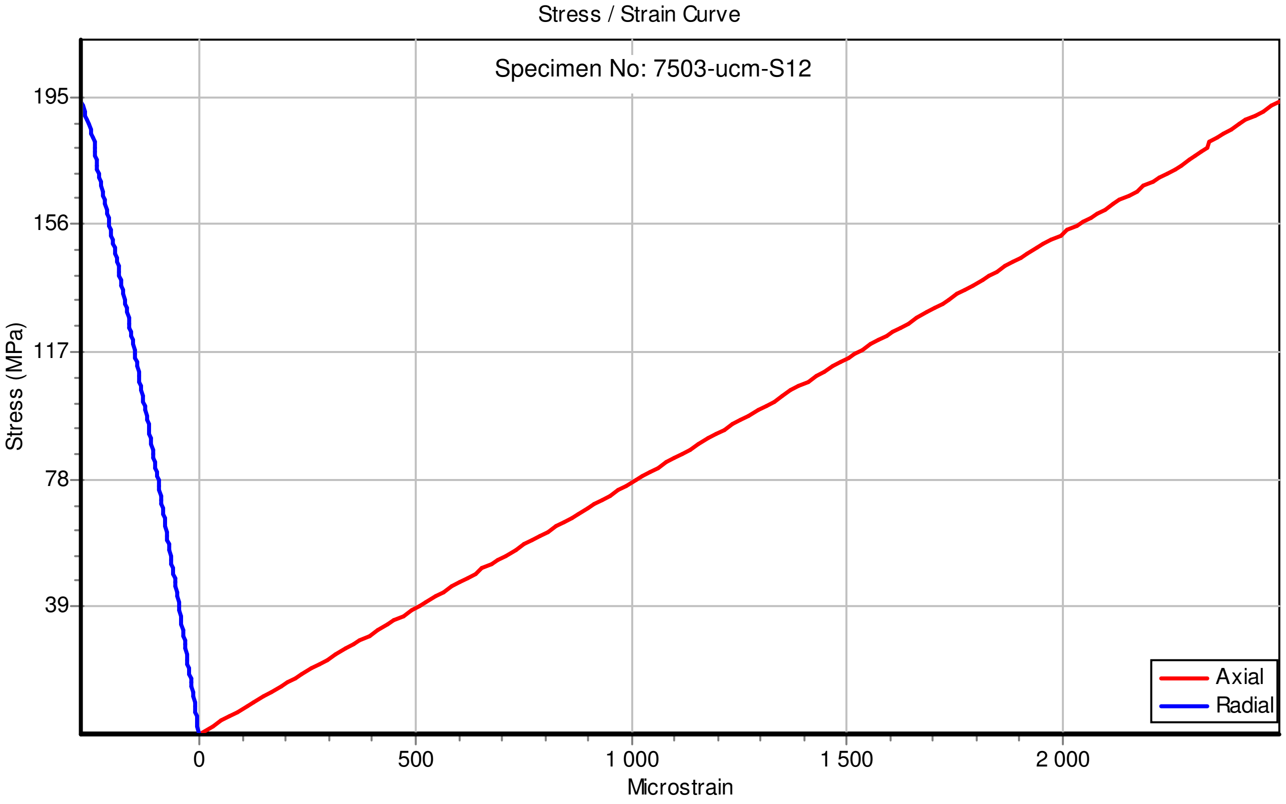
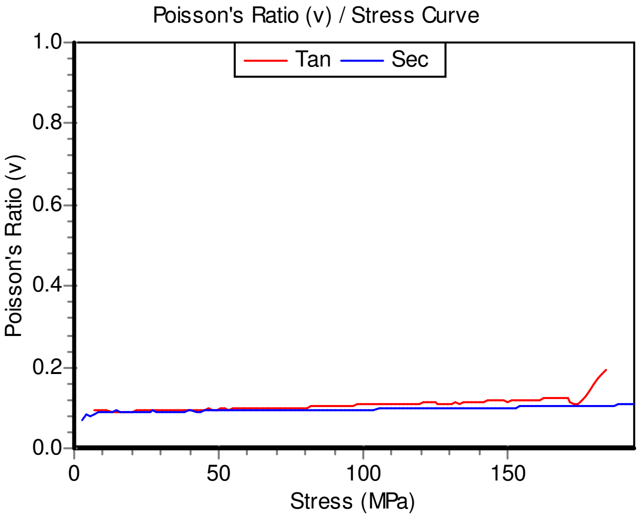
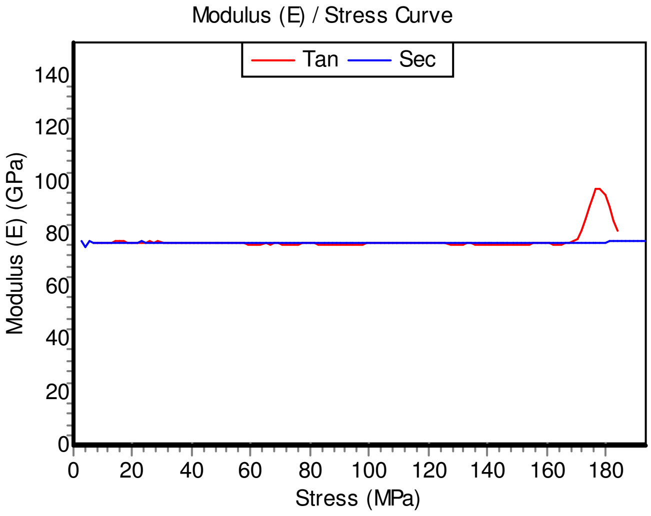
WITH ELASTIC MODULUS AND POISSON'S RATIO MEASUREMENTS BY MEANS OF STRAIN GAUGES





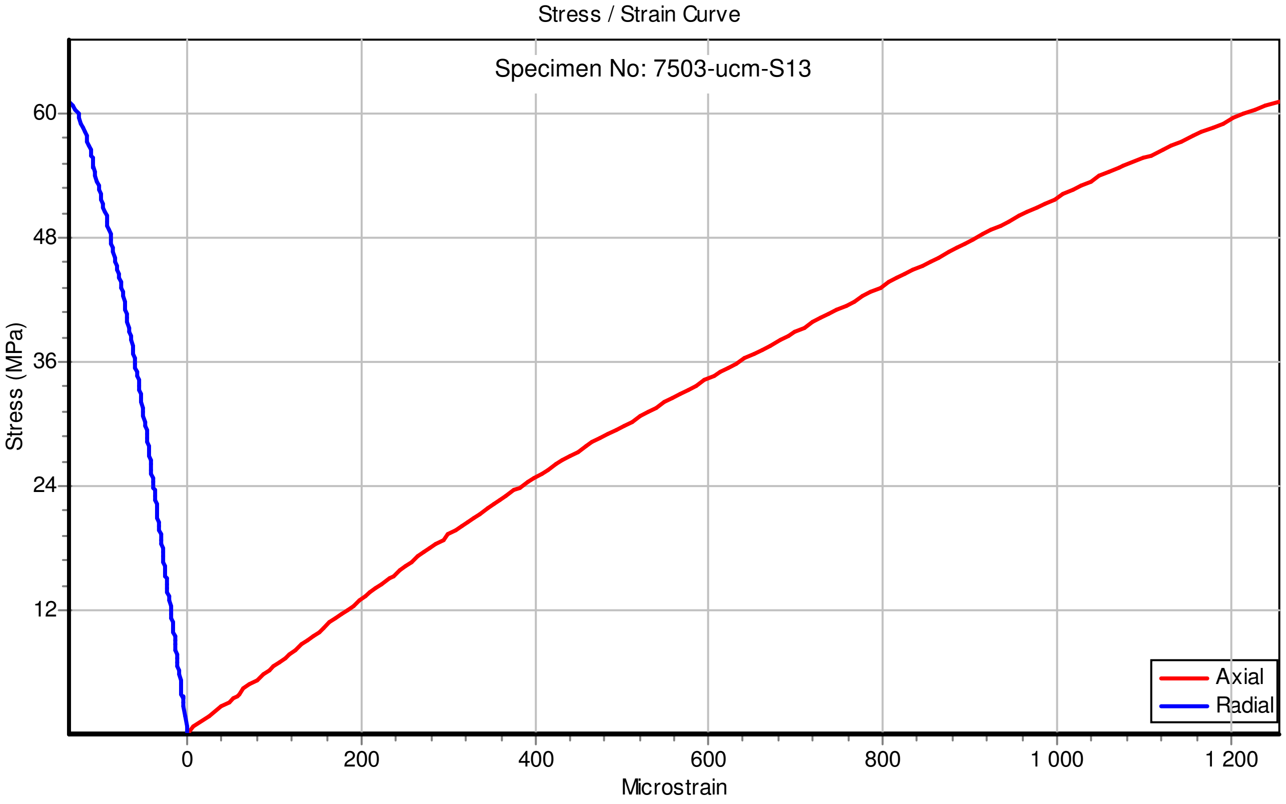


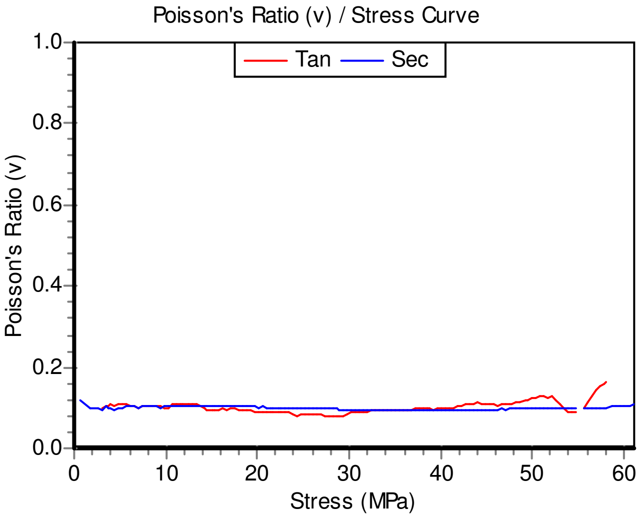
Failure Load: 548.4 kN Peak Strength: 193.6 MPa Axial Strain at Failure: 2499 microstrain

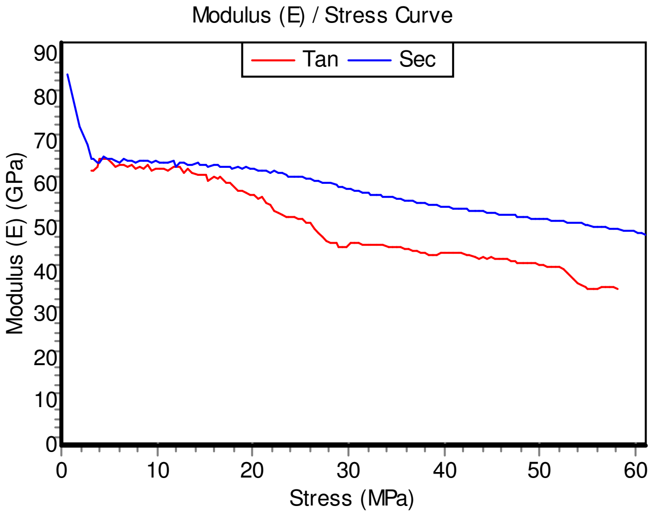
% Strength	Strength (MPa)	E Tan (GPa)	E Sec (GPa)	v Tan	v Sec
10	19.4	77.2	77.2	0.091	0.089
20	38.7	76.8	77.1	0.094	0.092
30	58.1	76.5	77.1	0.099	0.093
40	77.4	76.6	76.9	0.099	0.094
50	96.8	76.4	76.8	0.107	0.096
60	116	76.6	76.8	0.111	0.098
70	136	76.3	76.7	0.113	0.100
80	155	76.6	76.7	0.118	0.102
90	174	90.8	76.7	0.110	0.104

UNIAXIAL COMPRESSION TEST

WITH ELASTIC MODULUS AND POISSON'S RATIO MEASUREMENTS BY MEANS OF STRAIN GAUGES







Failure Load: 129.9 kN

Peak Strength: 61.06 MPa

Axial Strain at Failure: 1256 microstrain

% Strength	Strength (MPa)	E Tan (GPa)	E Sec (GPa)	v Tan	v Sec
10	6.11	64.5	65.3	0.106	0.103
20	12.2	64.1	65.2	0.108	0.102
30	18.3	59	64.4	0.095	0.102
40	24.4	52.3	61.8	0.082	0.099
50	30.5	46.5	58.9	0.091	0.095
60	36.6	45	56.3	0.095	0.094
70	42.7	43.5	54.2	0.108	0.095
80	48.8	42.1	52.5	0.119	0.097
90	55	36.1	50.6	0.100	0.099

UNIAXIAL COMPRESSION TEST

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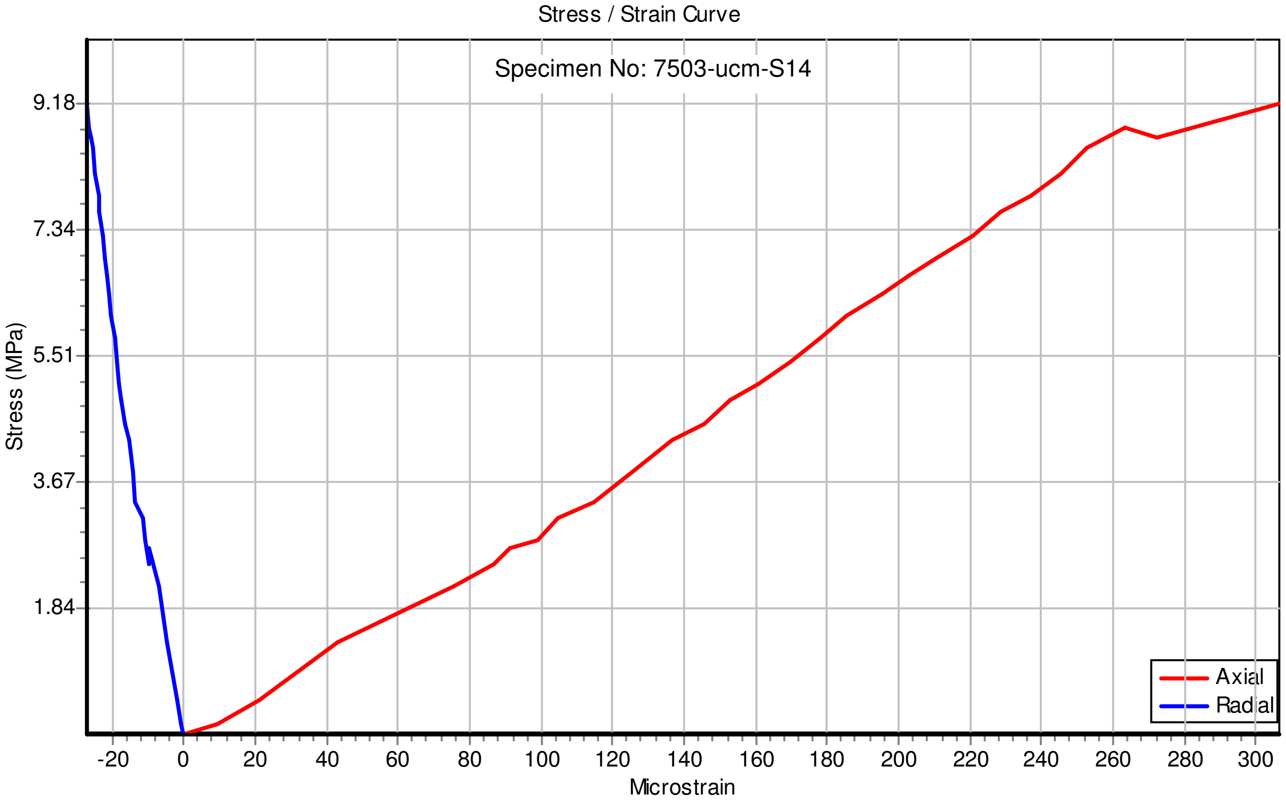
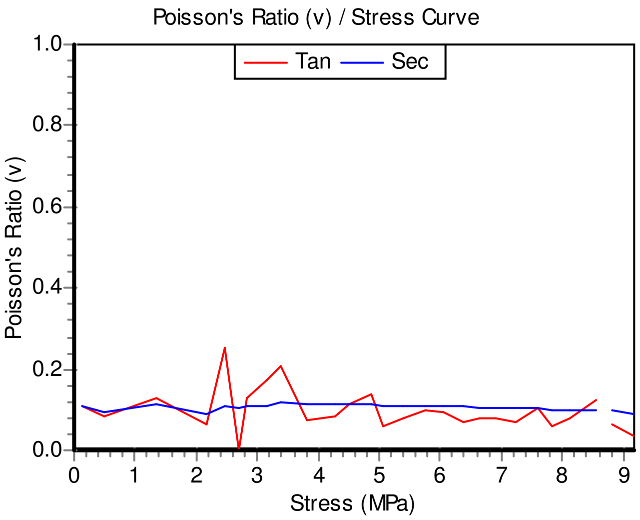
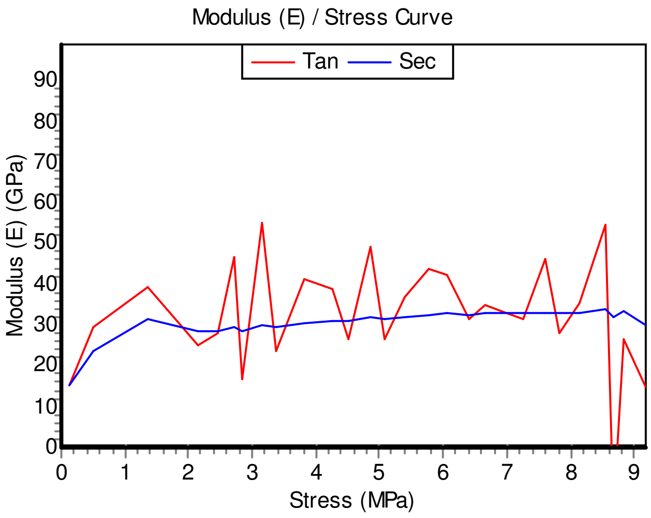
WITH ELASTIC MODULUS AND POISSON'S RATIO MEASUREMENTS BY MEANS OF STRAIN GAUGES







Failure Load: 26.78 kN

Peak Strength: 9.18 MPa

Axial Strain at Failure: 307 microstrain

% Strength	Strength (MPa)	E Tan (GPa)	E Sec (GPa)	v Tan	v Sec
10	0.918	39.2	31.4	0.129	0.112
20	1.84	25	28.6	0.062	0.090
30	2.75	16.9	28.6	0.130	0.107
40	3.67	41.5	30.5	0.075	0.115
50	4.59	49.3	31.8	0.137	0.114
60	5.51	43.9	32.4	0.098	0.109
70	6.43	35.1	32.8	0.078	0.105
80	7.34	46.1	33.2	0.103	0.103
90	8.26	54.8	33.8	0.123	0.101

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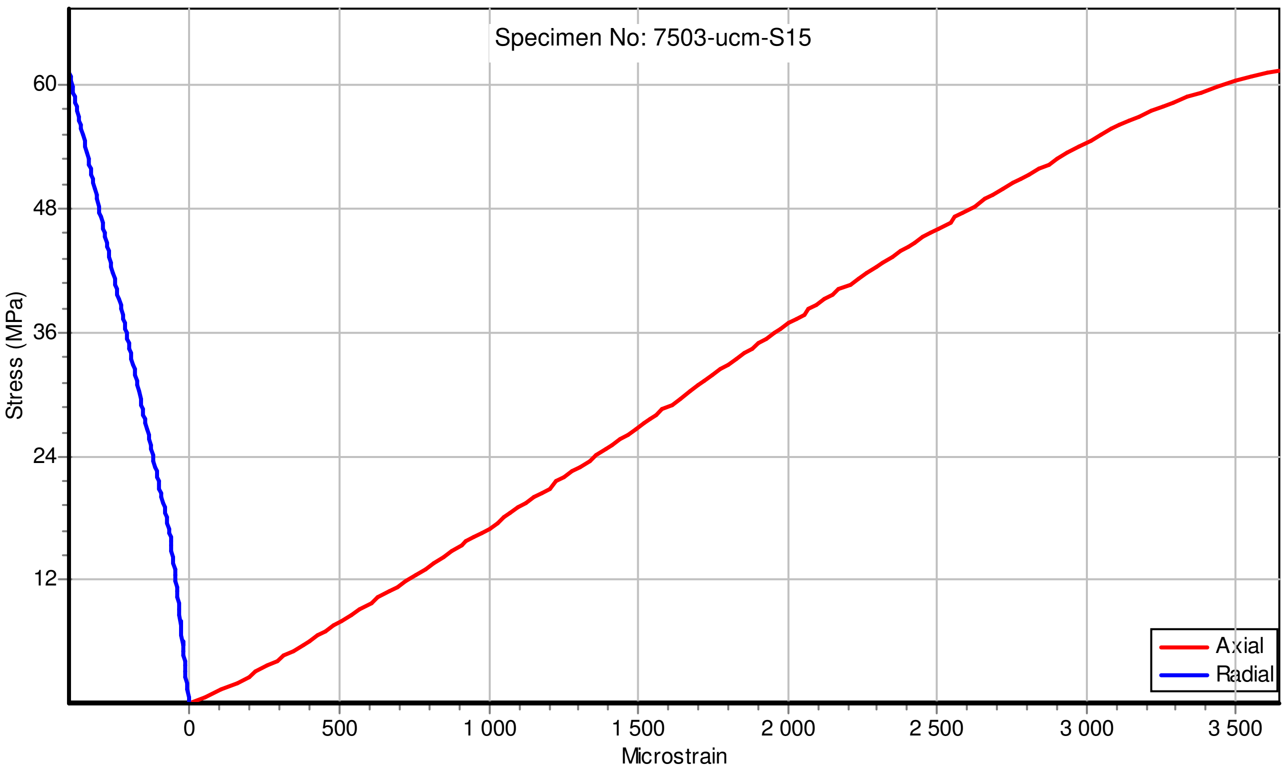
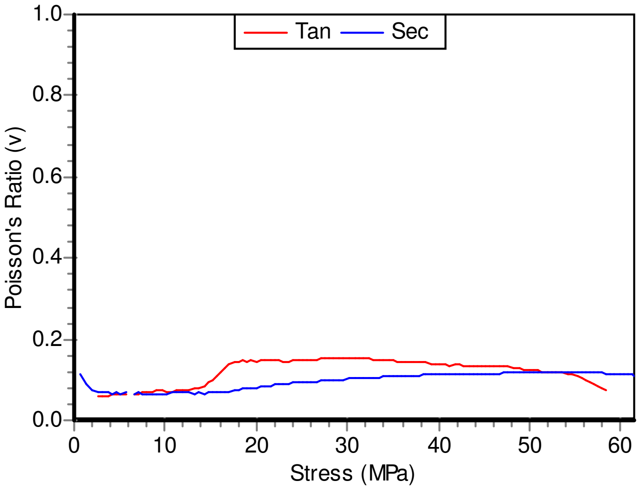
UNIAXIAL COMPRESSION TEST

WITH ELASTIC MODULUS AND POISSON'S RATIO MEASUREMENTS BY MEANS OF STRAIN GAUGES

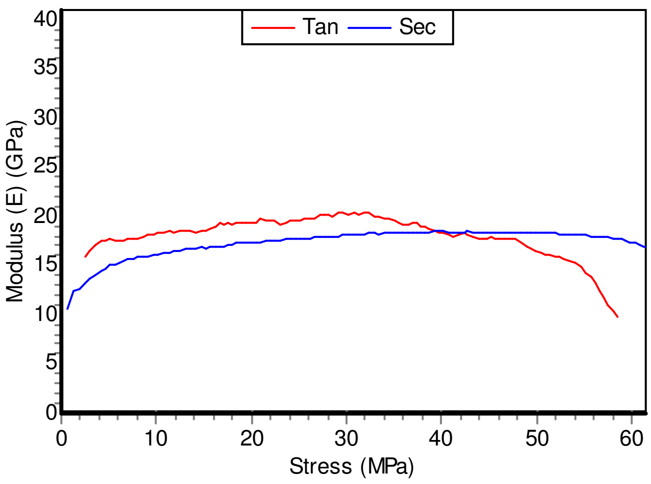
Stress / Strain Curve



Poisson's Ratio (v) / Stress Curve



Modulus (E) / Stress Curve



Failure Load: 172.2 kN

Peak Strength: 61.45 MPa

Axial Strain at Failure: 3647 microstrain

% Strength	Strength (MPa)	E Tan (GPa)	E Sec (GPa)	v Tan	v Sec
10	6.15	17.6	15.5	0.065	0.066
20	12.3	18.5	16.5	0.076	0.068
30	18.4	19.5	17.3	0.147	0.077
40	24.6	19.5	17.7	0.147	0.093
50	30.7	20.3	18.1	0.153	0.103
60	36.9	19.3	18.4	0.145	0.110
70	43	18	18.4	0.135	0.115
80	49.2	16.7	18.4	0.125	0.117
90	55.3	13.8	18	0.104	0.117

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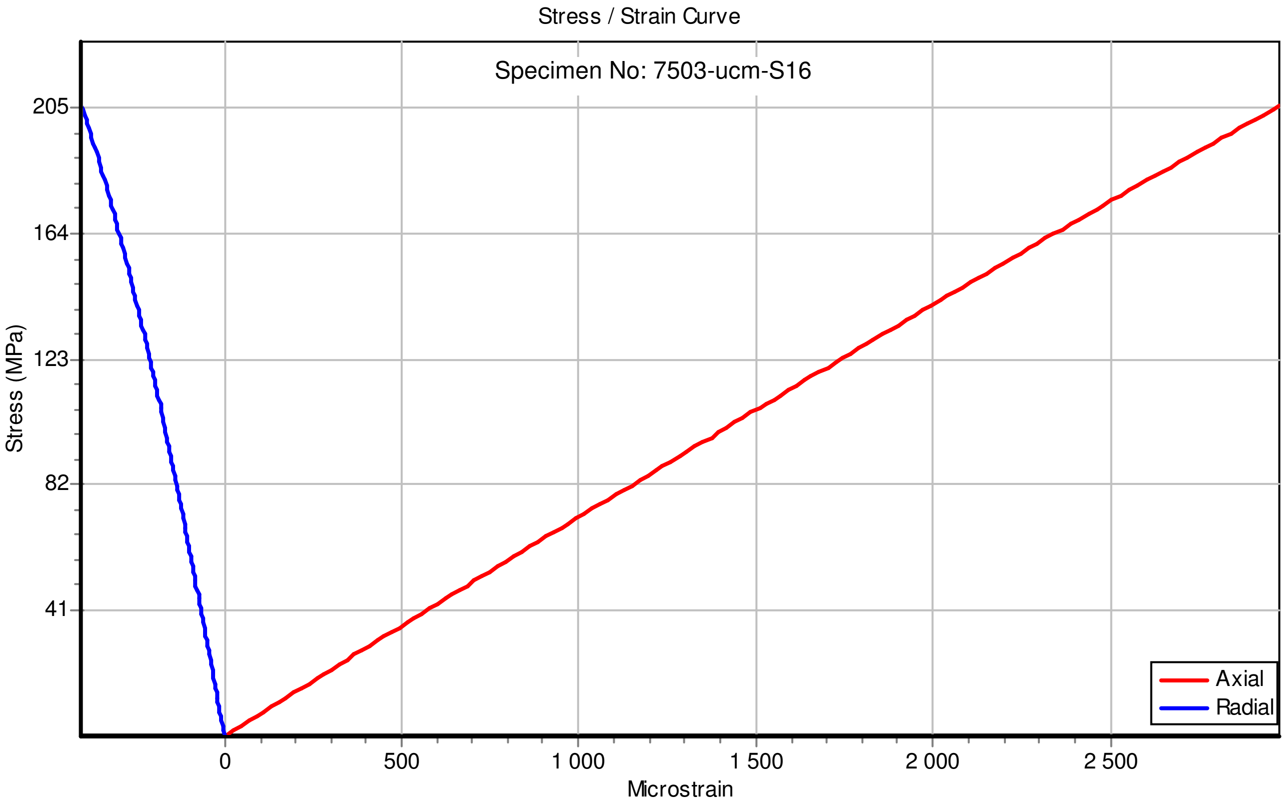
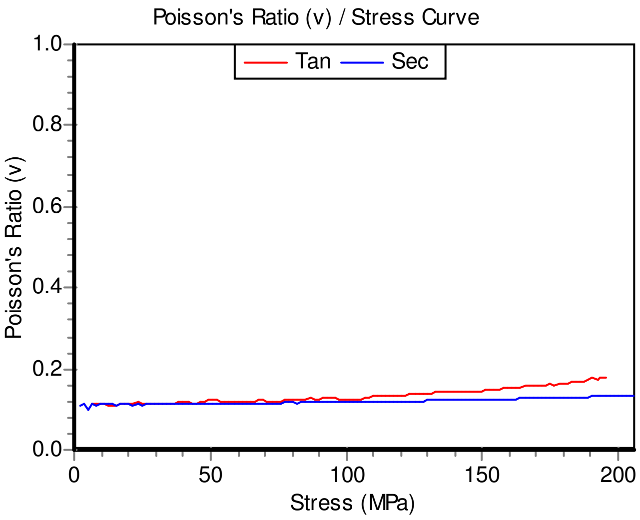
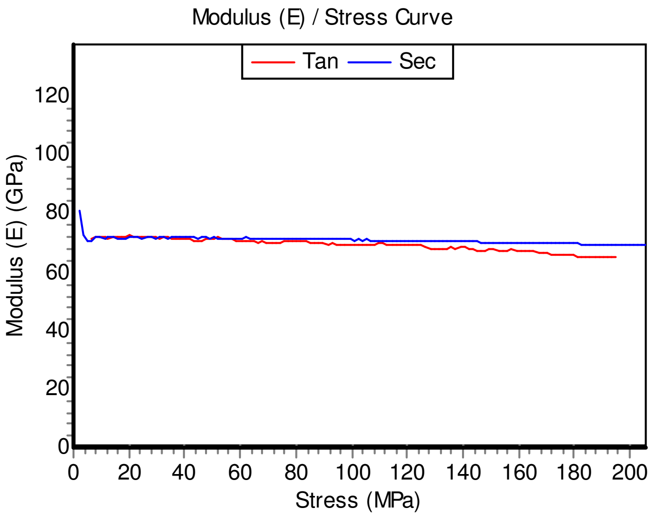
WITH ELASTIC MODULUS AND POISSON'S RATIO MEASUREMENTS BY MEANS OF STRAIN GAUGES







Failure Load: 588.3 kN

Peak Strength: 205.7 MPa

Axial Strain at Failure: 2977 microstrain

% Strength	Strength (MPa)	E Tan (GPa)	E Sec (GPa)	v Tan	v Sec
10	20.6	72.1	71.8	0.115	0.111
20	41.1	71.1	72	0.117	0.114
30	61.7	70.8	71.8	0.118	0.116
40	82.3	70.5	71.3	0.124	0.117
50	103	69.3	71	0.122	0.119
60	123	69.2	70.7	0.138	0.121
70	144	67.6	70.4	0.144	0.124
80	165	67	70	0.157	0.127
90	185	65.4	69.6	0.169	0.130

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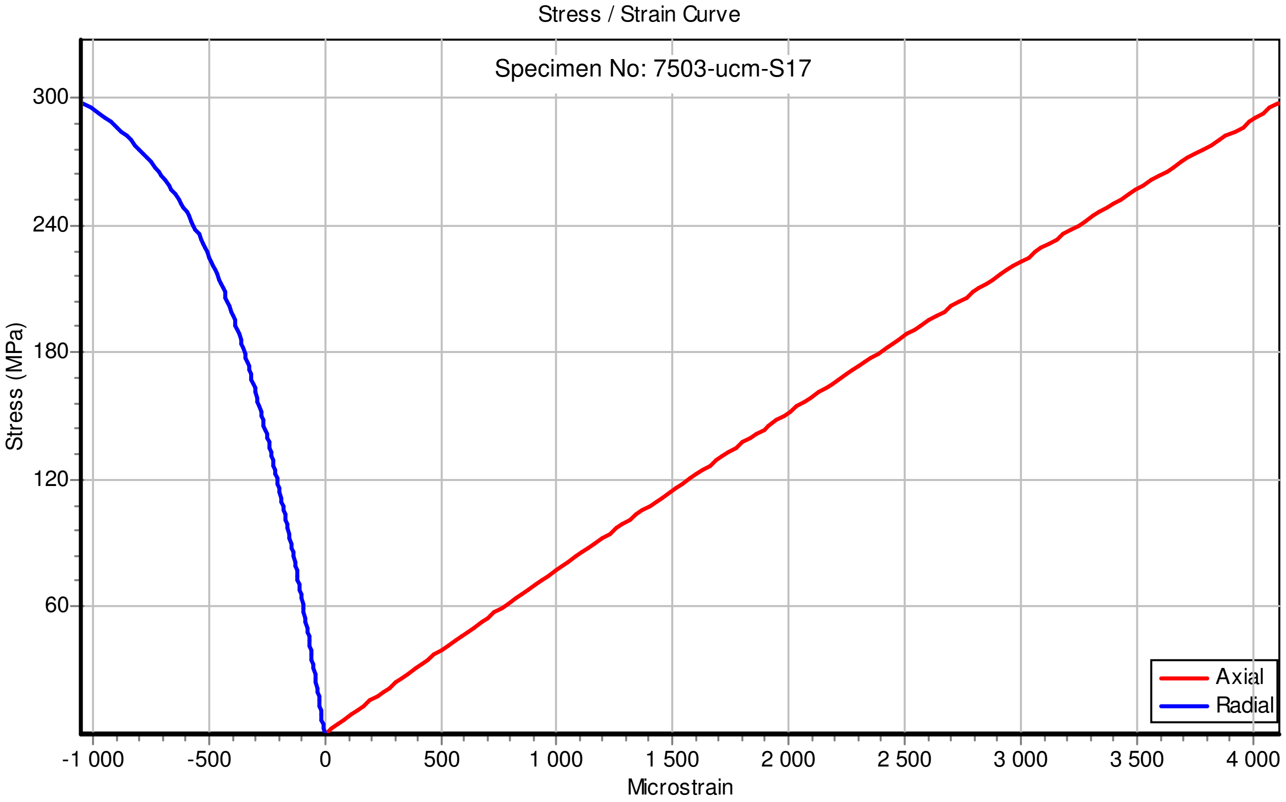
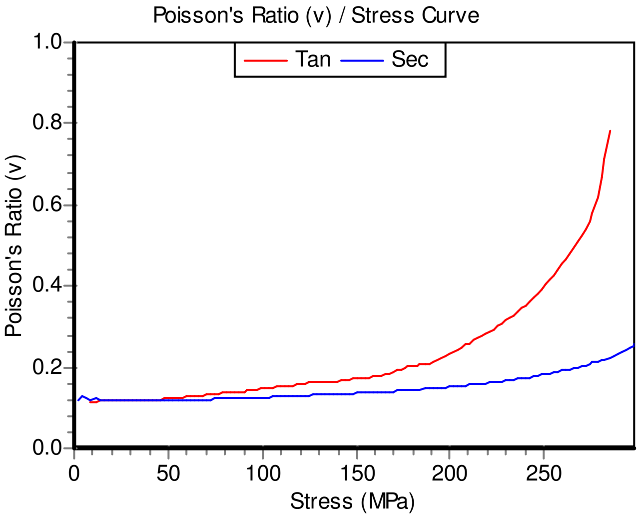
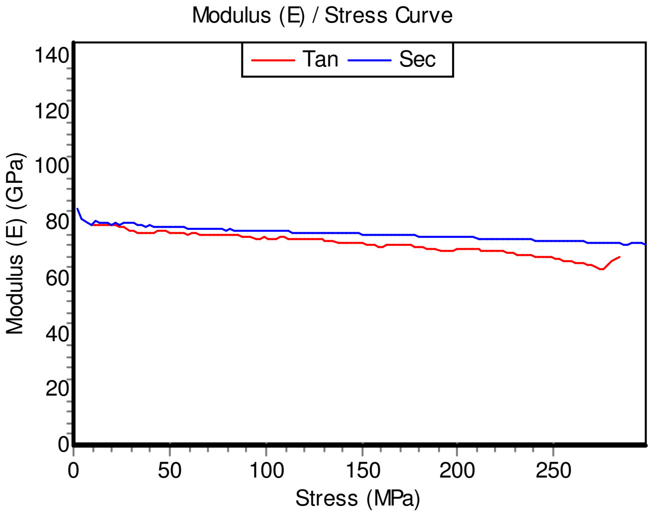
WITH ELASTIC MODULUS AND POISSON'S RATIO MEASUREMENTS BY MEANS OF STRAIN GAUGES







Failure Load: 848 kN

Peak Strength: 297.8 MPa

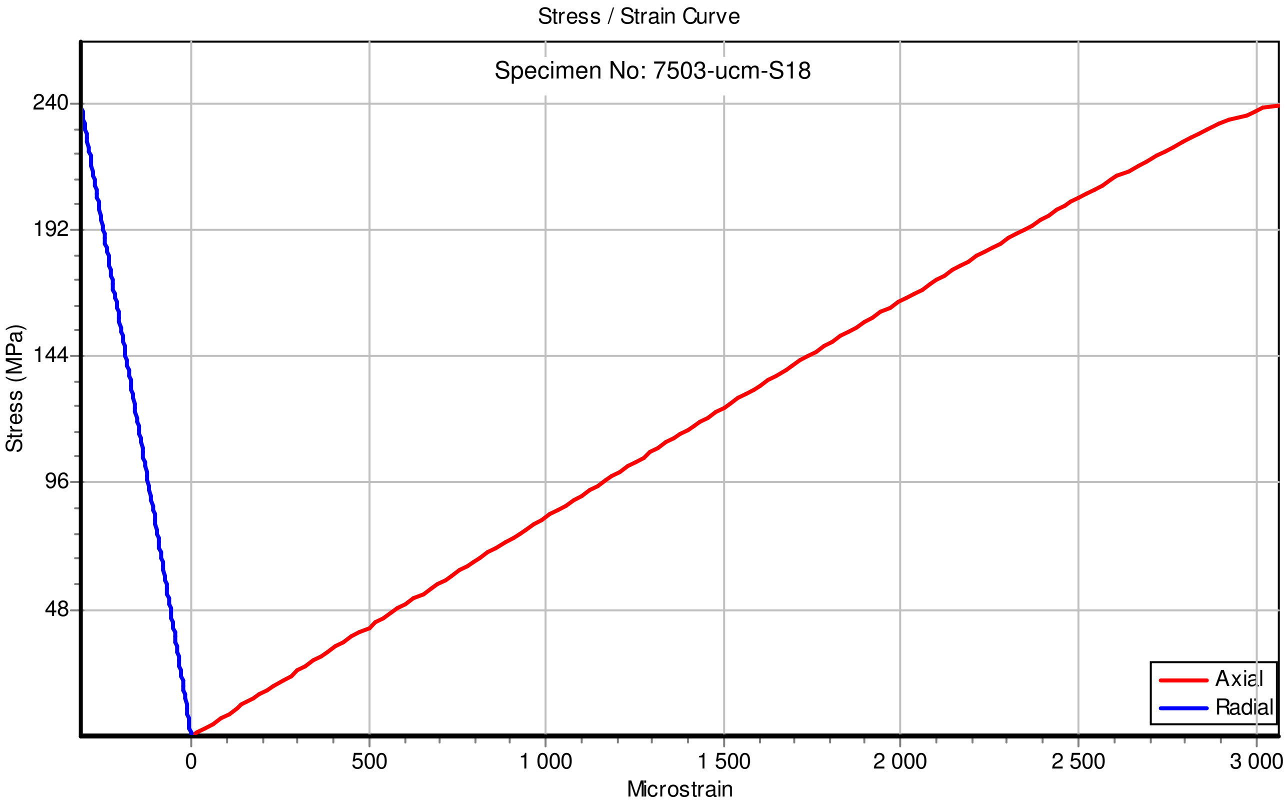
Axial Strain at Failure: 4114 microstrain

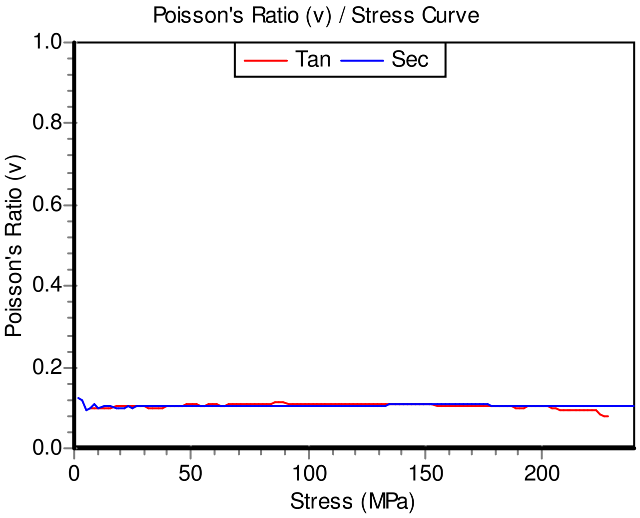
% Strength	Strength (MPa)	E Tan (GPa)	E Sec (GPa)	v Tan	v Sec
10	29.8	77	79.8	0.118	0.119
20	59.6	76.2	78.2	0.128	0.120
30	89.3	74.9	77.4	0.139	0.125
40	119	74.4	76.7	0.159	0.130
50	149	72.7	76	0.173	0.137
60	179	71.4	75.3	0.204	0.144
70	208	70.5	74.6	0.259	0.156
80	238	68.1	73.9	0.353	0.174
90	268	64.6	73.1	0.523	0.203

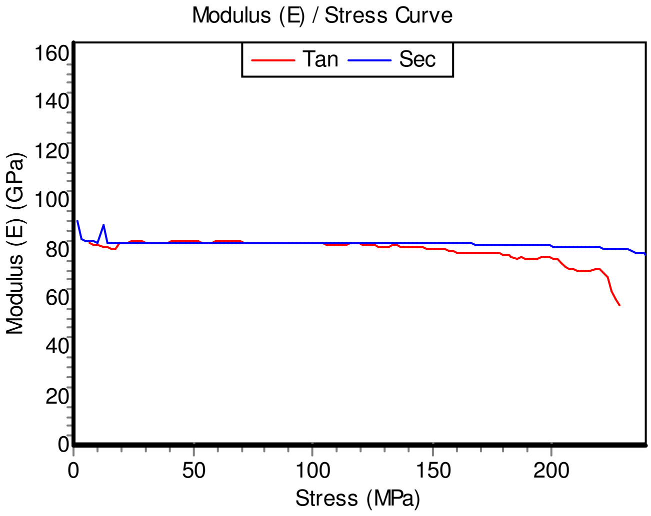
UNIAXIAL COMPRESSION TEST

2018/06/06 01:33:03 PM

WITH ELASTIC MODULUS AND POISSON'S RATIO MEASUREMENTS BY MEANS OF STRAIN GAUGES







Failure Load: 689 kN

Peak Strength: 239.3 MPa

Axial Strain at Failure: 3065 microstrain

% Strength	Strength (MPa)	E Tan (GPa)	E Sec (GPa)	v Tan	v Sec
10	23.9	83.4	83	0.105	0.101
20	47.9	83.4	83.1	0.107	0.102
30	71.8	83	83.2	0.107	0.103
40	95.7	82.8	83.1	0.109	0.106
50	120	82.3	83	0.109	0.106
60	144	81.4	82.9	0.108	0.107
70	168	78.7	82.5	0.105	0.107
80	191	76.3	81.9	0.101	0.106
90	215	71.7	81	0.095	0.105

APPENDIX 3

CLASSIFICATION OF ROCK SPECIMEN FAILURE MODE INFLUENCED / NOT INFLUENCED BY DISCONTINUITIES DURING COMPRESSION TESTING

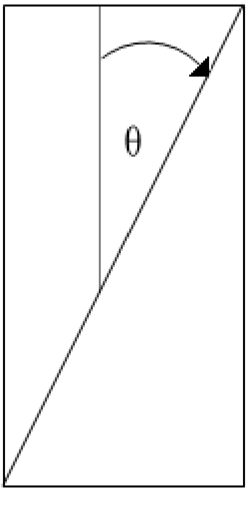
FAILURE NOT INFLUENCED BY DISCONTINUITIES (INTACT)

TYPE CODE	DESCRIPTION OF SUB CODES	
	A	B
X	SLIDING SHEAR FAILURE	COMPLETE CONE DEVELOPMENT
Y	SPLITTING	BREAKING INTO A LOT OF PIECES

FAILURE INFLUENCED BY DISCONTINUITIES

TYPE CODE	DESCRIPTION OF SUB CODES	
	A	B
	PARTIAL FAILURE ON DISCONTINUITY	FAILURE COMPLETELY ON DISCONTINUITY
1	AT 0-10° TO AXIS	AT 0-10° TO AXIS
2	AT 11-20° TO AXIS	AT 11-20° TO AXIS
3	AT 21-30° TO AXIS	AT 21-30° TO AXIS
4	AT 31-40° TO AXIS	AT 31-40° TO AXIS
5	AT 41-50° TO AXIS	AT 41-50° TO AXIS
6	AT 51-70° TO AXIS	AT 51-70° TO AXIS
7	AT 71-90° TO AXIS	AT 71-90° TO AXIS
0	Multiple Discontinuities	Multiple Discontinuities

Example: Failure Type3B: Failure completely on a discontinuity with an orientation of between 21°and 30° to the specimen axis.



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Email: info@soillab.co.za

PO Box 72928, Lynnwood Ridge,
South Africa, 0040

Project:	ROCKLAB
Project No.:	#7503
Date:	2018/06/20

TESTS ON CRUSHED STONE AGGREGATES		
Soillab sample number	S18-1183-01	S18-1183-02
Sample Number	CRUSHED STONE	CRUSHED STONE
Sample Position	S1	S2
Description of Rock	QUARTZITE	QUARTZITE

SIEVE ANALYSIS (% Passing)			
Sieve size (mm)	**SANS 3001-AG1**		
50.0			
37.5			
28			
20			
14			
10			
7.1			
5			
2			
1			
0.600			
0.425			
0.300			
0.150			
0.075			
Flakiness Index (%) **(SANS 3001-AG4)**	-28mm + 20mm		
	-20mm + 14mm		

Other Tests					
Atterberg Limits	**SANS 3001-GR10/GR11**	<0.425	<0.075	<0.425	<0.075
Liquid Limit					
Plasticity Index					
Linear Shrinkage					

		Wet	Dry	Glycol	Wet	Dry	Glycol
Aggregate Crushing value	**SANS 3001-AG10**						
10% Fines value (kN)	**SANS 3001-AG10**						
Wet/Dry Ratio	**SANS 3001-AG10**						
Average least dimension (mm)	**SANS 3001-AG2**						
Sand equivalent	**SANS 3001-AG5**						
pH	**TMH 1 A20**						
* Total water sol. Salts (%)	**SANS 5849**						
* Total water sol. Sulphates (%)	**SANS 5850**						
Conductivity (Sm^{-1})	**TMH 1 A21T**						
* Chloride Content	**SANS 202**						
* Sugar	**SANS 5833**						
* Methylene Blue Adsorption	**SANS 6243**						
* Bulk density (uncompacted) (kg/m^3)	**SANS 5845**						
* Bulk density (compacted) (kg/m^3)	**SANS 5845**						
Bulk Relative Density	**SANS 3001-AG20/AG21**						
App. Relative Density	**SANS 3001-AG22**						
Water absorption (%)	**SANS 3001-AG20**						
* Ethylene Glycol: Durability Index	**SANS 3001-AG14/COLTO 8105**						
* Los Angeles Abrasion loss (%) after 100/500 rev	**SANS 5846**						
* Adhesion (Riedel & Weber no.)	**TMH 1 B11**						
* Alkali silica reaction	**SANS 6245**						
* Shrinkage as percent of Quartzite reference	**SANS 5836**						
* Expansion as percent of Quartzite reference	**SANS 5836**						
* Weathering MgSO$_4$ Representative loss (%)	**SANS 5839**	0.43			0.16		

Note: Items marked with an asterisk (*) is Not Accredited

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La Montagne, Pretoria, 0184
PO Box 72928, Lynnwood Ridge,
South Africa, 0040

Project:	ROCKLAB
Project No.:	#7503
Date:	2018/06/20

TESTS ON CRUSHED STONE AGGREGATES		
Soillab sample number	S18-1183-03	
Sample Number	S25 - S34	
Sample Description	CRUSHED STONE	
Description of Rock	QUARTZITE	

SIEVE ANALYSIS (% Passing)

Sieve size (mm)	**SANS 3001-AG1**		
50.0			
37.5			
28			
20			
14			
10			
7.1			
5			
2			
1			
0.600			
0.425			
0.300			
0.150			
0.075			
Flakiness Index (%) **(SANS 3001-AG4)**	-28mm + 20mm	30.7	
	-20mm + 14mm	26.5	

Other Tests

Atterberg Limits	**SANS 3001-GR10/GR11**	**<0.425**	**<0.075**	**<0.425**	**<0.075**
Liquid Limit					
Plasticity Index					
Linear Shrinkage					

		Wet	**Dry**	**Glycol**	**Wet**	**Dry**	**Glycol**
Aggregate Crushing value	**SANS 3001-AG10**	16.1	15.0				
10% Fines value (kN)	**SANS 3001-AG10**	270	295				
Wet/Dry Ratio	**SANS 3001-AG10**	92					
Average least dimension (mm)	**SANS 3001-AG2**						
Sand equivalent	**SANS 3001-AG5**						
pH	**SANS 5854**						
* Total water sol. Salts (%)	**TMH 1 B16T**						
* Total water sol. Sulphates (%)	**TMH 1 B17T/BS1377**						
Conductivity (Sm^{-1})	**SANS 6240**						
* Organic Impurities	**SANS 5845**	LIGHTER THAN INDICATOR					
* Bulk density (uncompacted) (kg/m^3)	**SANS 5845**						
* Bulk density (compacted) (kg/m^3)	**SANS 5845**						
Apparent Density (kg/m^3)	**SANS 3001-AG22**	2551					
Bulk Relative Density (kg/m^3)	**SANS 3001-AG20**	2518					
Apparent Relative Density (kg/m^3)	**SANS 3001-AG20**	2564					
Water absorption (%)	**SANS 3001-AG20**	0.7					
* Ethylene Glycol: Durability Index	**SANS 3001-AG14/COLTO 8105**						
* Los Angeles Abrasion loss (%) after 100/500 rev	**SANS 5846**						
* Adhesion (Riedel & Weber no.)	**TMH 1 B11**						
* Alkali silica reaction	**SANS 6245**	0.064					
* Shrinkage as percent of Quartzite reference	**SANS 5836**	84.3					
* Expansion as percent of Quartzite reference	**SANS 5836**	73.3					
* Weathering NaSO$_4$ Representative loss (%)	**SANS 5839**						

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PO Box 72928, Lynnwood Ridge,
South Africa, 0040

Client: ROCKLAB
Project: 7503
Project No.: S18-1183
Date: 2018/06/05

TEST RESULTS: CHEMICAL

Soillab No	**Sample No**	**Cl content (%) *SANS 202**	**Soluble SO3 (%) *SANS 5850**	**Sugar *SANS 5833**	**Methylene Blue Adsorption *SANS 6243**
S18-1183-03	S25 - S34	0.0117	0.0175	Not Present	0.05
		0.0131	0.0178	Not Present	0.05
		0.0106	0.0171		
		0.0106	0.0171		
S18-1183-04	S3				0.05
S18-1183-05	S4				0.05

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ALKALI-SILICA REACTIVITY - SANS 6245*

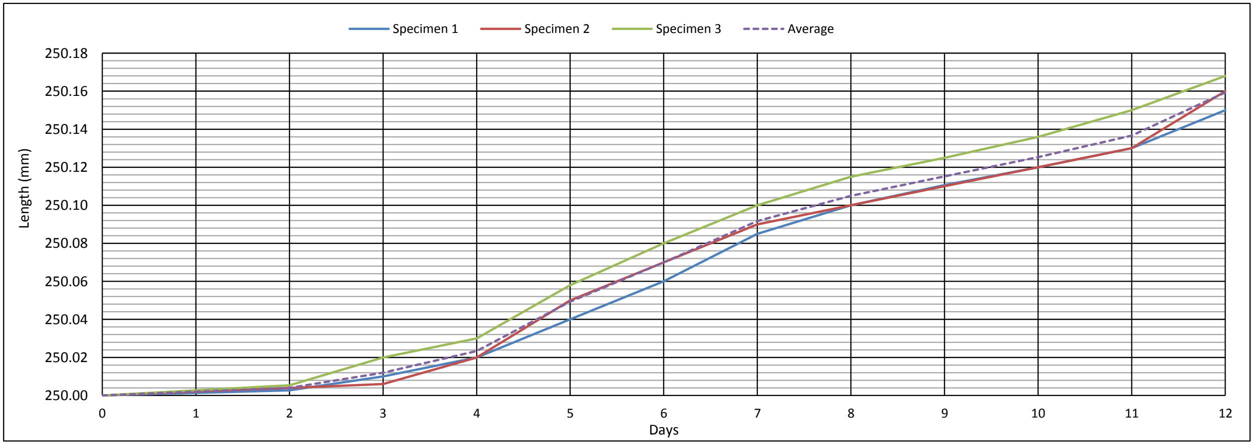
Client:	ROCKLAB	**Soillab Job No.:**	S18-1183
Project:	7503		
Sample description:	S25, S26, S27, S28, S29, S30, S31, S32, S33, S34		
Cement used:	PPC OPC 52,5N	**Flow of mortar (%):**	116.5

PROPORTIONATE AGGREGATE FRACTIONS

Sieve Size (mm)	Mass Retained (g)	% Passing	Method of Preparation
4.75	0	100	Sample washed, dried, crushed and sieved according to SANS 6245
2.36	135	90	
1.18	338	65	
0.60	338	40	
0.30	338	15	
0.15	203	0	

LINEAR EXPANSIONS

	Specimen Length (mm)			
Date	**Specimen 1**	**Specimen 2**	**Specimen 3**	**Average**
15-Jun	250.00	250.00	250.00	250.00
16-Jun	250.00	250.00	250.00	250.00
17-Jun	250.00	250.00	250.01	250.00
18-Jun	250.01	250.01	250.02	250.01
19-Jun	250.02	250.02	250.03	250.02
20-Jun	250.04	250.05	250.06	250.05
21-Jun	250.06	250.07	250.08	250.07
22-Jun	250.09	250.09	250.10	250.09
23-Jun	250.10	250.10	250.12	250.11
24-Jun	250.11	250.11	250.13	250.12
25-Jun	250.12	250.12	250.14	250.13
26-Jun	250.13	250.13	250.15	250.14
27-Jun	250.15	250.16	250.17	250.16
Total Linear Expansion (%)	**0.060**	**0.064**	**0.067**	**0.064**



CRITERIA - According to COLTO - 1998 Edition

Percentage of linear expansion after:	10 days	12 days
The alkali reactivity of the aggregate is not harmful	<0.08	<0.10
The alkali reactivity of the aggregate is harmful and the aggregate is expanding slowly	≥ 0.08 but < 0.20	≥ 0.10 but < 0.25
The alkali reactivity of the aggregate is harmful and the aggregate is expanding rapidly	≥ 0.20	≥ 0.25

INTERPRETATION - According to COLTO - 1998 Edition

For aggregates falling in the slowly expanding group, the alkalinity per m^3 of concrete shall not exceed 2.80 kg of an Na_2O equivalent.

For aggregates falling in the rapidly expanding group, the alkalinity per m^3 of concrete shall not exceed a value of 2.10 kg of an Na_2O equivalent per m^3, depending on the reactivity.

The dilution and palliative effect of extenders in the cementitious binders, such as slagment (where permitted in structural concrete) and fly ash, shall be taken into account in the interpretation of the results.

ADDITIONAL NOTES

** Not Accredited*

Dr Sabine Verryn

m: 083 548 0586
f: 086 565 7368
e: sabine.verryn@xrd.co.za

XRD Analytical and Consulting cc
75 Kafue Street, Lynnwood Glen,
0081, South Africa

CLIENT: Soillab

DATE: 12 June 2018

SAMPLES: 1 Sample (S25-S34)

ANALYSIS: Petrographic analysis & XRD

REPORT ON 1 Sample in duplicate

1. SERVICE REQUESTED

Petrographic description & XRD

2. SAMPLE DESCRIPTION

Stone

3. TESTS CONDUCTED

2 x Thin Section, 2 x XRD

4. DESCRIPTION & ANALYSIS

Two thin sections were prepared from a fragment set in epoxy and the remainder of the sample was crushed, split and milled for XRD analysis.

NOTE:

Quantities of minerals shown in the petrographic description are largely based on amounts calculated from XRD analysis as this reflects a more representative composition.

XRD

The material was prepared for XRD analysis using a back loading preparation method.
It was analysed with a PANalytical Aeris diffractometer with PIXcel detector and fixed slits with Fe filtered Co-Kα radiation. The phases were identified using X'PertHighscore plus software.

The relative phase amounts (weight %) were estimated using the Rietveld method. Mineral names may not reflect the actual compositions of minerals identified, but rather the mineral group. Due to crystallite size and preferred orientation effects, results may not be as accurate as shown. Mineral quantities observed of the overall sample in thin section are in agreement with those calculated from XRD.

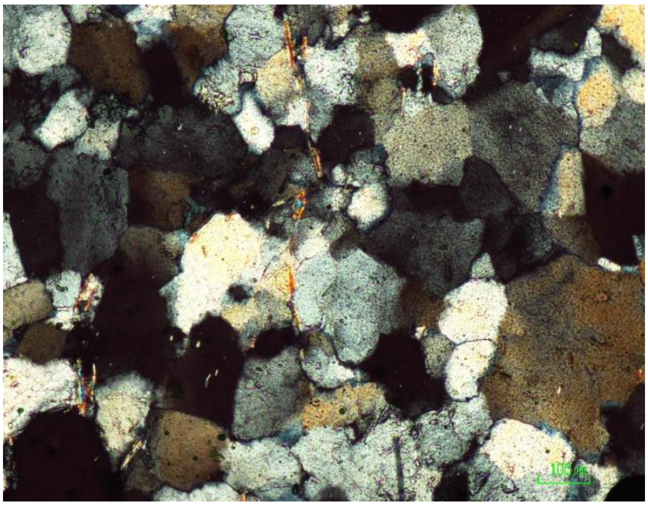
XRD Results:

Soillab_525-535		**Soillab_525-535_2**	
Kaolinite	2	Kaolinite	1
Muscovite	1	Muscovite	1
Quartz	97	Quartz	98

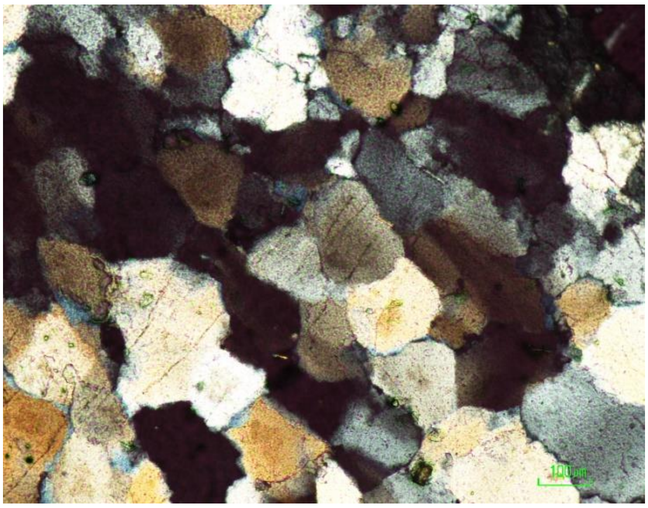
PETROGRAPHIC DESCRIPTIONS

Soillab_S25-S34 - 1

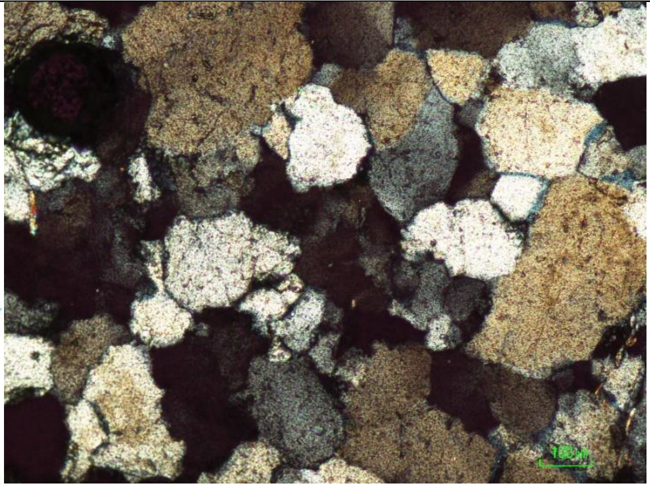
Sample type:	Meta-Sandstone
Macroscopic description:	The sample is composed of rock fragments of light grey rock of fine grain size.
Microscopic description:	The sample investigated in thin section overall comprises of quartz (~97%) showing moderate to high degree undulatory extinction with minor kaolinite (~2%) and minor muscovite (~1%). The sample consists of mainly interlocking holocrystalline quartz grains with finely dispersed muscovite and therefore may represent meta-sandstone. With the making of thin section, the kaolinite probably was plugged out and left behind tiny holes, which can be seen under the microscope.
.	
Grain size data:	100 - 500 micron



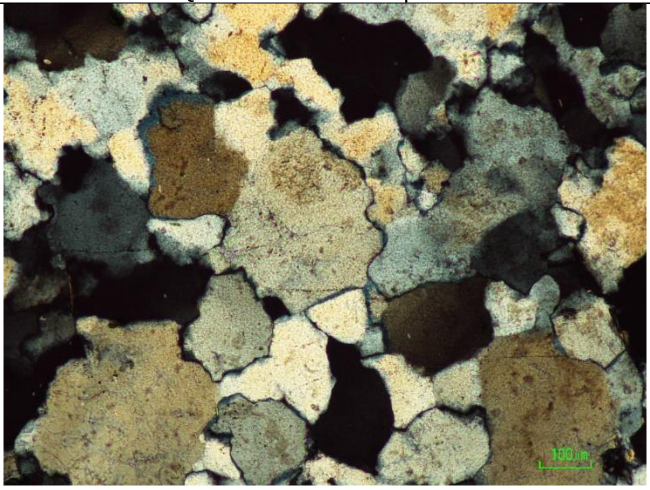
Photomicrograph**:** Cross polarized light. 10x Magnification. Quartz and fine needles of muscovite



Photomicrograph**:** Cross polarized light. 10x Magnification. Quartz and strained quartz



Photomicrograph**:** Cross polarized light. 10x Magnification. Quartz



Photomicrograph**:** Cross polarized light. 10x Magnification. Quartz and strained quartz

Soillab_S25-S34 - 2

Sample type:	Meta-Sandstone
Macroscopic description:	The sample is composed of rock fragments of light grey rock of fine grain size.
Microscopic description:	The sample investigated in thin section overall comprises of quartz (~98%) showing moderate to high degree undulatory extinction with minor kaolinite (~1%) and minor muscovite (~1%). The sample consists of mainly interlocking holocrystalline quartz grains with finely dispersed muscovite and therefore may represent meta-sandstone. With the making of thin section, the kaolinite probably plugged out which left behind tiny holes, visible under the microscope. .

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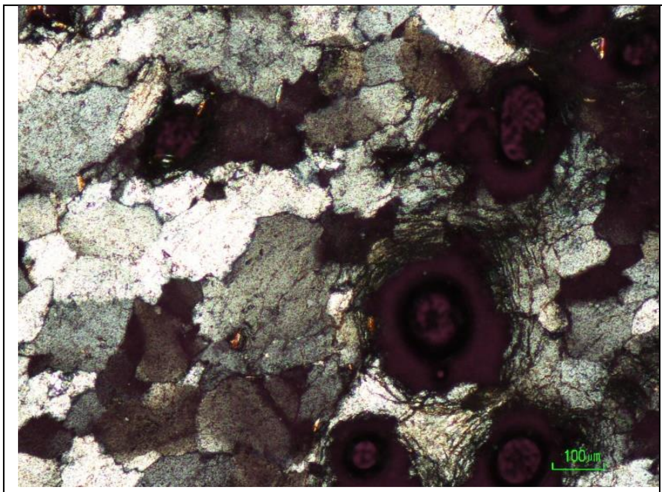
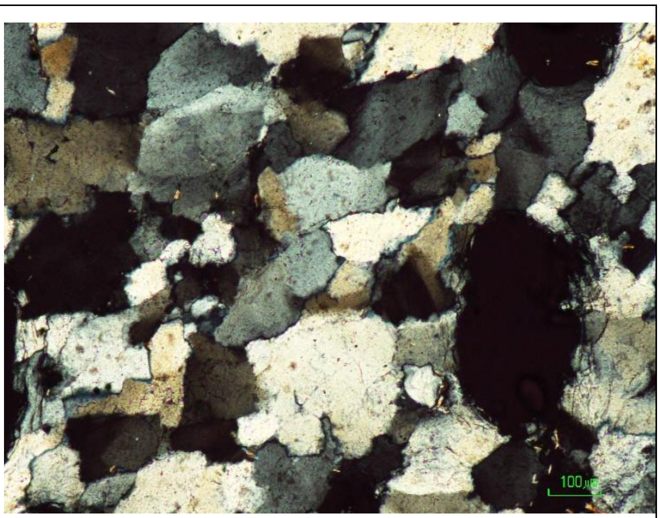
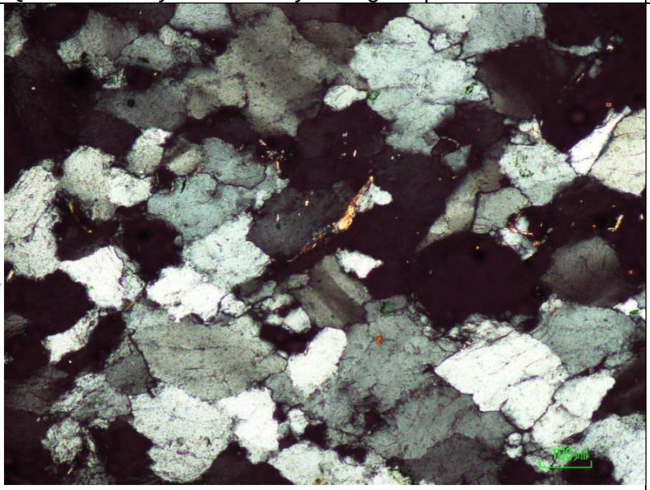
Grain size data:	100 - 500 micron



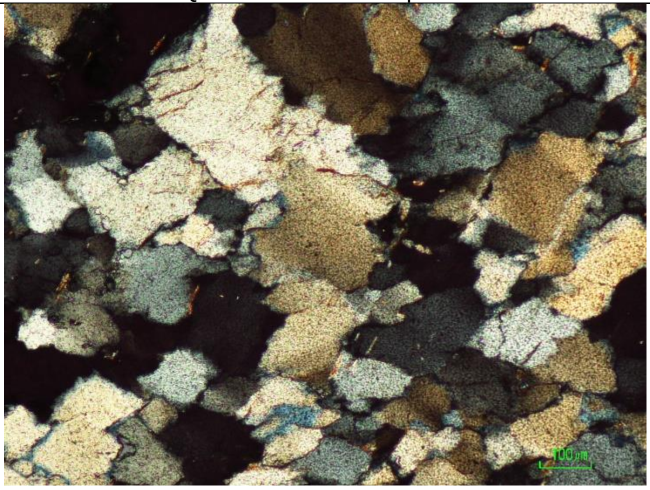
Photomicrograph**:** Cross polarized light. 10x Magnification. Quartz and tiny holes – maybe original position of kaolinite



Photomicrograph**:** Cross polarized light. 10x Magnification. Quartz and strained quartz



Photomicrograph**:** Cross polarized light. 10x Magnification. Quartz and fine needles of muscovite



Photomicrograph**:** Cross polarized light. 10x Magnification. Quartz and strained quartz

5. **COMMENTS**

Rock-types are based on mineralogy and texture rather than stratigraphic position

Depending on the intended use of the material the following comments can be made:

- The samples essentially consist of quartz, showing moderate to high undulatory extinction.
- Due to the high amount of strained quartz in the samples, reaction with alkalis in cement can occur - unless otherwise shown by additional tests.
- The sample maybe classified as meta-sandstone.

SVerryn.

Dr SMC VERRYN (Ph.D., Pr.Sci.Nat).

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