GEOTECHNICAL INVESTIGATION FOR THE PROPOSED ARLINGTON CEMETERY

Prepared by:

DWALA GROUP
No Limitations

Prepared for:

NKETOANA LOCAL MUNICIPALITY

Document prepared by:
Dwala Group Pty LTD
2014/223042/07

T +27 64 538 580
F +27 64 538 580
E info@dwalagroup.com
W dwalagroup.com

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EXECUTIVE SUMMARY

Dwala Group (Pty) Ltd was appointed by Nketoana Local Municipality to conduct a geotechnical investigation for the proposed Arlington Cemetery in the Free State Province.

The field investigation was carried out on the 1st of September 2021. The investigation comprised excavation of five (5 No) test pits. Selected representative samples were retrieved and submitted to a SANAS accredited laboratory testing. The geotechnical assessment is mandatory for identifying potential risks associated with the geotechnical conditions and constraints on the proposed new cemetery site.

According to the 1:250 000 geological map of the Winburg Sheet 2826 (Council for Geoscience, 1992), the proposed site is underlain by fine- to medium-grained, yellow and khaki-coloured sandstone; red, purple, blue and green mudstone of the Tarkstad Subgroup of the Beaufort Group of the Karoo Sequence.

The geotechnical investigation revealed that the profile across the site comprises the following horizons:

- Transported horizon;
- Pedogenic horizon;
- Residual mudrock horizon;and
- Mudrock bedrock horizon;

Where there is shallow bedrock (<1.8m); excavatibilty with a pick and shovel will be a problem. It is recommended that a machine such as a TLB be used in the excavation of the graves at this site.

The study area is classified as poor according to Hall and Hanbury. The development of a cemetery on this site is permissible provided that precautions against environmental pollution are implemented. The precautions which should be applied include close attention to surface contours during site preparation, the provision of adequate storm water drainage, and the monitoring of water quality (pathogens, nitrogen compounds and phosphate levels as a minimum) in downstream drainage courses within 1 km of the site.

1. Introduction

Nketoana Local Municipality appointed Dwala Group (Pty) Ltd to conduct a geotechnical investigation for the proposed cemetery located in Arlington in the Nketoana Local Municipality, Free State Province. This geotechnical investigation was undertaken at the site on the 1st of September 2021. The investigation was carried out as per the latest guidelines for cemetery investigations in ***Report WRC Report No:2449/1/189 by Water Research Commission*** and will be evaluated and ranked according to ***Hall and Hanbury (1993)***.

A geotechnical assessment is mandatory for identifying potential risks associated with the geotechnical conditions and constraints on the cemetery site, and assesses the following:

- Site topography;
- Unstable sidewalls;
- Excavatability;
- Shallow groundwater;
- Soil types with reference to their internal drainage characteristics; and
- Soil workability.

The assessment for this study is based on a desk study and on observations made during the field investigation as well as laboratory testing. The assessment also relies on experience in cemetery geotechnical studies elsewhere in South Africa. The groundwater study is not included in this report.

The purpose of this report is to:

- Describe the investigation procedure;
- Present a discussion on the prevailing geology and any geotechnical related problems with regard to selection of a potential cemetery site;
- Determine the characteristics of the in-situ soil by means of laboratory testing;
- Evaluate and zone the areas investigated according to the suitably for development of a new cemetery site.
- Comment on any other geotechnical considerations that may have a bearing on the development.

2. Available Information

At the time of the investigation the following information was available:

- The 1:250 000 scale geological map of Winburg 2826. Geological Survey, printed in the Republic of South Africa, 1998.
- Aerial photographs, sourced from Google Earth®.

3. Site Description

3.1 Site Locality

The study area is located in Arlington, Free State, South Africa. It is located approximately 53km south west of Petrus Steyn. The site can be accessed via the R707. Figure 1 below shows the location of the investigated site.

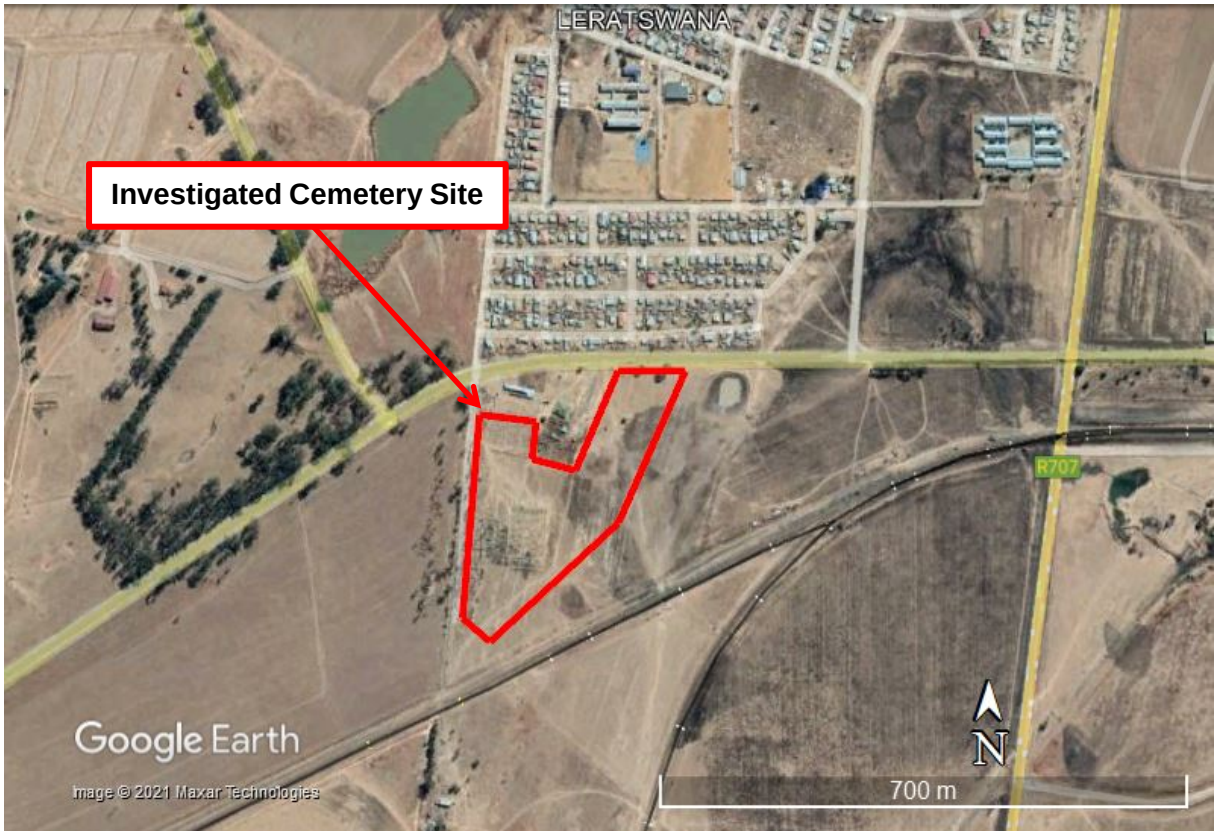

Figure 1: Showing the investigated cemetery area (red outline).

3.2 Topography and Vegetation

Topographically the investigated site for the proposed cemetery is characterized by a gentle slope, with slope angles of less than 3˚. The vegetation found at the site consists of short grass isolated short trees.

4. Climate

Arlington's climate is classified as warm and temperate. The summers are much rainier than the winters. The Köppen-Geiger climate classification is Cwb. The temperature here averages 15.7°C. The annual rainfall is 748mm, with most rainfall occurring during summer in December, with an average of 135 mm. It receives the lowest rainfall (8 mm) in July. With an average temperature of 20.4°C, January is the warmest month. July is the coldest month, with temperatures averaging 8.4°C (Climate-Data.Org: 2012).

The Weinert Climatic N-value for the area (Weinert, 1980) which is <5 indicating that the climate is semi-humid and chemical weathering processes is dominant.

5. Geology

According to the 1:250 000 geological map of the Winburg Sheet 2826 (Council for Geoscience, 1992), the proposed site is underlain by fine- to medium-grained, yellow and khaki-coloured sandstone; red, purple, blue and green mudstone of the Tarkstad Subgroup of the Beaufort Group of the Karoo Sequence as shown in Figure 2 below.

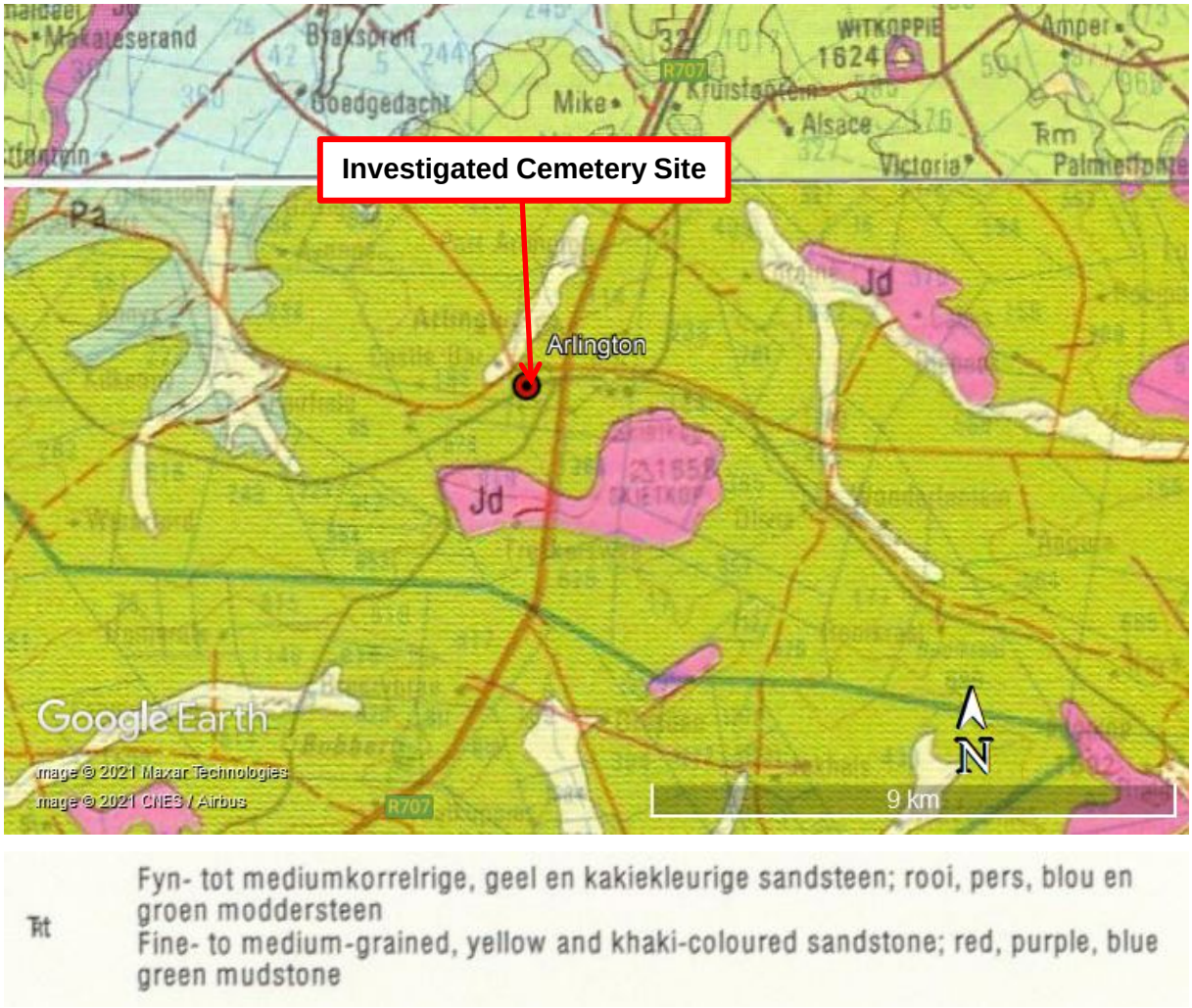

Figure 2: Showing the general geology map of the site area (red dot); (Geological Survey, printed by the Republic of South Africa, 1998).

6. Investigation Methodology

The geotechnical study was carried out in phases. The first phase was a desktop study which was followed by a second phase of fieldwork. The desktop study commenced before the field work. During the fieldwork representative samples were collected and taken to a SANAS accredited laboratory for soil testing. The investigation was carried out as per the latest guidelines for cemetery investigations in ***Report WRC Report No:2449/1/189 by Water Research Commission*** and was evaluated and ranked according to ***Hall and Hanbury (1990)***.

6.1 Desktop study

The desk study of available geological information involved perusing of aerial images, available published geological maps and relevant literature. The purpose of the study was to give technical guidance on the expected geological and geotechnical conditions on the site.

6.2 Fieldwork

The fieldwork comprised of the following;

- Walk over survey;
- Excavation and profiling of test pits; and
- Collection of representative soil samples for laboratory testing.

6.2.1 Walk over survey

Subsequent to the desktop study, a site walkover was undertaken at the proposed new cemetery, to assess the current topographical and geological conditions from surface without any intrusive work

6.2.2 Test Pitting

The field investigation comprised an excavation and profiling of five (5 No.) test pits. Test pits were excavated using a VOLVO BL61B TLB to a depth of 2.0 m or refusal on hard material. Test pits positions were marked using a hand-held GPS, on the UTM grid and WGS84 datum.

A two-person team carried out the test pitting in order to comply with accepted safety requirements as reflected in the Site Investigation Code of Practice (SAICE, 2010). The test pits were set out and profiled by a team of engineering geologists/ geotechnical engineers in accordance with South African standards (Jennings, J E B, Brink, A B A and Williams, A A B, 1973. Revised Guide to Soil Profiling for Civil Engineering Purposes in Southern Africa. The Civil Engineer in S A, p 3-12 January 1973.) The details of the test pits are summarised in Table 1 below. The detailed test pit soil profiles are attached in Appendix B.

Table 1: Summary of test pits.

Test Pit No.	GPS Coordinates (UTM WGS 84)		Depth(m)	Remarks
	Latitude (dd.mm.ss)	Longitude (dd.mm.ss)		
AL01	28° 1'57.08"S	27°50'21.78"E	2.0	Refusal on medium hard mudrock bedrock
AL02	28° 1'53.17"S	27°50'21.86"E	2.0	Refusal on medium hard mudrock bedrock
AL03	28° 1'49.90"S	27°50'21.54"E	2.0	No refusal
AL04	28° 1'52.59"S	27°50'26.25"E	2.0	No refusal
AL05	28° 1'49.14"S	27°50'28.61"E	2.0	No refusal

7. Results of Investigation

The detailed descriptions of the soil profiles encountered in the test pits are presented in Appendix B; while the geological profiles are summarised below, based on the soil profiles.

The geotechnical investigation revealed that the profile across the site is generally uniform, comprising of the following horizons:

- Transported horizon;
- Pedogenic horizon;
- Residual mudrock horizon; and
- Mudrock bedrock

The individual horizons of the geological profiles for the site are described below:

7.1 Transported Horizon

The site is generally covered by a relatively thick transported horizon, which was at encountered at a minimum depth of 0.4m and extends to a maximum depth of 0.8m in test pit AL03. It comprises slightly moist, dark brown, firm to stiff, sandy clay with roots. The consistency of this horizon is micro-shattered.

7.2 Pedogenic horizon

The pedogenic horizon, which underlies the transported horizon in only one (1 No) test pit (AL04), comprises moist, greyish orange, ferruginised clayey gravel. It was profiled as having a consistency that is dense to very dense. This horizon has a thickness of 1.30m.

7.3 Residual mudrock horizon

The residual mudrock horizon, which underlies the transported horizon in test pits AL01, AL02, AL04 and AL05 generally comprises slightly moist, brownish yellow, silty clay/ sandy clay. It was profiled as having a consistency that is slicken-sided. This horizon has a minimum thickness of 0.5m in test pit AL02 and a maximum thickness of 1.2m in test pit AL01.

7.4 Mudrock bedrock

The mudrock bedrock is described as completely to highly weathered, light brown yellow, very closely jointed, very soft to soft, very fine grained rock. The mudrock bedrock has a minimum thickness of 0.1m in test pit AL03 and a maximum thickness of 1.1m in test pit AL02.

Figure 3: Showing a typical test pit profiled on site.

8. Groundwater Conditions

Ground water was not encountered in any of the test pits at the site but ferruginisation, which indicates the seasonal change of ground water levels, was intercepted in test pit AL04 excavated at the site. Localised problems due to groundwater seepage may therefore be expected, especially during and after a very wet rainy season.

Drainage consists predominantly of seepage, but in case of thunderstorms surface sheetwash may occur. Such sheetwash will take place at the site as the site is generally gently sloping.

9. Laboratory Tests

9.1 Foundation Indicator (FI) Tests

Representative samples were collected for laboratory testing at specific positions. The detailed test results are attached in Appendix C and summarised in Table 2 below.

Table 2: Foundation indicator results

Test Pit	Depth (m)	GM	Particle size (%)				Atterberg Limits %			Activity	Unified Classification
			Clay	Silt	Fine Sand	Coarse sand	LL	WPI	LS		
PEDOGENIC											
AL04	0.7 – 2.0	0.8	32.5	8.8	54.6	2.3	31	27	7.0	LOW	SC
RESIDUAL MUDROCK											
AL01	0.4 – 1.6	2.5	13.6	12.9	13.5	59.9	42	3	9.0	LOW	SP/SC
AL02	0.9 – 2.0	2.2	12.6	13.2	27.4	46.8	36	3	4.9	LOW	SC
AL03	0.8 – 1.9	1.6	29.6	6.5	18.1	45.9	60	14	11.9	LOW	SC
AL05	1.4 – 2.0	1.9	34.5	32.3	29.8	3.4	40	8	9.7	LOW	SC

Where:
GM = Grading modulus
LL = Liquid Limit
PI = Plasticity Index
WPI = Weighted Plasticity Index (PI x % passing the 0.425 mm sieve)
LS = Linear Shrinkage
Activity = Expansiveness of the soil according to Van der Merwe's method
SP = Poorly Sorted Sand
SC = Clayey Sand

From the results in Table 2 below it is evident that:

The **pedogenic** horizon consists of clayey sand **(SC).** The horizon has a moderate (1.26) grading moduli. The fine fractions of this material exhibit a very low (0%) to moderate (35%) liquid limit and a very low (0%) to very high (35%) linear shrinkage. The material has a low to moderate potential expansiveness, according to the method proposed by Van der Merwe (1973).

The **residual mudrcok** horizon consists of poorly sorted sand **(SP)** clayey sand **(SC).** The horizon has very high grading moduli values ranging from 1.6 to 25. The fine fractions of this material exhibit moderate (36%) to high (35%) liquid limit values and low (4.9%) to high (11.9%) linear shrinkage values. The material has a low potential expansiveness, according to the method proposed by Van der Merwe (1973).

10. Cemetery Site Selection Criteria

The Council of Geoscience has produced a document titled ***"Geotechnical Investigation Guidelines for Cemetery Site Selection"***, which proposed a number of criteria that should be assessed in determining if a site is suitable for use as a cemetery. Furthermore ***Hall and Hanbury (1990) have recommended a method of*** evaluating and ranked a proposed cemetery site. These geotechnical factors relevant to cemetery development are discussed in detail below:

10.1 Site Topography

According to Croukamp & Richards (2003) the maximum slope angle of the ground should be within 2° to 9°, from the horizontal, in order to enable human and mechanical mobility across the site and to minimize erosion potential.

The investigated area has a topography that allows for people and mechanical mobilization on site. The proposed new cemetery site has a sloping angle of less than 3°. The slope angle of the site is within the acceptable maximum slope angles required for a grave site. The proposed site therefore has a suitable topography to be used as a cemetery site.

10.2 Soil Excavatibility

The ease at which the soil can be excavated is an important criterion in the selection of a site. For cemetery purposes the soil at a cemetery site must be excavatable to at least a depth of 1.8 m for single burials and 2.10 m for double burials.

Grave digging to a minimum depth of 1.8 m can be achieved with some difficulty using a TLB due to the presence of medium hard mudrock bedrock in the profile in test pits AL01 and AL02. Where refusal was encountered, it was on medium hard rock and at a minimum depth of 1.80m below the ground level. It will however not be possible to excavate a hole to a depth of 1.80 m below ground level without some difficulty with a pick and shovel in most parts of the site as a result of the presence of medium hard mudrock bedrock in the profile.

It is recommended that a machine such as a TLB be used in the excavation of the graves at this site.

10.3 Site Drainage

Site drainage is very important as the ingress of surface water into open graves must be minimised and storm water run-off should be controlled as far as possible for the following reasons:

- High velocity run-off increases the erosion potential causing erosion gullies;
- Poor site drainage will increase the risk of flooding open grave sites;
- Poor drainage results in marshy conditions, reducing mobility around grave sites; and
- Poor drainage creates the impression of a badly kept cemetery site, which in turn gives the families an impression that their loved ones are not well looked after.

Due to the gently sloping site, the rapid movement of surface water, groundwater and storm water run-off should be controlled as far as possible. The need of the drainage of surface water needs proper consideration so as to avoid erosion of graves. .

10.4 Soil Permeability

Soil permeability is the major factor determining the rate of fluid movement through the soil. For cemetery purposes, soil permeability must fall within predetermined permeability range. A measure of flexibility is again permitted to accommodate variable conditions. Table 3 below shows the permeability of different soil types.

Table 3: Soil type and predicted permeability ranges

SYMBOL (ASTM)[12]	SOIL TYPE (ASTM)[12]	PERMEABILITY[13] (cm per sec)	CEMETERY SUITABILITY
GW	Well-graded gravel	1×10^{-1} to 1×10^{-3}	Totally unsuitable
GP	Poorly graded gravel	5×10^{0} to 1×10^{-3}	Totally unsuitable
GM	Silty gravel	1×10^{-4} to 1×10^{-7}	Partially suitable
GC	Clayey gravel	1×10^{-5} to 1×10^{-8}	Suitable
SW	Well-graded sand	5×10^{-2} to 5×10^{-4l}	Unsuitable
SP	Poorly graded sand	5×10^{-1} to 5×10^{-5}	Unsuitable
SM	Silty sand	5×10^{-4} to 1×10^{-7}	Ideal
SC	Clayey sand	5×10^{-5} to 1×10^{-8}	Ideal
CL	Lean clay	1×10^{-6} to 1×10^{-8}	Partially suitable
ML	Silt	5×10^{-5} to 1×10^{-8}	Suitable
OL/OH	Organic silt / clay	1×10^{-5} to 1×10^{-8}	Partially suitable
CH	Fat clay	1×10^{-8} to 1×10^{-10}	Totally unsuitable
MH	Elastic silt	1×10^{-7} to 1×10^{-9}	Unsuitable

From the laboratory test undertaken on samples retrieved from the test pits, the soils are classified as being clayey sand (SC) which has a permeability in the range of 5×10^{-5} to 1×10^{-8} cm per sec as well as poorly sorted sand (SP) which has a permeability in the range of 5×10^{-1} to 5×10^{-5} as shown in Table 3 above.

From the permeability range of the soil types at the site, the soil permeability of the studied site is generally considered ideal for cemetery development, although an isolated case of unsuitable materials does occur.

10.5 Positioning in respect to domestic water supplies

The positioning in relation to water sources which are utilised for human consumption is the most important consideration for the location of a cemetery site. Water borne diseases reaching water courses must be prevented at all costs. The minimum distance from the cemetery site and the nearest water source has therefore been prescribed and is based on the permeability of the subsoil as shown in Table 4 below.

Table 4: Safe distances to domestic water sources

SOIL PERMEABILITY	SAFE
1 x 10^{-4} cm/s	465 metres
5 x 10^{-5} cm/s	308 metres
1 x 10^{-5} cm/s	182 metres
5 x 10^{-6} cm/s	166 metres
1 x 10^{-6} cm/s	153 metres
5 x 10^{-7} cm/s	152 metres
1 x 10^{-7} cm/s	150 metres

The minimum safe distance from a water supply for this site based on the soil permeability and the soil type at the site is 308m.

The distance between the cemetery and the nearest river (non-perennial) is approximately 55 meters. This distance is less than the prescribed safe distance required for the soil type encountered at the site, which is 308 meters. The cemetery site is therefore NOT positioned at a safe distance from a domestic water source.

10.6 Positioning in respect to drainage features

The positioning of a cemetery in relation to a drainage feature of any description is of outmost importance, and pollutants emanating from a cemetery site must not contaminate the water course, conversely the cemetery must not be under threat of flooding from the water course. A minimum prescribed distance to drainage features is given, in Table 5 below, again depending on the permeability.

Table 5: Safe distances to drainage features

SOIL PERMEABILITY	SAFE DISTANCE	SAFE DISTANCE (Arid Regions)
1 x 10^{-4} cm/s	415 metres	365 metres
5 x 10^{-5} cm/s	258 metres	208 metres
1 x 10^{-5} cm/s	132 metres	82 metres
5 x 10^{-6} cm/s	116 metres	66 metres
1 x 10^{-6} cm/s	103 metres	53 metres
5 x 10^{-7} cm/s	102 metres	52 metres
1 x 10^{-7} cm/s	100 metres	50 metres

The minimum prescribed distance to drainage features based on the soil type and permeability for the cemetery site is 258m.

The distance between the cemetery and the nearest (non-perennial) river is approximately 55 meters. This distance is less than the prescribed safe distance required for the soil type encountered at the site. The cemetery site is therefore NOT positioned at a safe distance from the drainage feature.

10.7 Basal Buffer Zone

A basal buffer zone refers to the vertical soil succession which occurs between the base of the deepest grave and the water table (permanent or perched). This buffer zone (aeration zone or attenuation zone), essentially forms a barrier between the source of pollution and the water table. The effective depth of this attenuation zone depends largely on the prevailing soil permeability conditions and a few of the other factors. A minimum buffer zone of 2.5 m will adequately cater for most conditions if the recommended permeability limits are complied with. However, the buffer zone should ideally be even deeper than 2.5 m.

At the time of investigation, groundwater was not encountered in any of the test pits excavated and profiled at the site, but ferruginisation, which indicates the seasonal change of ground water levels, was intercepted in test pit AL04 excavated at the site. Localised problems due to groundwater seepage may therefore be expected, especially during and after a very wet rainy season.

10.8 Sidewall Stability

Grave excavation stability refers to the competence of the grave sides and the grave verge or lip. Stability is required for the following reasons:

- A period of a few days usually elapses after the excavation of a grave and the actual burial.
- At the time of burial many people move around the sides of the grave causing a disturbance.
- Excessive crumbling of the excavation verge may hinder the smooth lowering of a coffin.

The side walls of the test pits excavations were generally stable to refusal. Due to the cohesive materials encountered on the investigated site, the side walls were stable without any signs of side wall collapse, with the exception of test pit AL02, where the sidewalls were not stable.

It is advisable that the grave digger contractor should constantly assess sidewall safety on the site and provide shoring if necessary.

10.9 Soil Workability

Another potentially important consideration is the soil workability which refers to the ease at which soil can be manipulated in and out of the grave. Clay soils are known to be the most difficult soils to work with and manipulate in and out of a grave due to their cohesiveness.

The soil types encountered on the site generally consist of silty/ sandy clay. ***These materials are considered to be fair in terms of workability and will not be difficult to work with and manipulate during excavation and backfilling.***

11. Site Suitability Assessment

11.1 Soil comparison

The suitability of the soil profile for cemetery purposes has therefore been evaluated according to the guidelines proposed by Hall and Handbury (1990). In this assessment method numerical values (ratings) are given to various aspects of the soil profile at each test pit position. The various assessment parameters are shown in the Table 6 and the respective ratings of each test pit is found in Table 7.

Table 6: Soil constraints and Classification Index

Constraint:	Characteristic	Score
Excavatability	Easy Spade	15
	Pick and Spade	10
	Machine	5
	Blasting	0
Stability	Stable	20
	Over break	15
	Slightly unstable	8
	Unstable	F
Workability	Excellent/Good	10
	Fair	5
	Poor	2
	Very Poor	0
Water Table	Deep Water Table > 8m	25
	Intermediate 4 – 8m	15
	Possible perched water table 0-4m	5
	Waterlogged Soil	F
Subsoil Permeability	Impermeable	15
	Relatively impermeable	20
	Relatively permeable	10
	Permeable	0
Backfill Permeability	Impermeable	5
	Relatively impermeable	10
	Relatively permeable	7
	Permeable	0

The individual ratings must be summed to give a single rating that can be used to compare different sites and/or different areas within a site for suitability.

Where a site and/or area have an F rating the site and/or area should not be considered and/or excluded from the development area.

In terms of the suitability of the soil profile with respect to use as a burial ground, the guidelines give the following values and their meanings in this respect as follow:

F rating = Fatal Flaw in the site, site must be rejected

Final Rating:	*Site Suitability*
>90	Very Good
75-90	Satisfactory
60-75	Poor: precautions needed
< 60	Unacceptable

Applying the above classification index to the different sub soils encountered in the test pits and data analysis, the following matrix was compiled to evaluate the different test pits for acceptability for the establishment of a cemetery as shown in Table 7 below.

Table 7: Individual test pit rating for cemetery suitability.

Test Pit	Excavatability Rating	Stability Rating	Workability Rating	Water Table Rating	Subsoil Permeability Rating	Backfill Permeability Rating	Total
AL01	5	20	5	15	20	10	**75**
AL02	5	15	5	15	20	10	**70**
AL03	5	20	5	15	20	10	**75**
AL04	5	20	5	5	20	10	**65**
AL05	5	20	5	15	20	10	**75**

From the investigation, the assessment done and soil constraint and classification index criteria (Table 6) used for the site and the soil type encountered at the site, the proposed site for the extension of the cemetery ***has an overall rating of 72, which is classified Poor with Pracutions according to Hall and Hanbury.*** **This site can be developed as a cemetery but environmental precautions must be adhered to.**

12. Recommendations

The following recommendations with respect to the site are offered for consideration:

12.1 Monitoring of water quality

The cemetery site should ideally should be installed with a monitoring borehole opposite the proposed cemetery within the valley of the natural drainage for regular water quality monitoring purposes.

If possible a ground water quality monitoring program must be instituted, it is recommended that monitoring should be conducted at least every six months, but preferably three times a year. As a minimum, Faecal Coli, Nitrate and Phosphate should be measured. It is also important that the monitoring program should be initiated before commissioning of the cemetery so that base line data can be generated with which to compare monitoring data in the future. Thus any pollution caused by the graves can be detected at an early stage before such pollution reaches high levels.

It is considered important to conduct such a monitoring program as outlined above because it will serve as an early warning system of pollution that may occur from the cemetery site. A decision to proceed with anti-pollution measures based on factual data can then be considered at some future stage.

13. Conclusions

Below are the conclusions of the geotechnical investigation carried out for the proposed cemetery site at Arlington:

The soil types encountered on the site generally consist of clayey sand (SC) and poorly sorted sand (SP). These materials are considered to be fair in terms of workability and will not be difficult to work with and manipulate during excavation and backfilling. These materials are fair material in terms of workability and fall behind good materials such as well graded gravel, well graded sand or poorly graded gravel.

Where shallow bedrock (<1.8m) is encountered, excavatibilty with a pick and shovel will be a problem. It is recommended that a machine such as a TLB be used in the excavation of the graves at this site.

The proposed cemetery site has an overall rating of **72**, which is classified as poor according to Hall and Hanbury. This site can however be developed as a cemetery site but will require that precautions against environmental pollution be implemented. The precautions which should be applied include close attention to surface contours during site preparation, the provision of adequate storm water drainage, and the monitoring of water quality (pathogens, nitrogen compounds and phosphate levels as a minimum) in downstream drainage courses within 1 km of the site.

14. References

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Appendix A

Summary Of Standard Soil And Rock Profile Description Terminology

STANDARD DESCRIPTIONS USED IN SOIL PROFILING

1. MOISTURE CONDITION

Term	Description
Dry	
Slightly moist	Requires addition of water to reach optimum moisture content for compaction
Moist	Near optimum content
Very Moist	Requires drying to attain optimum content
Wet	Fully saturated and generally below water table

2. COLOUR

The Predominant colours or colour combinations are described including secondary coloration described as banded, streaked, blotched, mottled, speckled or stained.

3. CONSISTENCY

3.1 Non-Cohesive Soils

Term	Description
Very Loose	Crumbles very easily when scraped with geological pick
Loose	Small resistance to penetration by sharp end of geological pick
Medium Dense	Considerable resistance to penetration by sharp end of geological pick
Dense	Very high resistance to penetration to sharp end of geological pick. Requires many blows of hand pick for excavation.
Very Dense	High resistance to repeated blows of geological pick. Requires power tools for excavation

3.2 Cohesive Soils

Term	Description
Very soft	Easily penetrated by thumb. Sharp end of pick can be pushed in 30 - 40mm. Easily moulded by fingers.
Soft	Pick head can easily be pushed into the shaft of handle. Moulded by fingers with some pressure.
Firm	Indented by thumb with effort. Sharp end of pick can be pushed in up to 10mm. Can just be penetrated with an ordinary spade.
Stiff	Penetrated by thumbnail. Slight indentation produced by pushing pick point into soil. Cannot be moulded by fingers. Requires hand pick for excavation.
Very Stiff	Indented by thumbnail. Slight indentation produced by blow of pick point. Requires power tools for excavation.

4. STRUCTURE

Term	Description
Intact	Absence of fissures or joints
Fissured	Presence of closed joints
Shattered	Presence of closely spaced air filled joints giving cubical fragments
Micro-shattered	Small scale shattering with shattered fragments the size of sand grains
Slickensided	Polished planar surfaces representing shear movement in soil
Bedded Foliated	Many residual soils show structures of parent rock.

5. SOIL TYPE

5.1 Particle Size

Term	Size (mm)
Boulder	>200
Pebbles	60 – 200
Gravel	60 – 2
Sand	2 – 0,06
Silt	0,06 – 0,002
Clay	<0,002

6. ORIGIN

6.1 Transported Soils

Term	Agency of Transportation
Colluvium	Gravity deposits
Talus	Scree or coarse colluvium
Hillwash	Fine colluvium
Alluvial	River deposits
Aeolian	Wind deposits
Littoral	Beach deposits
Estuarine	Tidal – river deposits
Lacustrine	Lake deposits

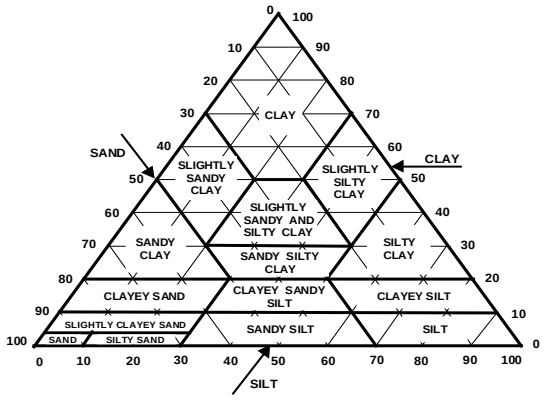
6.2 Residual soils

These are products of in situ weathering of rocks and are described as e.g. Residual Shale

6.3 Pedocretes

Formed in transported and residual soils etc.
calcrete, silcrete, manganocrete and ferricrete.

5.2 Soil Classification



SUMMARY OF DESCRIPTIONS USED IN ROCK CORE LOGGING

1. WEATHERING

Term	Symbol	Diagnostic Features
Residual Soil	W5	Rock is discoloured and completely changed to a soil in which original rock fabric is completely destroyed. There is a large change in volume.
Completely Weathered	W5	Rock is discoloured and changed to a soil but original fabric is mainly preserved. There may be occasional small corestones.
Highly Weathered	W4	Rock is discoloured, discontinuities may be open and have discoloured surfaces, and the original fabric of the rock near the discontinuities may be altered; alternation penetrates deeply inwards, but corestones are still present.
Moderately Weathered	W3	Rock is discoloured, discontinuities may be open and will have discoloured surfaces with alteration starting to penetrate inwards, intact rock is noticeably weaker than the fresh rock.
Slightly Weathered	W2	Rock may be slightly discoloured, particularly adjacent to discontinuities, which may be open and will have slightly discoloured surfaces, the intact rock is not noticeably weaker than the fresh rock.
Unweathered	W1	Parent rock showing no discolouration, loss of strength or any other weathering effects.

2. HARDNESS

Classification	Field Test	Compressive Strength Range MPa
Extremely Soft Rock	Easily peeled with a knife	<1
Very Soft Rock	Can be peeled with a knife. Material crumbles under firm blows with the sharp end of a geological pick.	1 to 3
Soft Rock	Can be scraped with a knife, indentation of 2 to 4 mm with firm blows of the pick point.	3 to 10
Medium Hard Rock	Cannot be scraped or peeled with a knife. Hand held specimen breaks with firm blows of the pick.	10 to 25
Hard Rock	Point load tests must be carried out in order to distinguish between these classifications	25 - 70
Very Hard Rock	These results may be verified by uniaxial compressive strength tests on selected samples.	70 - 200
Extremely Hard Rock		>200

3. COLOUR

The predominant colours or colour combination are described including secondary colouration described as banded, streaked, blotched, mottled, speckled or stained.

4. FABRIC

4.1 Grain Size		4.2 Discontinuity Spacing		
Term	Size (mm)	Description for: Bedding, foliation, laminations	Spacing (mm)	Descriptions for joints, faults, etc.
Very Coarse	>2,0	Very Thickly Bedded	> 2000	Very Widely
Coarse	0,6 – 2,0	Thickly Bedded	600 – 2000	Widely
Medium	0,2 – 0,6	Medium Bedded	200 – 600	Medium
Fine	0,06 – 0,2	Thinly Bedded	60 – 200	Closely
Very Fine	< 0,06	Laminated	3 – 60	Very closely
		Thinly Laminated	<3	

5. ROCK NAME

Classified in terms of origin:

IGNEOUS	Granite, Diorite, Gabbro, Syenite, , Dolerite, Trachyte, Andesite, Basalt.
METAMORPHIC	Slate, Felsite, Gneiss, Schist, Quartzite
SEDIMENTARY	Shale, Mudstone, Siltstone, Sandstone, Dolomite, Conglomerate, Tillite, Limestone.

6. STRATIGRAPHIC HORIZON

Identification of rock type in terms of stratigraphic horizons.

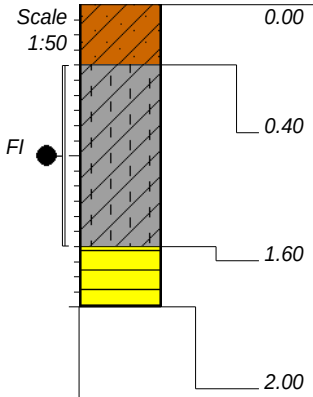
Appendix B

Soil Profile Descriptions

NKETOANA MUNICIPALITY
ARLINGTON CEMETRY GEOTECHNICAL INVESTIGATION

HOLE No: **AL01**
Sheet 1 of 1

JOB NUMBER: 000



Slightly moist, dark brown, SOFT to FIRM, micro-shattered, sandy clay with roots.
Transported.

Slightly moist, brownish yellow, STIFF to VERY STIFF, slickensided, silty clay.
Residual Mudrock.

Completely to highly weathered, brownish yellow, laminated, VERY SOFT to SOFT ROCK, very fine-grained.
Mudrock Bedrock.

END OF HOLE.

NOTES

1) Sidewalls are stable.
2) No groundwater seepage intercepted.
3) Refusal on medium hard Mudrock bedrock.
4) FI sample taken at 0.4--1.6m.

CONTRACTOR :
MACHINE : VOLVO BL61B TLB
DRILLED BY :
PROFILED BY : SM

TYPE SET BY : SM
SETUP FILE : WATERM~1.SET

INCLINATION :
DIAM :
DATE :
DATE : 01/09/2021

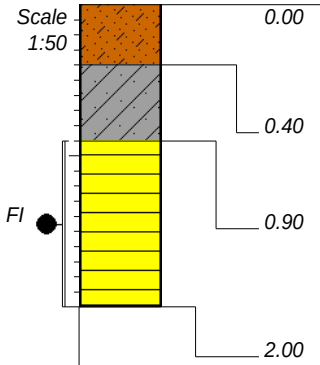
DATE : 07/09/2021 21:07
TEXT : ..teries\Arlingtonlogs.txt

ELEVATION :
X-COORD :
Y-COORD :

NKETOANA MUNICIPALITY
ARLINGTON CEMETRY GEOTECHNICAL INVESTIGATION

HOLE No: **AL02**
Sheet 1 of 1

JOB NUMBER: 000



Slightly moist, light reddish brown, MEDIUM DENSE, intact, clayey sand with roots.
Transported.

Slightly moist, dark brown, SOFT to FIRM, micro-shattered, sandy clay.
Residual.

Completely to highly weathered, brownish yellow, laminated, VERY SOFT to SOFT ROCK, very fine-grained.
Mudrock Bedrock.

END OF HOLE.

NOTES

1) Sidewalls are not stable.
2) No groundwater seepage intercepted.
3) No Refusal.
4) FI sample taken at 0.9--2.0m.

CONTRACTOR :
MACHINE : VOLVO BL61B TLB
DRILLED BY :
PROFILED BY : SM
TYPE SET BY : SM
SETUP FILE : WATERM~1.SET

INCLINATION :
DIAM :
DATE :
DATE : 01/09/2021
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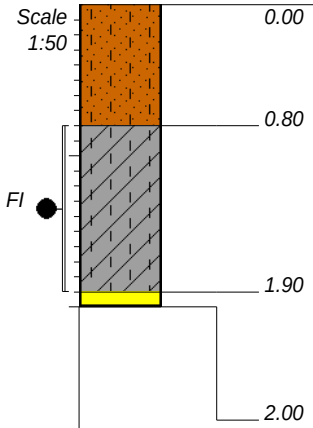
TEXT : ..teries\Arlingtonlogs.txt

ELEVATION :
X-COORD :
Y-COORD :

NKETOANA MUNICIPALITY
ARLINGTON CEMETRY GEOTECHNICAL INVESTIGATION

HOLE No: **AL03**
Sheet 1 of 1

JOB NUMBER: 000



0.00

Moist, light reddish brown, MEDIUM DENSE, intact, silty sand with roots. Transported.

0.80

Moist, orangey brown, STIFF to VERY STIFF, slickensided, slightly ferruginised silty clay.
Residual Mudrock.

1.90

Completely to highly weathered, brownish yellow, very closely jointed, VERY SOFT to SOFT ROCK, very fine-grained.
Mudrock Bedrock.

2.00

END OF HOLE.

NOTES

1) Sidewalls are stable.
2) No groundwater seepage intercepted.
3) No Refusal.
4) FI sample taken at 0.8--1.9m.

CONTRACTOR :
MACHINE : VOLVO BL61B TLB
DRILLED BY :
PROFILED BY : SM

TYPE SET BY : SM
SETUP FILE : WATERM~1.SET

INCLINATION :
DIAM :
DATE :
DATE : 01/09/2021

DATE : 07/09/2021 21:07
TEXT : ..teries\Arlingtonlogs.txt

ELEVATION :
X-COORD :
Y-COORD :

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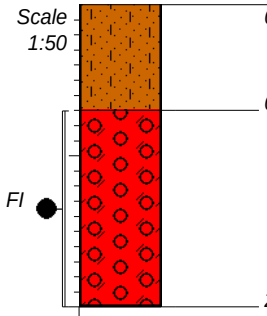
ARLINGTON CEMETRY GEOTECHNICAL INVESTIGATION

HOLE No: **AL04**
Sheet 1 of 1

JOB NUMBER: 000



0.00

Moist, dark brown, MEDIUM DENSE, intact, silty sand with roots.
Transported.

0.70

Moist, greyish orange, DENSE to VERY DENSE, intact, ferruginised clayey gravel.
Pedogenic.

2.00

END OF HOLE.

NOTES

1) Sidewalls are stable.
2) No groundwater seepage intercepted.
3) No Refusal.
4) FI sample taken at 0.7--2.0m.

CONTRACTOR :
MACHINE : VOLVO BL61B TLB
DRILLED BY :
PROFILED BY : SM

TYPE SET BY : SM
SETUP FILE : WATERM~1.SET

INCLINATION :
DIAM :
DATE :
DATE : 01/09/2021

DATE : 07/09/2021 21:07
TEXT : ..teries\Arlingtonlogs.txt

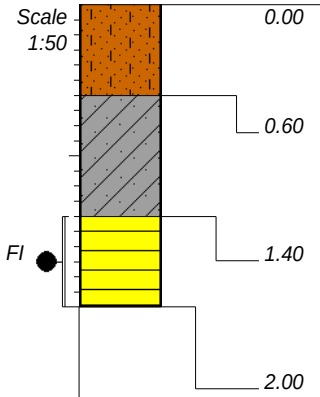
ELEVATION :
X-COORD :
Y-COORD :

dotPLOT 7022

NKETOANA MUNICIPALITY
ARLINGTON CEMETRY GEOTECHNICAL INVESTIGATION

HOLE No: **AL05**
Sheet 1 of 1

JOB NUMBER: 000



Slightly moist, dark brown, MEDIUM DENSE to DENSE, intact, silty sand with roots.
Transported.

Slightly moist, light reddish orange, STIFF to VERY STIFF, slickensided, ferruginised sandy clay.
Residual Mudrock.

Completely to highly weathered, light brownish yellow, very closely jointed, VERY SOFT to SOFT ROCK, very fine-grained.
Mudrock Bedrock.

END OF HOLE.

NOTES

1) Sidewalls are stable.
2) No groundwater seepage intercepted.
3) No Refusal.
4) FI sample taken at 1.4--2.0m

CONTRACTOR :
MACHINE : VOLVO BL61B TLB
DRILLED BY :
PROFILED BY : SM

TYPE SET BY : SM
SETUP FILE : WATERM~1.SET

INCLINATION :
DIAM :
DATE :
DATE : 01/09/2021

DATE : 07/09/2021 21:07
TEXT : ..teries\Arlingtonlogs.txt

ELEVATION :
X-COORD :
Y-COORD :

dotPLOT 7022

NKETOANA MUNICIPALITY
ARLINGTON CEMETRY GEOTECHNICAL INVESTIGATION

LEGEND
Sheet 1 of 1

JOB NUMBER: 000

	GRAVEL	{SA02}
	SAND	{SA04}
	SANDY	{SA05}
	SILTY	{SA07}
	CLAY	{SA08}
	CLAYEY	{SA09}
	MUDROCK	{SA12}
Name ●	DISTURBED SAMPLE	{SA38}

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY :

INCLINATION :
DIAM :
DATE :
DATE :

ELEVATION :
X-COORD :
Y-COORD :

TYPE SET BY : SM
SETUP FILE : WATERM~1.SET

DATE : 07/09/2021 21:07
TEXT : ..teries\Arlingtonlogs.txt

LEGEND
SUMMARY OF SYMBOLS

Appendix C

Laboratory Test Results

LTG CIVIL SERVICES
Civil Engineering Materials Laboratory

1350 Hartbeestspruit Street, Hatfield, Pretoria, 0083
012 362 2352 | 082 784 5667
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Reg. No: 2003/007845/23 | Vat No: 4500204070

GRAVEL, SOIL AND SAND ANALYSIS REPORT

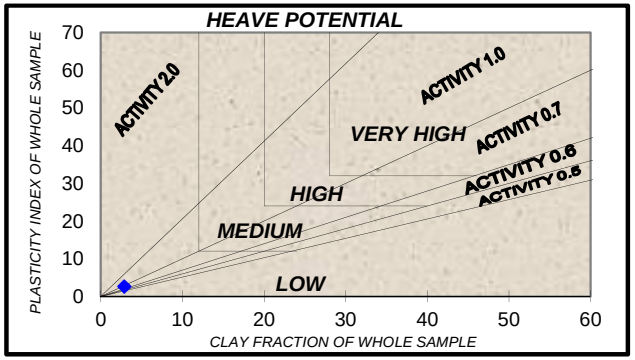
Report No.:	DG/AL 21 09-001

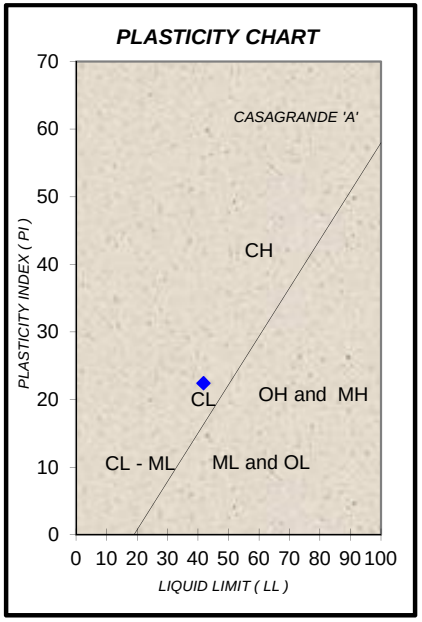
Project :	*Arlington Cemetery*	**Date Received :**	02-09-2021
Client :	Dwala Group (Pty) Ltd.	**Report Date :**	17-09-2021

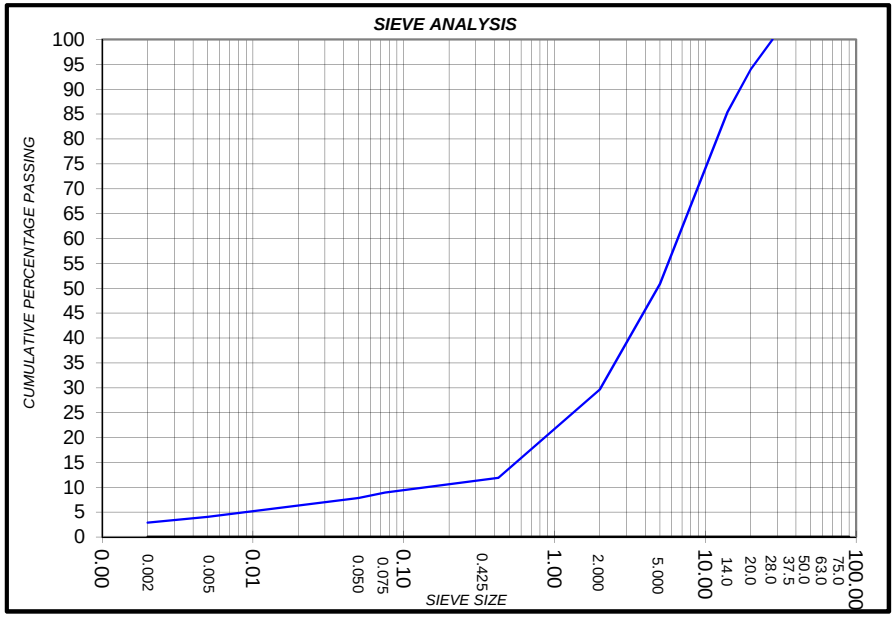
Your Reference :	*AL 01, 0.4 - 1.6m*	**Environmental Conditions :**	Not Specified	**Sample No. :**	21/1038
Sampled By :	Client			**Sampling Method :**	Not Specified

Description	MDD / OMC SANS 3001-GR20 & GR30		Sieve Analysis SANS 3001-GR1 Cumulative percentage passing														Grading Modulus SANS 3001-PR5	Soil Mortar Analysis % of mat. <2,00 mm				Atterberg Limits SANS 3001-GR10			Classification			
(Unified Soil Classification)	Maximum Dry Density kg/m³	Optimum Moisture Content %	100.0mm	75.0mm	63.0mm	50.0mm	37.5mm	28.0mm	20.0mm	14.0mm	5.00mm	2.00mm	0.425mm	0.075mm	0.05 mm	0.005 mm	0.002 mm		Coarse - sand <2,0 >0,425mm	Fine - sand <0,425 >0,05mm	Silt <0,05 >0,005mm	Clay <0,005 mm	Liquid Limit %	Plasticity Index	Linear Shrinkage %	Unified Soil	Colto	US. Highway	Group Index
Light Olive Poorly Graded Clayey Sand	-	-	-	-	-	-	-	100	94	85	51	30	12	9	7.9	4.0	2.9	2.5	59.9	13.5	12.9	13.6	42	22	9.0	SP/SC	-	A-2-7	0

GENERAL :		CBR RESULTS :	
Effective size :	0.139	SANS 3001-GR40	
Uniformity co-eff. :	47.3	**@ 100% comp. :**	-
Curvature co-eff. :	4.5	**@ 98% comp. :**	-
Oversize Index :	0	**@ 97% comp. :**	-
Shrinkage Product :	108	**@ 95% comp. :**	-
Grading co-eff. :	35.8	**@ 93% comp. :**	-
Swell @ 100% :	-	**@ 90% comp. :**	-







REMARKS:

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Reg. No: 2003/007845/23 | Vat No: 4500204070

GRAVEL, SOIL AND SAND ANALYSIS REPORT

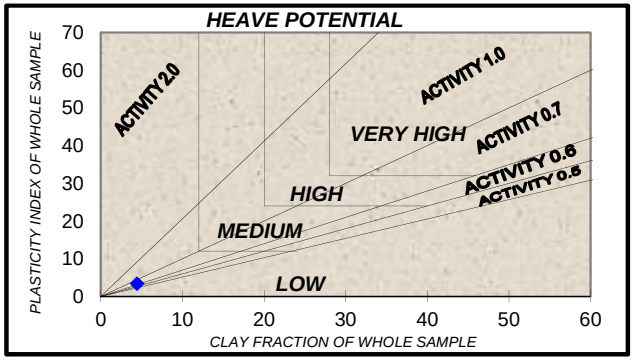
Report No.:	DG/AL 21 09-001

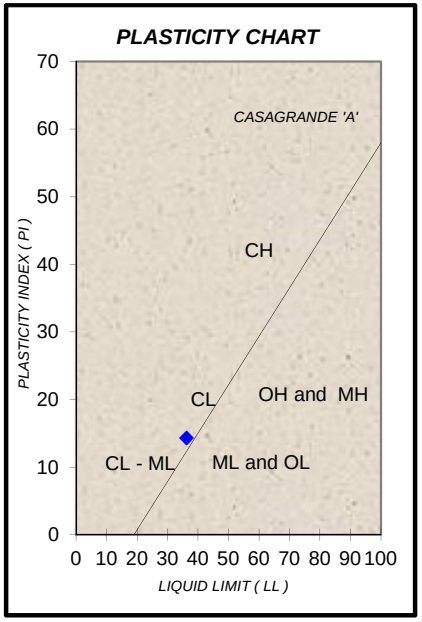
Project :	*Arlington Cemetery*	**Date Received :**	02-09-2021
Client :	Dwala Group (Pty) Ltd.	**Report Date :**	17-09-2021

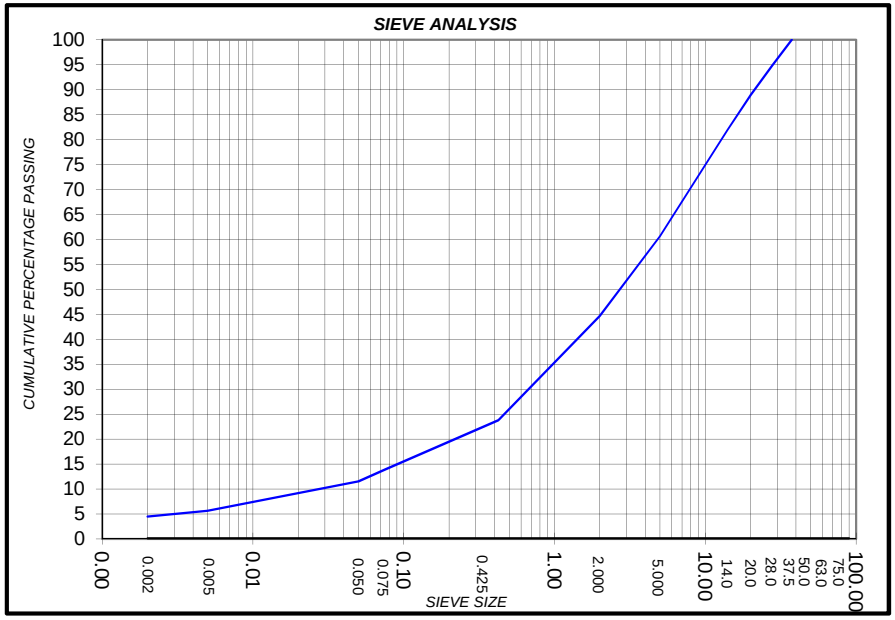
Your Reference :	*AL 02, 0.9 - 2.0m*	**Environmental Conditions :**	Not Specified	**Sample No. :**	21/1039
Sampled By :	Client			**Sampling Method :**	Not Specified

Description	**MDD / OMC** SANS 3001-GR20 & GR30		**Sieve Analysis** SANS 3001-GR1 **Cumulative percentage passing**															**Grading Modulus** SANS 3001-PR5	**Soil Mortar Analysis % of mat. <2,00 mm**				**Atterberg Limits** SANS 3001-GR10			**Classification**			
(Unified Soil Classification)	**Maximum Dry Density kg/m³**	**Optimum Moisture Content %**	**100.0mm**	**75.0mm**	**63.0mm**	**50.0mm**	**37.5mm**	**28.0mm**	**20.0mm**	**14.0mm**	**5.00mm**	**2.00mm**	**0.425mm**	**0.075mm**	**0.05 mm**	**0.005 mm**	**0.002 mm**		**Coarse - sand <2,0 >0,425mm**	**Fine - sand <0,425 >0,05mm**	**Silt <0,05 >0,005mm**	**Clay <0,005 mm**	**Liquid Limit %**	**Plasticity Index**	**Linear Shrinkage %**	**Unified Soil**	**Colto**	**US. Highway**	**Group Index**
Dark Olive Brown Clayey Sand	-	-	-	-	-	-	100	95	89	82	61	45	24	14	11.5	5.6	4.4	2.2	46.8	27.4	13.2	12.6	36	14	4.9	SC	-	A-2-6	0

GENERAL :		**CBR RESULTS :**	
Effective size :	0.028	SANS 3001-GR40	
Uniformity co-eff. :	175.3	**@ 100% comp. :**	-
Curvature co-eff. :	3.4	**@ 98% comp. :**	-
Oversize Index :	0	**@ 97% comp. :**	-
Shrinkage Product :	116	**@ 95% comp. :**	-
Grading co-eff. :	30.5	**@ 93% comp. :**	-
Swell @ 100% :	-	**@ 90% comp. :**	-







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Reg. No: 2003/007845/23 | Vat No: 4500204070

GRAVEL, SOIL AND SAND ANALYSIS REPORT

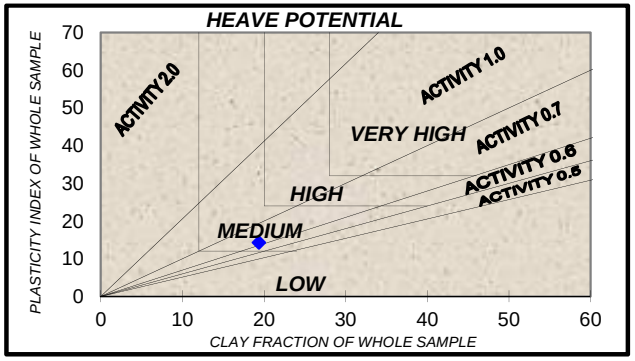
Report No.:	DG/AL 21 09-001

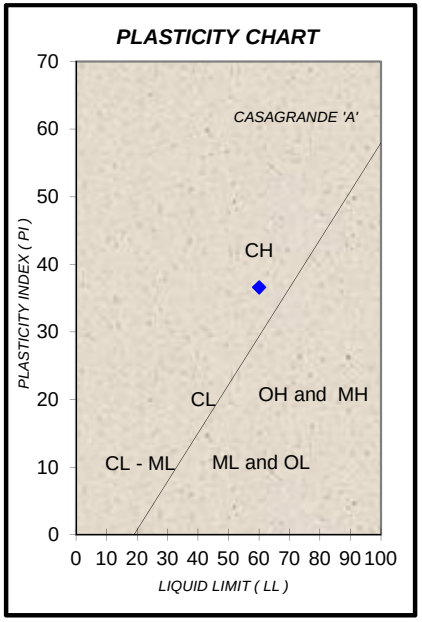
Project :	*Arlington Cemetery*	**Date Received :**	02-09-2021
Client :	Dwala Group (Pty) Ltd.	**Report Date :**	17-09-2021

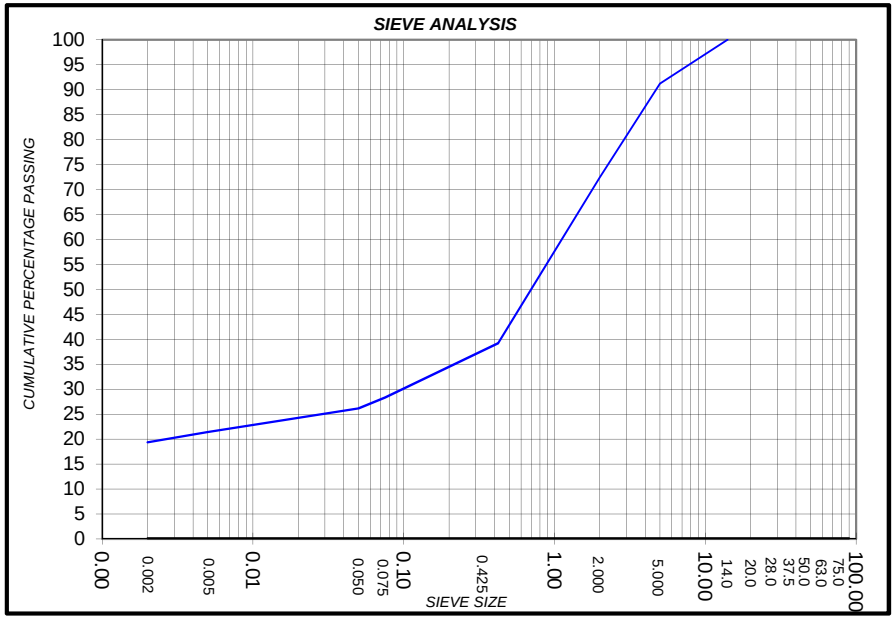
Your Reference :	*AL 03, 0.75 - 1.85m*	**Environmental Conditions :**	Not Specified	**Sample No. :**	21/1040
Sampled By :	Client			**Sampling Method :**	Not Specified

Description	MDD / OMC SANS 3001-GR20 & GR30		Sieve Analysis SANS 3001-GR1 Cumulative percentage passing														Grading Modulus SANS 3001-PR5	Soil Mortar Analysis % of mat. <2,00 mm				Atterberg Limits SANS 3001-GR10			Classification			
(Unified Soil Classification)	Maximum Dry Density kg/m³	Optimum Moisture Content %	100.0mm	75.0mm	63.0mm	50.0mm	37.5mm	28.0mm	20.0mm	14.0mm	5.00mm	2.00mm	0.425mm	0.075mm	0.05 mm	0.005 mm	0.002 mm		Coarse - sand <2,0 >0,425mm	Fine - sand <0,425 >0,05mm	Silt <0,05 >0,005mm	Clay <0,005 mm	Liquid Limit %	Plasticity Index	Linear Shrinkage %	Unified Soil	Colto	US. Highway	Group Index
Light Olive Brown Clayey Sand	-	-	-	-	-	-	-	-	-	100	91	72	39	28	26.1	21.4	19.4	1.6	45.9	18.1	6.5	29.6	60	37	11.9	SC	-	A-2-7	3

GENERAL :		CBR RESULTS :	
Effective size :	<0.002	SANS 3001-GR40	
Uniformity co-eff. :	1122.3	**@ 100% comp. :**	-
Curvature co-eff. :	8.6	**@ 98% comp. :**	-
Oversize Index :	0	**@ 97% comp. :**	-
Shrinkage Product :	466	**@ 95% comp. :**	-
Grading co-eff. :	25.2	**@ 93% comp. :**	-
Swell @ 100% :	-	**@ 90% comp. :**	-







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GRAVEL, SOIL AND SAND ANALYSIS REPORT

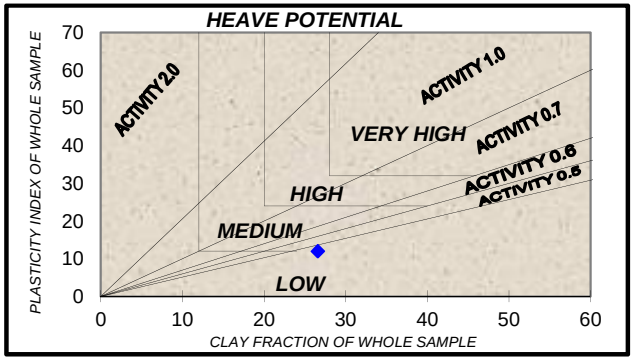
Report No.:	DG/AL 21 09-001

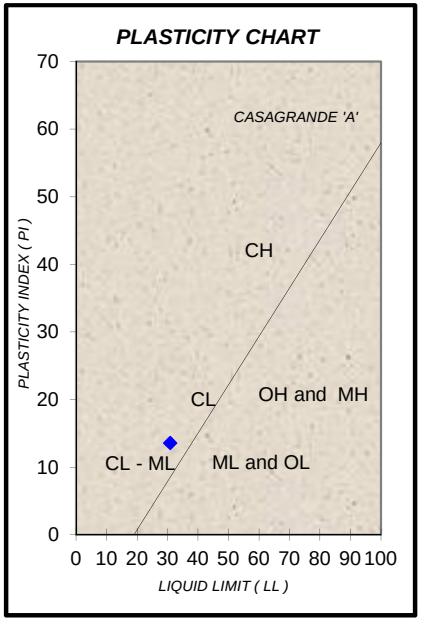
Project :	*Arlington Cemetery*	**Date Received :**	02-09-2021
Client :	Dwala Group (Pty) Ltd.	**Report Date :**	17-09-2021

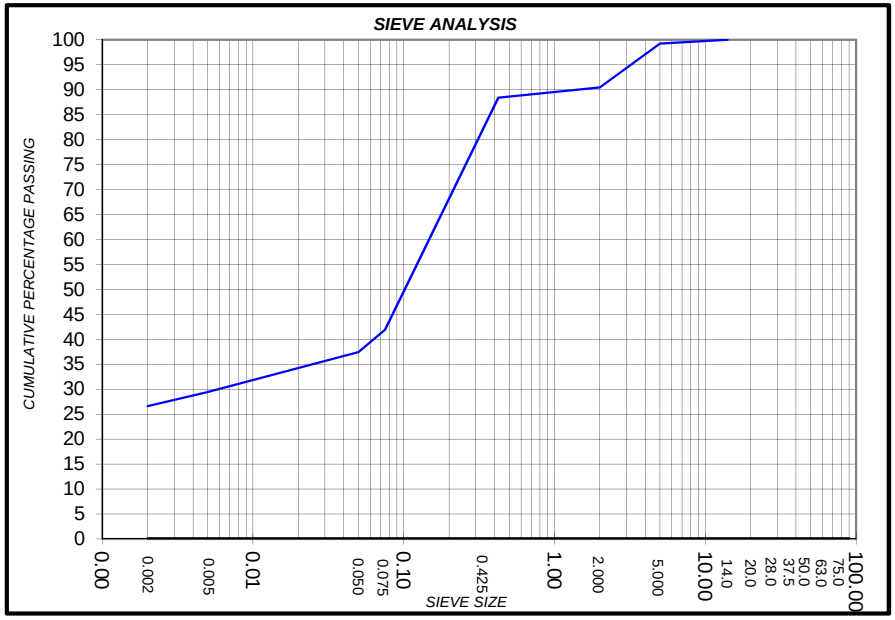
Your Reference :	*AL 04, 0.7 - 2.0m*	**Environmental Conditions :**	Not Specified	**Sample No. :**	21/1041
Sampled By :	Client			**Sampling Method :**	Not Specified

Description	**MDD / OMC** SANS 3001-GR20 & GR30		**Sieve Analysis** SANS 3001-GR1 **Cumulative percentage passing**														**Grading Modulus** SANS 3001-PR5	**Soil Mortar Analysis % of mat. <2,00 mm**				**Atterberg Limits** SANS 3001-GR10			**Classification**			
(Unified Soil Classification)	**Maximum Dry Density kg/m³**	**Optimum Moisture Content %**	**100.0mm**	**75.0mm**	**63.0mm**	**50.0mm**	**37.5mm**	**28.0mm**	**20.0mm**	**14.0mm**	**5.00mm**	**2.00mm**	**0.425mm**	**0.075mm**	**0.05 mm**	**0.005 mm**	**0.002 mm**		**Coarse - sand <2,0 >0,425mm**	**Fine - sand <0,425 >0,05mm**	**Silt <0,05 >0,005mm**	**Clay <0,005 mm**	**Liquid Limit %**	**Plasticity Index**	**Linear Shrinkage %**	**Unified Soil**	**Colto**	**US. Highway**	**Group Index**
Dark Orange Brown Clayey Sand	-	-	-	-	-	-	-	-	-	100	99	90	88	42	37.4	29.4	26.6	0.8	2.3	56.4	8.8	32.5	31	14	7.0	SC	-	A-6	2

GENERAL :		**CBR RESULTS :**	
Effective size :	<0.002	SANS 3001-GR40	
Uniformity co-eff. :	147.4	**@ 100% comp. :**	-
Curvature co-eff. :	0.2	**@ 98% comp. :**	-
Oversize Index :	0	**@ 97% comp. :**	-
Shrinkage Product :	622	**@ 95% comp. :**	-
Grading co-eff. :	9.5	**@ 93% comp. :**	-
Swell @ 100% :	-	**@ 90% comp. :**	-







REMARKS:

LTG CIVIL SERVICES
Civil Engineering Materials Laboratory

1350 Hartbeestspruit Street, Hatfield, Pretoria, 0083
012 362 2352 | 082 784 5667
info@Labworx.co.za | www.labworx.co.za
Reg. No: 2003/007845/23 | Vat No: 4500204070

GRAVEL, SOIL AND SAND ANALYSIS REPORT

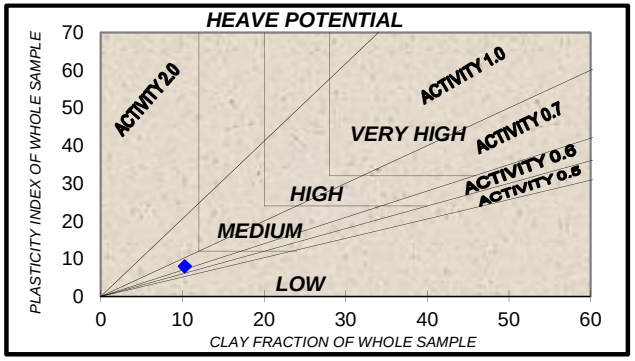
Report No.:	DG/AL 21 09-001

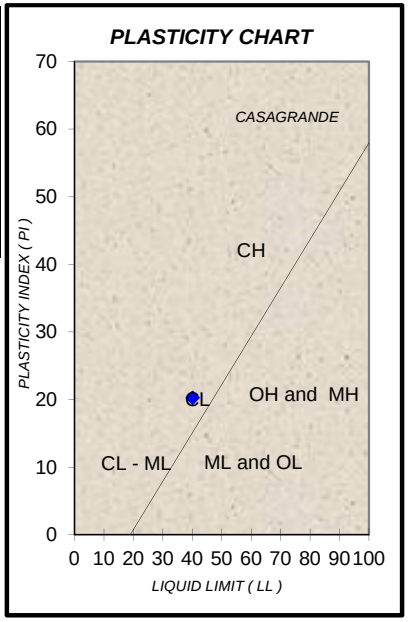
Project :	*Arlington Cemetery*	**Date Received :**	02-09-2021
Client :	Dwala Group (Pty) Ltd.	**Report Date :**	17-09-2021

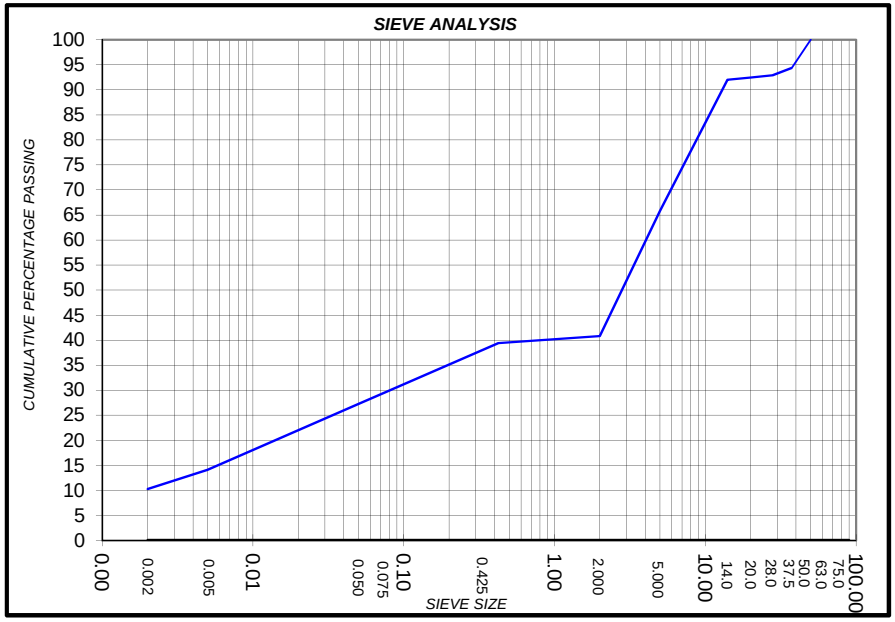
Your Reference :	*AL 05, 1.4 - 2.0m*	**Environmental Conditions :**	Not Specified	**Sample No. :**	21/1042
Sampled By :	Client			**Sampling Method :**	Not Specified

Description	**MDD / OMC** SANS 3001-GR20 & GR30		**Sieve Analysis** SANS 3001-GR1 **Cumulative percentage passing**														**Grading Modulus** SANS 3001-PR5	**Soil Mortar Analysis % of mat. <2,00 mm**				**Atterberg Limits** SANS 3001-GR10			**Classification**			
(Unified Soil Classification)	**Maximum Dry Density kg/m³**	**Optimum Moisture Content %**	**100.0mm**	**75.0mm**	**63.0mm**	**50.0mm**	**37.5mm**	**28.0mm**	**20.0mm**	**14.0mm**	**5.00mm**	**2.00mm**	**0.425mm**	**0.075mm**	**0.05 mm**	**0.005 mm**	**0.002 mm**		**Coarse - sand <2,0 >0,425mm**	**Fine - sand <0,425 >0,05mm**	**Silt <0,05 >0,005mm**	**Clay <0,005 mm**	**Liquid Limit %**	**Plasticity Index**	**Linear Shrinkage %**	**Unified Soil**	**Colto**	**US. Highway**	**Group Index**
Dark Yellowish Olive Clayey Sand	-	-	-	-	-	100	94	93	92	92	66	41	39	30	27.3	14.1	10.3	1.9	3.4	29.8	32.3	34.5	40	20	9.7	SC	-	A-2-6	1

GENERAL :		**CBR RESULTS :**	
Effective size :	<0.002	SANS 3001-GR40	
Uniformity co-eff. :	4040.1	**@ 100% comp. :**	-
Curvature co-eff. :	1.6	**@ 98% comp. :**	-
Oversize Index :	80	**@ 97% comp. :**	-
Shrinkage Product :	381	**@ 95% comp. :**	-
Grading co-eff. :	34.3	**@ 93% comp. :**	-
Swell @ 100% :	-	**@ 90% comp. :**	-







REMARKS: