REPORT ON THE PRELIMINARY GEOTECHNICAL INVESTIGATION CARRIED OUT FOR THE PROPOSED TOWNSHIP DEVELOPMENT MARIKANA EXTENSION 14 - NORTH WEST PROVINCE

Prepared for:

Homes 2000 (Pty) Ltd

Preliminary reporting stage

Report by:

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1. INTRODUCTION

Geo Simplicity Geotechnical Engineering (Pty) Ltd was appointed to carry out a *preliminary* geotechnical investigation for the proposed township development earmarked for Portions 16, 57, 58, 194 to 196, 198 to 207 and 355 of the Farm Rooikoppies 297-JQ.

The development includes, but is not limited, to the following:

- RDP and bonded units - single and possibly double storey structures,
- High density areas - 3 and possibly 4 storey structures,
- Community facilities - single and possibly double storey structures,
- Mixed use areas - Single storey structures.

At the time of our fieldwork, the site was predominantly being covered by cultivated lands and savannah grassland, whilst a relatively small portion is occupied by an existing homestead and associated gardens, some scattered trees, rocky outcrops and a wetland.

The investigation was carried out at the request of Mrs Keshia Mthimunye, representing the Client, Messrs Homes 2000 (Pty) Ltd.

Permission to proceed with the geotechnical investigation was granted via email and the fieldwork was carried out between 07 and 08 October 2019.

The samples for laboratory testing were handed over to Messrs Roadlab (Pty) Ltd for physical and chemical testing.

2. PURPOSE OF THE INVESTIGATION

The purpose of the preliminary geotechnical investigation is to:

- Establish an overview of the engineering properties of the soils and rock expected to underlie the site.
- Provide an indication of the soil/rock horizons underlying the site, all in accordance with standard practice.
- Identify any potential problematic soils which may contribute to differential settlement and/or heave for preliminary reporting purposes.
- Provide an indication of the allowable bearing capacity and settlement characteristics of the in-situ soils and/or rock.
- Provide an indication of the expected excavatability within the in-situ materials.
- Assess and provide recommendations with regards to slope stability.
- Test and provide recommendations with regards to potential soil aggressiveness and the treatment thereof.
- Provide the site class designation in accordance with the NHBRC for preliminary design purposes.
- Put forward recommendations with regards to the founding of the proposed structure for preliminary design purposes.
- Provide an indication of the in-situ material for use in road fill and pavement layers.

3. METHOD OF INVESTIGATION

3.1 *Digging of test holes and soil profiling*

In total, 41No representative test holes were dug as such not to damage any known underground services, and where it was safe and accessible to carry out our fieldwork.

The test holes were dug by means of a JCB 3DX Super Tractor Loader & Backactor (TLB) supplied by the Client. The machine was in an excellent working condition with no mechanical problems to be reported, allowing effective advance to its digging refusal which generally occurred within VERY SOFT ROCK AND HARDER, norite bedrock, generally between 1,0m and 2,6m below Ground Level at Geotechnical Investigation (GGL) stage. In test holes TH20 and TH25, digging was terminated due to digging refusal of the machine within cobbles and boulders (up to 0,8m in diameter), non-engineered fill between 1,4m and 1,5m below GGL. In test hole TH17, digging was advanced to the maximum reach of the machine which were established to be 3,3m below GGL.

The soil was profiled in-situ and it was carried out in accordance with the "Revised Guide to Soil Profiling for Civil Engineering Purposes in S.A." by Jennings, Brink and Williams, immediately after digging thereof by a professionally registered geotechnical engineer.

From a safety precautionary measure point of view, all test holes were thoroughly backfilled immediately after profiling was completed.

3.2 *Sampling and laboratory testing*

In total, 12No representative samples of the in-situ material were taken for laboratory testing.

The occurrence of scattered grass roots, a shattered and slickensided soil structure within the upper silty CLAY with scattered coarse grained sand in profile, residual norite and the occurrence of gravel with depth within the deeper silty and gravelly SAND, residual norite, made undisturbed sampling impossible.

However, sufficient visual information was gathered during soil profiling to carry out our assessment and to provide recommendations accordingly.

The following laboratory testing was carries out:

- 11No x Foundation Indicator Tests, which comprises of Atterberg Limits, dry and wet grading analysis (sieve analysis and hydrometer testing, respectively),
- 1No x Road Indicator Tests, as above but excludes wet grading (hydrometer) analysis,
- 1No x Maximum Dry Density and Optimum Moisture (MOD) Tests,
- 1No x California Bearing Ratio (CBR) Tests, and
- 8No x pH and Conductivity Tests.

The purpose for requesting these tests to be carried out on representative samples are as follows:

- Foundation and Road indicator testing: To provide basic classification of the soils in terms of potential expansiveness and to predict their re-use potential for backfill, and possibly, for pavement construction purposes.
- MOD, CBR and UCS testing: To confirm the re-use potential of the in-situ materials.
- Chemical soil aggressiveness testing: To determine the proneness of the in-situ material to corrosivity with specific reference to underground services (stormwater, water reticulation and sewer pipes and electrical cables).

The laboratory test results are included in Annexure C of the report.

4. GEOLOGY AND GENERALIZED SOIL PROFILE

According to the 1:250 000 Rustenburg 2526 geological map, the site is underlain by Norite of the Rustenburg Layered Suite, Bushveld Complex.

From a macro point of view, the following distinctive generalized soil profiles and associated geotechnical zones were encountered, namely:

- *Zone A*: Potentially expansive silty CLAY with scattered coarse grained sand in profile, residual norite, underlain by potentially compressible (in some places) silty and gravelly SAND, residual norite and ultimately underlain by norite bedrock.
- *Zone B*: Near surface norite bedrock and/or outcrops, sporadically overlain by a thin layer of potentially expansive silty CLAY with scattered coarse grained sand in profile, residual norite and potentially compressible silty and gravelly SAND, residual norite.
- *Zone C*: Non-engineered fill, comprising of a thin layer of potentially expansive silty CLAY, followed by fine to coarse grained GRAVEL, COBBLES AND BOULDERS (up to 0.8m in diameter and possibly larger) in a fine to coarse grained silty sand matrix with an expected highly variable in-situ soil consistency and associated stiffness.

From a macro point of view, the majority of the site is underlain by potentially *expansive highly to completely weathered,* silty CLAY with scattered coarse grained sand in profile, residual norite, which in turn is underlain by fine to medium grained silty and gravelly SAND, interspersed with silty clay lenses over the upper reached in places, residual norite and ultimately by VERY SOFT ROCK AND HARDER, norite bedrock with depth.

Norite corestones, ranging between moderately to highly weathered, medium hard rock hardness and unweathered to slightly weathered, extremely hard rock hardness and between <0,5m and >1,0m in diameter were sporadically encountered (see test holes TH23 and TH35 specifically) and is expected to occur randomly within the residual soils across the site.

Zone A:
Approximately 88% of the site

Generally, ranging between dry to slightly moist and slightly moist to moist, dark olive-black, ranging between *firm and very stiff, shattered and slickensided*, *potentially expansive*, silty CLAY with frequent scattered coarse grained sand and grass, plant and tree roots in places (especially over the upper reached of the horizon), residual norite occurs between GGL and to between 0,5m and 2,1m below GGL across the site.

The potentially expansive, residual norite is underlain by dry to slightly moist and slightly moist in places, light beige and olive-white (light olive-brown and beige-white in some areas), micro-speckled olive-black, with in-situ soil consistencies ranging between *loose and very dense, intact and friable*, fine to medium grained silty and gravelly SAND, residual norite, generally to between 1,2m and 2,9m below GGL and associated thickness' ranging between 0,2m and 1,1m.

In test holes TH35 to TH39, TH26 & TH27, the gravelly SAND, residual norite is interspersed with streaked olive-black, silty clay lenses over the upper reaches of the horizon. These lenses fortunately only range to between 0,7m and 1,1m and are generally thin (between 0,15m and 0,4m), where encountered.

The residual soils are underlain by light beige and olive-white or light olive-green and dusky white in places, micro-speckled olive-black, coarse grained, intact and friable, generally highly to completely weathered, very closely spaced and predominantly stained black jointed, VERY SOFT ROCK AND HARDER, norite bedrock ranging between 0,9m and 2,9m below GGL within this zone.

Zone B:
Approximately 5% of the site

Near surface (between GGL and 1,0m below GGL) norite bedrock, generally the same as per Zone A but less weathered, overlies this portion of the site.

Where encountered, the same as per Zone A's potentially expansive, silty CLAY with scattered coarse grained sand in profile, residual norite and gravelly SAND, residual norite overlies the shallow bedrock.

Zone C:
Approximately 7% of the site

Generally, the small footprint represented by this zone is underlain by dry to slightly moist, dark olive-black, *firm, shattered and slickensided*, silty CLAY with frequent scattered coarse grained sand and abundant scattered grass roots in profile, non-engineered fill (residual norite silty clay used in fill), which in turn is underlain by a boulder fill, comprising of slightly moist, light olive-brown and beige-green, speckled, mottled and blotched light beige and olive-black, *dense, massive*, fine to coarse grained GRAVEL, COBBLES AND BOULDERS (up to 0.8m in diameter and possibly larger) in a fine to coarse grained silty sand matrix non-engineered fill.

The regional geology of the site and surrounding area, together with an approximate location differentiation of the above respective generalized soil profiles and associated geotechnical zones as encountered during profiling are illustrated in the figures included in Annexure A.

The detailed material horizons, with specific reference to moisture content, colour, soil consistency/rock weathering, structure, discontinuity description (in the case of rock specifically), soil type/rock hardness and origin are summarized in the comprehensive test hole profiles forming part of this report - see Annexure B.

5. DISCUSSION AND RECOMMENDATIONS

5.1 *Topography and drainage*

A natural watercourse transverses the site from the South to the North, approximately 500m from the Eastern boundary which provides adequate surface drainage of the immediate surrounding areas. In addition, the site generally falls moderately from the South to the North with an estimated nominal slope of 1%.

Therefore, at the time of our fieldwork, moderate natural surface water run-off with a moderate to high probability of sporadic ponding is expected to occur on the site during downpours.

It is therefore advisable that all new building platforms, access roads and parking areas slightly be elevated in relation to the immediate surroundings in order to assist channelling of surface water run-off and to contribute towards the internal stability of structures and road pavements.

5.2 *Mode of weathering*

The weathering products of rock depend mainly on the rock forming minerals (parent material), the climatic conditions under which they had formed and the time of exposure to weathering processes.

In arid conditions, the weathering of rock results mainly from mechanical disintegration through wind erosion and temperature changes. The resultant soil consists mainly of the original rock forming minerals without significant changes that have taken place of the mineral composition.

In warm humid conditions chemical decomposition is the dominant mode of weathering which may change the original rock forming minerals into secondary minerals within the zone of weathering. Minerals in this zone react with water, oxygen and carbon dioxide at atmospheric pressures to produce residual soils. The residual soils produced are a mixture of resistant primary minerals such as quartz, insoluble weathering products such as alumina or silica and new or secondary minerals such as clays. It may also contain soluble products such as chloride, sulphate and bicarbonate of sodium, potassium, magnesium, or calcium, which may subsequently be leached out.

Climate does not only determine the mode of weathering which is likely to take place, but also the rate of weathering. The effect of climate on the weathering process (i.e. soil formation) is determined by the climatic N-value defined by Weinert. A climatic N-value of > 5, is associated with arid regions, where mechanical disintegration is the predominant rock weathering mode and an N-value of < 5 is associated with the humid warm areas and a surplus of water, where chemical decomposition is the predominant rock weathering mode.

The climatic N-value of the site is approximately 3, therefore chemical decomposition rather than mechanical disintegration of the parent rocks is deemed the principal mode of weathering.

5.3 *Problem soils*

5.3.1 *Collapse potential*

A collapsible grain structure was **not** noted in any of the material horizons encountered on site.

Therefore, no problems associated with collapse potential are foreseen for this development.

5.3.2 *Compressibility and settlement*

When considering the behaviour in terms of compressibility and associated potential settlement of the in-situ soils at *conventional, near surface (shallow), conventional foundation elevation*, the following criteria needs to be considered:

- The cut/fill scenario at each structural founding footprint position.
- The structural column loads and associated bearing pressures, should economical shallow foundation and corresponding footing dimensions be considered. The following allowable bearing capacity requirements, should conventional near surface founding be considered, were used in our settlement analysis:
  - Single storey structures - strip foundations - 50kPa,
  - Double storey structures - strip foundations - 80kPa or pad foundations - 150kPa, and
  - 3 to 4 storey structures - pad foundations - 300kPa
- The influence of the in-situ moisture content on the in-situ allowable bearing capacity and settlement of the different soil layers, especially when an increased in-situ moisture content and degree of saturation occur during the rainy season for instance.
- The consistency and structure of the in-situ soils in relation to the in-situ allowable bearing capacity and settlement of the different soil layers. Both parameters provides an indication of the material's inherent stiffness and associated strength.

At time of reporting, normal cut to fill operations associated with conventional platform preparation were planned for the development.

The following table provides a guideline of the minimum *continuous* soil consistencies/rock hardness requirements in relation to founding considerations, should the different minimum allowable bearing capacities be considered.

	Depth to founding (m)			
	Single storey structures	**Double storey structures**		**3-4 storey structures**
Soil horizon	**$P_{Required}$ = 50kPa**	**$P_{Required}$ = 80kPa**	**$P_{Required}$ = 150kPa**	**$P_{Required}$ = 300kPa**
Non-engineered fill	Dense	NE	NE	NE
Silty CLAY with scattered coarse grained sand, residual norite	Firm to stiff and better	NE	NE	NE
Gravelly SAND, residual norite	Medium dense and better	Medium dense to dense and better	Dense and better	NE
Norite, bedrock	Very soft rock and harder			

$P_{Required}$ = Allowable bearing capacity required (kPa)

NE = Not encountered

Minimum in-situ soil consistencies required vs allowable bearing capacity requirements

It should be noted that intolerable settlement (immediate, time related and/or tertiary creep) is expected to occur, should structural foundations be placed atop or within the different material horizons encountered with weaker/poorer continuous in-situ soil consistencies tabulated above.

In addition, we strongly recommend that stiff, reinforced concrete raft foundations only be considered, should founding of single (and possibly double storey) structures within firm to stiff and better, silty CLAY with scattered coarse grained sand in profile, residual norite be considered, in order to accommodate ad hoc moisture fluctuations and associated reduction in effective stresses and associated reduction in soil stiffness.

The following table provides an indication of the minimum recommended founding depths in relation to the predicted allowable bearing capacities, should shallow founding in relation to the different material horizons encountered during our fieldwork, be considered:

Test hole	Depth to founding (m)			
	Single storey structures	Double storey structures		3-4 storey structures
	$P_{Required}$ = 50kPa	$P_{Required}$ = 80kPa	$P_{Required}$ = 150kPa	$P_{Required}$ = 300kPa
TH01	0,2	1,6	1,6	1,6
TH02	0,6	0,6	0,6	1,2
TH03	1,5	1,5	1,5	1,9
TH04	1,6	1,6	1,6	1,8
TH05	1,5	1,5	1,5	1,8
TH06	1,4	1,7	1,7	2,0
TH07	0,3	1,1	1,1	1,4
TH08	1,2	1,2	1,2	2,1
TH09	1,4	1,4	1,4	1,9
TH10	1,4	1,4	1,4	1,9
TH11	1,2	1,2	1,2	1,2
TH12	0,8	0,8	0,8	0,8
TH13	GGL	1,45	1,45	1,6
TH14	0,4/1,3	1,7	1,7	2,3
TH15	0,7	1,5	1,5	2,6
TH16	0,7	1,3	1,3	1,5
TH17	0,6	1,9	1,9	2,9
TH18	0,4	1,1	1,1	1,7
TH19	GGL	1,15	1,15	1,5
TH20	0,2	NE	NE	NE
TH21	0,6	1,8	1,8	2,6
TH22	0,6	1,1	1,1	2,1
TH23	0,5	2,0	NE	NE
TH24	0,3/2,0	2,1	2,1	2,1
TH25	0,2	NE	NE	NE
TH26	0,2	0,85	1,5	1,7
TH27	GGL/0,5	1,7	1,7	1,7
TH28	0,2	0,95	0,95	1,5
TH29	0,2	1,0	1,0	1,7
TH30	GGL	2,1	2,1	2,4

Test hole	Depth to founding (m)			
	Single storey structures	Double storey structures		3-4 storey structures
	$P_{Required}$ = 50kPa	$P_{Required}$ = 80kPa	$P_{Required}$ = 150kPa	$P_{Required}$ = 300kPa
TH31	0,6	1,1	1,1	2,1
TH32	0,3	2,1	2,1	2,4
TH33	0,8	0,8	0,8	1,0
TH34	0,7	0,7	0,7	2,0
TH35	GGL	0,6	1,4	1,4
TH36	0,55	0,55	0,55	0,9
TH37	1,1	1,1	1,1	1,1
TH38	0,3/0,7	1,1	1,1	1,3
TH39	0,3/0,8	1,0	1,0	1,4
TH40	0,8	0,8	0,8	0,8
TH41	0,2	1,05	1,05	1,8

$P_{Required}$ = Allowable bearing capacity required (kPa)

0,2	Single storey: First encounter of *firm to stiff and better*, silty CLAY with sacttered coarse grained sand, residual norite
1,4	Single storey: First encounter of *medium dense and better*, gravelly SAND, residual norite
0,4/1,3	Single storey: First encounter of *firm to stiff and better*, silty CLAY with scattered coarse grained sand, residual norite, or *medium dense and better*, gravelly SAND, residual norite
1,6	Double storey P = 80kPa: First encounter of *medium dense to dense and better*, gravelly SAND, residual norite
1,6	Double storey P = 150kPa: First encounter of *dense and better*, gravelly SAND, residual norite
2,2	3-4 storey structures: First encounter of VERY SOFT ROCK AND HARDER, norite bedrock

NE = Not encountered

Recommended minimum conventional shallow founding level vs allowable bearing capacity

The actual predicted allowable bearing capacities of all the horizons encountered during profiling are provided within the detailed soil profiles annexed to the report - refer to Annexure B.

5.3.3 *Potential Expansiveness*

The laboratory test results of the in-situ soils, *except* for the silty CLAY with scattered coarse grained sand in profile, residual norite, indicate that Plasticity Indexes (PI's) may vary between Non-Plastic (NP) and 17%, with the PI of the whole sample (P_{whole} = PI x Percentage <0,425mm) of a representative samples being calculated to vary between zero and 4,1% and the percentage clay (%Clay) tested to range between 1,5% and 5,5%.

Therefore, these soils (excluding the silty CLAY with scattered coarse grained sand in profile, residual norite) have a "Low" potential for swell and are not considered to be expansive.

However, the silty CLAY with scattered coarse grained sand in profile, residual norite encountered across the site is prone to heave, should these soils experience significant (dry-to-wet) moisture fluctuations.

PI's of these soils are expected to range between 14% and 26%, whilst the PI_{whole} calculated to range between 13,2% and 24,7%, whilst the %Clay measured to vary between 38,2% and 42,5%.

However, in order to determine the risk and associated magnitude of heave, the following additional combined factors need to be considered:

- The magnitude of the envisaged superimposed loads.
- The thickness of the potentially expansive soil layers.
- The in-situ moisture content of the potentially expansive soils.

- The likelihood of the in-situ potentially expansive soils to undergo especially a dry-to-wet moisture cycle.

The soil characteristics of the potentially expansive soils, insofar heave is concerned, can be summarized as follows:

Soil type & origin:	PI (%)	PI_W	h1 (m)	h2 (m)	% Clay	Vdm	Heave (mm)
Silty CLAY with scattered coarse grained sand in profile. Residual norite.	26	24,7	0,5 - 2,1	GGL	38,2 to 42,5	Medium to high	±10 - ±60

With:
PI = Maximum Plasticity Index
PI_W = Weighted PI = PI x % passing the 0.425mm sieve
h1 = Typical thickness range of swelling layer (m)
h2 = Depth of top of swelling layer below ground surface (m)
GGL = Ground level at geotechnical investigation stage.
% Clay = Maximum % passing the 0.002mm sieve
Vdm = Critical heave class according to Van der Merwe (1964)
Heave = Predicted heave according to Van der Merwe (mm)

At the time of our fieldwork (October 2019), the in-situ moisture content of the potentially expansive soils was noted to vary between dry to slightly moist and slightly moist to moist, which indicates that the in-situ moisture content of these soils at the time of our fieldwork is most probably between 4% to 11% *below* the Predicted Equilibrium Moisture Content (PEMC).

Therefore and based on past experience, problems associated with heaving within the potentially expansive silty CLAY with scattered coarse grained sand in profile, residual norite can be expected to occur across the site.

5.4 *Groundwater*

No groundwater seepage was encountered during our fieldwork.

However, it should however be noted that the fieldwork was carried out towards the end of the dry season and the beginning of the rainy season (07 and 08 October 2019).

Therefore, groundwater seepage is possible to occur within foundation and service trench excavations especially at the contact of weaker and more competent horizons, normally in the form of a perched groundwater table and especially towards the end of the rainy season, or during a more profound rainy season.

We strongly recommend that proper surface run-off and subsurface drainage including damp proofing form part of the permanent works.

5.5 *Excavatibility*

Excavatibility up to the first occurrence of VERY SOFT ROCK AND HARDER, norite bedrock TLB refusal can be described as **"Soft"** excavation in accordance with SANS 1200D: Earthworks.

However, during its weathering process, norite is prone to the formation of corestones that may vary significantly in hardness from soft to extremely hard rock (1MPa < UCS > 70MPa) and is renowned to have a highly undulating bedrock profile which may vary significantly in hardness in both the horizontal and vertical plane and within short distances.

Both corestones and a variable depth to bedrock occurrence were established during our fieldwork. In addition, based on past experience, a sudden increase in rock hardness with depth is expected to occur, once the first occurrence of very soft rock and harder, norite bedrock is encountered.

Taking the expected sudden increase in rock hardness with depth into consideration, we recommend that the first occurrence of VERY SOFT ROCK, norite should be taken as "**Intermediate**" excavation, whilst SOFT ROCK TO MEDIUM HARD ROCK AND HARDER, norite bedrock should be taken as "**Hard**" excavation, all in accordance with SANS 1200D: Earthworks.

The table following on the next page summarizes what we believe can be taken as the different classes of excavation in accordance with SANS 1200D: Earthworks, should the information gathered from the test holes be considered as a guideline.

	Approximate depth range (m)				
TH position	**Soft excavation**	**Intermediate excavation**	**Hard excavation**	**Boulder A (>40% of excavation volume)**	**Boulder B (<40% of excavation volume)**
TH01	0,0-1,6	NE	1,6+	NE	NE
TH02	0,0-1,2	1,2+	NE	NE	NE
TH03	0,0-1,9	1,9+	NE	NE	NE
TH04	0,0-1,8	1,8+	NE	NE	NE
TH05	0,0-1,8	1,8+	NE	NE	NE
TH06	0,0-2,0	2,0+	NE	NE	NE
TH07	0,0-1,4	1,4+	NE	NE	NE
TH08	0,0-2,1	2,1+	NE	NE	NE
TH09	0,0-1,9	1,9+	NE	NE	NE
TH10	0,0-1,9	1,9+	NE	NE	NE
TH11	0,0-1,2	1,2+	NE	NE	NE
TH12	0,0-1,5	1,5+	NE	NE	NE
TH13	0,0-1,6	1,6+	NE	NE	NE
TH14	0,0-2,3	2,3+	NE	NE	NE
TH15	0,0-2,6	2,6+	NE	NE	NE
TH16	0,0-1,5	1,5+	NE	NE	NE
TH17	0,0-2,9	2,9+	NE	NE	NE
TH18	0,0-1,7	1,7+	NE	NE	NE
TH19	0,0-1,5	1,5+	NE	NE	NE
TH20	0,0-0,2	NE	NE	0,2-1,5+	NE
TH21	0,0-2,6	2,6+	NE	NE	NE
TH22	0,0-2,1	2,1+	NE	NE	NE
TH23	0,0-2,1	NE	NE	2,1+	NE
TH24	0,0-2,1	2,1+	NE	NE	NE
TH25	0,0-0,2	NE	NE	0,2-1,4+	NE
TH26	0,0-1,7	NE	1,7+	NE	NE
TH27	0,0-1,7	1,7+	NE	NE	NE
TH28	0,0-1,5	NE	1,5+	NE	NE
TH29	0,0-1,7	NE	1,7+	NE	NE
TH30	0,0-2,4	NE	2,4+	NE	NE

	Approximate depth range (m)				
TH position	Soft excavation	Intermediate excavation	Hard excavation	Boulder A (>40% of excavation volume)	Boulder B (<40% of excavation volume)
TH31	0,0-2,1	2,1+	NE	NE	NE
TH32	0,0-2,4	NE	2,4+	NE	NE
TH33	0,0-1,0	NE	1,0+	NE	NE
TH34	0,0-2,0	2,0+	NE	NE	NE
TH35	0,6-1,4	1,4+	NE	0,0-0,6	NE
TH36	0,0-0,9	NE	0,9+	NE	NE
TH37	0,0-1,1	NE	1,1+	NE	NE
TH38	0,0-1,3	NE	1,3+	NE	NE
TH39	0,0-1,4	1,4+	NE	NE	NE
TH40	0,0-0,8	NE	0,8+	NE	NE
TH41	0,0-1,8	1,8+	NE	NE	NE

Note: NE = Not encountered to digging reach

Potential excavation categories encountered in test holes

Notwithstanding the predicted excavatibility based on the information gathered from test pitting, adequate (extra over) allowances for the effective removal of material representing **"Intermediate"**, **"Hard"** and **"Boulder class B"** excavation categories should be allowed for bulk earthworks budget purposes to accommodate any variance with regards to excavatibility with depth.

Insofar excavation within **"Hard"** material is concerned, excavation by means of power tools, such as seismic pneumatic rock breaker attached to a 25t traxcavator for instance, should be considered as a minimum. Pre-splitting and controlled blasting may prove to be more economical when larger quantities need to be removed.

Allowance for the effective digging advance within the **"Boulder class A & B"** and potential **"Intermediate"** material by means of a 25t minimum traxcavator should preferably be allowed.

Insofar piled foundations for 3-4 storey structures, as recommended under clause 5.9.1 of the report in areas underlain by thick non-engineered fill or potentially expansive soils are concerned, percussion ROTA-type of piles to be considered within non-engineered fill or more modern European auger piling rigs where deep clay horizons are expected, should preferably be considered in order to mitigate advance through the possible occurrence of underground obstructions such as bouldery non-engineered fill or norite corestones, alike.

5.6 *Slope stability*

The test hole sidewalls appeared to be completely stable with no sidewall collapse noted during soil profiling.

However, sidewall stability can worsen drastically if water is to be encountered in excavations, albeit in the form of a perched water table and associated groundwater seepage, damaged water pipe or poor surface water run-off management which may result in water to accidently be draining into excavations during construction.

Therefore, excavation sides deeper than say 1,5m must either be battered back to 1:1,5 (vertical:horizontal) or shored; allowing safe working conditions for workers in these excavations.

No deep *vertical* excavations are foreseen for this development. Composite lateral support systems may be considered where deeper vertical and near vertical excavations are required, or where space restrictions prohibit battered back sloping for instance.

5.7 *Soil aggressiveness and corrosivity*

The pH and conductivity of soil is generally determined to get an indication of the potential corrosiveness of the soil. The pH of a soil gives an indication of the acidity of the soil. As a general guideline Evans [6.8] notes that corrosion may take place in soil with a pH of less than 6 and that should the pH be less than 4.5, the problem may be serious. It should however be borne in mind that a low pH value is not necessarily an indication of serious corrosiveness as the pH of the surrounding soil will generally start to rise as soon as corrosion starts.

Should one view the pH values only of the 8No samples tested (pH ranges between 7.31 and 8.57), then the in-situ soils is not expected to be prone to corrosivity at all.

However, corrosion is an electrochemical process whereby metals are changed and electrical energy is released. The conductivity of the soil therefore has a profound influence on the rate of corrosion of buried metallic objects.

Duligal [6.9] provides the following table for evaluation of the conductivity of soil:

Soil conductivity (mS/m)	Corrosion classification
More than 50	Extremely corrosive
26 - 50	Very corrosive
21 - 25	Corrosive
10 - 20	Mildly corrosive
Less than 10	Not generally corrosive

The soil corrosion classification can be summarized as follows:

Soil type and origin	Soil conductivity (mS/m)	Corrosion classification
Bouldery non-engineered fill	20	Very corrosive
Silty CLAY with scattered coarse grained sand, residual norite	109 - 115	Extremely corrosive
Fine to medium grained silty and gravelly SAND interspersed with silty clay lenses. Residual norite.	25	Corrosive
Fine to medium grained silty and gravelly SAND. Residual norite.	13-78	Ranging between not generally corrosive to being extremely corrosive

We strongly recommend that a **"Very Severe"** exposure condition rather be adopted as a minimum for concrete placed within the in-situ horizons encountered, all in accordance with SANS 1200G: Concrete (Structural), especially should the variable degree of corrosivity and the expected fluctuating perched groundwater table be considered.

In addition, subsurface services (non-concrete) should be treated/sleeved to prevent possible damages due to corrosion.

According to SANS 1200G: Concrete (Structural), concrete used for foundations of structures within potentially aggressive soils should have the following minimum concrete cover and maximum water:cement ratio's:

Exposure conditions	Specified strength of concrete (MPa)					Minimum cover for various exposure conditions (mm)
	20	25	30	40	50	
Mild	20	20	15	15	15	
Moderate	40	40	30	25	20	
Severe	NA	50	40	40	35	
Very severe	NA	75	60	60	50	

Type of structures	Exposure conditions			
	Mild	Moderate	Severe	Very severe
Thin sections, reinforced piles, all sections with less than 25mm cover to reinforcement	*	0.53	0.48	0.4
Moderate sections, retaining walls, piers, beams	*	*	0.53	0.43
Exterior portions of mass concrete	*	*	0.53	0.43
Concrete slabs laid on ground	*	0.53	0.48	*
Concrete protected from the weather, inside buildings, or in ground below frost level	*	*	*	*
* In these cases the ratio will be based on strength for workability required				

The soil aggressiveness and corrosivity laboratory test results are included in Annexure C to the report.

5.8 *Site class designation*

The site, from a geotechnical site class designation point of view, can be divided into three zones, namely Zones A, B & C.

Zone A class as "H2/S2/R", Zones B as "R/H2/S2" and Zone C as "P(Uncontrolled fill)/S2/H2", all in accordance with the NHBRC classification system.

Reference should be made to Figure 2: Geotechnical zoning (Annexure A), annexed to the report.

5.9 *Founding recommendations*

5.9.1 *Structural founding*

Pending on the final micro-positioning of the various structures on site, one of the following founding recommendations can be considered, namely:

- All structures within near surface/economical founding areas: Conventional shallow, albeit strip or pad, foundations. *Allowable bearing capacity requirements ranges between 50kPa to 300kPa.*
- Single and double storey structures accommodating ad-hoc thick clay lenses and non-engineered fill (double storey structures specifically): Combined engineered fill and stiff, reinforced concrete raft foundations. *Maximum allowable bearing capacity (P) for design purposes: P = 50kPa.*
- 4-storey structures accommodating thick ad-hoc non-engineered fill/potentially expansive soils: Piled foundations.

Single storey structures - P = 50kPa
Engineered fill combined with conventional strip foundations

Conventional reinforced shallow foundations must be placed within gravelly SAND, residual norite with or without intermittent silty clay lenses and with a ***continuous*** *medium dense and better* in-situ soil consistency and associated soil stiffness, should an allowable bearing capacity requirement of 50kPa be considered.

It should be noted that **all** potentially expansive silty CLAY with scattered coarse grained sand be removed and replaced with an engineered fill, comprising of **G6/G7** quality material, compacted to 95% of Mod AASHTO density and in 150mm thick layers, prior to surface bed construction.

Double storey structures
Engineered fill combined with strip foundations (P = 80kPa), or
Engineered fill combined with pad foundations (P =150kPa)

Conventional reinforced shallow foundations must be placed within gravelly SAND, residual norite with or without intermittent silty clay lenses and with ***continuous*** *medium dense to dense and better, or dense and better*, in-situ soil consistencies and associated soil stiffness, should an allowable bearing capacity requirement of 80kPa and 150kPa, respectively, be considered.

All potentially expansive silty CLAY with scattered coarse grained sand should be removed and replaced with an engineered fill, comprising of **G6/G7** quality material, compacted to 95% of Mod AASHTO density and in 150mm thick layers, prior to surface bed construction.

Single and double storey structures - P = 50kPa maximum
Engineered fill combined with stiff, reinforced concrete raft foundations

In areas where thick potentially expansive soils, or non-engineered fill (double storey structures specifically) occur, stiff, reinforced concrete raft foundations are to be founded within a **G6/G7** quality engineered granular fill, compacted in 150mm thick layers and to 95% of Mod AASHTO density at the material's optimum moisture content, once all *less than firm to stiff*, silty CLAY with scattered coarse grained sand, residual norite is removed. The engineered fill should extend to 300mm (2 x 150mm layers) *below* raft foundations and must extend to a minimum of 0,5m beyond structural footprints.

3-4 storey structures - P = 300kPa
Conventional pad foundations

Conventional reinforced shallow foundations must be placed within ***VERY SOFT ROCK AND HARDER***, norite bedrock should an allowable bearing capacity requirement of 300kPa be considered.

All potentially expansive silty CLAY with scattered coarse grained sand should be removed and replaced with an engineered fill, comprising of **G6/G7** quality material, compacted to 95% of Mod AASHTO density and in 150mm thick layers, prior to surface bed construction.

The bottom of *all* foundation excavations must however be completely dry and free of any loose material. Where shallow foundations are formed within gravelly SAND, residual norite, in-situ compaction to 95% of Mod AASHTO density at the in-situ-material's optimum moisture content *must* first be carried out as a precautionary measure, prior to placement of reinforcing or concrete for all single and double storey foundations.

3-4 storey structures underlain by thick non-engineered/potentially expansive soils
Piled foundations

ROTA type percussion bored piles, should be considered where 3-4 storey structures are to be founded in areas of expected ad-hoc thick non-engineered fill, whilst Auger Cast In-Situ (ACIS) piles may be considered in areas of thick potentially expansive soil occurrences.

We believe that typical pile drilled lengths should not exceed 6m. However, the pile design (diameter, rock socket requirements and ultimately, drilled lengths) can only be finalised once the column loads are known and the initial pile holes have been drilled.

We recommend that 0,8m wide (minimum) apron slabs be constructed around the perimeter of structures, purely as an attempt to prevent moisture content fluctuations of the underlying, potentially expansive soils.

We strongly recommend that a competent person check and accept foundation excavations and engineered fill construction, including pile designs and installation methodologies, prior to reinforcing and concrete placement and we confirm our availability to assist in arriving at a working model in this regard, should it be requested.

The in-situ predicted allowable bearing capacities of all the material horizons are provided within the detailed soil profiles annexed to the report - refer to Annexure B.

5.9.2 *Surface bed, access road and parking areas*

The founding of access roads and parking areas, as well as surface beds where piled foundations are employed (3-4 storey structures specifically) are summarized as follows:

- Clear and remove the upper organic contaminated soils, where encountered.
- Allowance should be made for 100mm thick void formers (polystyrene or alike) to accommodate potential heave and to be installed prior to surface bed construction, piled foundations are employed (3-4 storey structures specifically).
- For all access roads and parking areas, a minimum of 1m of the upper potentially expansive, in-situ silty CLAY with scattered coarse grained sand, residual norite must be removed in its entirety, prior to roadbed preparation.
- Rip and re-compact the upper say 300mm (minimum) of in-situ soils to a minimum of 93% Mod AASHTO in-situ density, for surface beds and access road beds formed within gravelly SAND, residual norite material. In areas where surface beds and access road beds need to be formed within potentially expansive soils, rip and re-compact the upper 300mm (minimum) of in-situ silty CLAY with scattered coarse grained sand, residual norite to a minimum of 95% Proctor in-situ density.
- Import minimum one layer of **G7** minimum quality natural soils/gravels and compact to 95% of Mod AASHTO at optimum moisture content for all surface bed preparation and selected road layer works construction purposes.
- A minimum of 1No x 150mm thick layer, comprising of **G5/G6** material stabilized to **C4** base/subbase quality material (minimum) should be considered for road pavement construction purposes.
- Interlocking block paving surfacing should preferably be considered as final road and parking area surfacing. In addition, we recommend that pavement shoulders be covered 1,0m beyond the perimeter of all road and parking areas, purely as an attempt to prevent moisture content fluctuations which may result in differential movement within potentially expansive alluvium transported soils.

5.10 *Re-use potential of the in-situ material*

The laboratory test results of the in-situ soils with their associated classification in accordance with TRH14, are summarized in the table following on the next page.

Based on the foundation indicator related laboratory test results, the fine to medium grained silty and gravelly SAND interspersed with silty clay lenses, residual norite and the fine to coarse grained clayey and gravelly SAND, residual norite encountered in test hole TH27 specifically class between **G8** and **G9** material and may be considered for bulk backfilling purposes only.

The fine to medium grained silty and gravelly SAND, residual norite, as well as the fine to coarse grained GRAVEL, COBBLES AND BOULDERS (up to 0.8m in diameter) in a fine to coarse grained silty sand matrix, non-engineered fill class between **G7** and **G9** material and may be considered for bulk backfilling and selected layer/surface bed/engineered fill construction, should quality control related laboratory testing results meet the minimum **G7** requirement for selected layer/surface bed/engineered fill construction specifically.

Soil type and origin	TH No	DS No	Depth range (m):	Layer thickness (m)	GM	PI	%<0,425	PI_{whole}	%Clay	Heave class	CBR			TRH14	Soil aggressiveness		
											90%	93%	95%		pH	Cond	Degree
Silty CLAY with frequent scattered coarse grained sand in profile. Residual norite.	TH39	DS1	0,0-0,8	0,80	0,34	26	95	24,7	42,5	Medium to high	-	-	-	>G10	7,68	109	Extremely corrosive
Fine to medium grained silty and gravelly SAND interspersed with silty clay lenses. Residual norite.	TH39	DS2	0,8-1,0	0,20	1,77	NP	43	0,0	3,8	Low	-	-	-	G8/G9[1]	8,02	25	Corrosive
Fine to medium grained silty and gravelly SAND. Residual norite.	TH39	DS3	1,0-1,4	0,40	1,78	NP	45	0,0	2,3	Low	-	-	-	G7/G8[1]	8,14	13	Mildly corrosive
Fine to coarse grained clayey and gravelly SAND. Residual norite.	TH27	DS4	0,7-1,7	1,00	2,30	17	24	4,1	5,5	Low	-	-	-	G8/G9[1]	-	-	-
Fine to coarse grained GRAVEL, COBBLES AND BOULDERS (up to 0.8m in dia) in a fine to coarse grained silty sand matrix. Non-engineered fill.	TH25	DS5	0,2-1,4	1,20	2,26	NP	27	0,0	2,1	Low	-	-	-	G7/G8[1]	8,57	20	Mildly corrosive
Silty CLAY with frequent scattered coarse grained sand in profile. Residual norite.	TH19	DS6	0,0-1,15	1,15	0,44	14	94	13,2	38,2	Low to medium	-	-	-	>G10	7,31	115	Extremely corrosive
Fine to medium grained silty and gravelly SAND. Residual norite.	TH19	DS7	1,15-1,5	0,35	1,97	SP	36	0,0	3,9	Low	-	-	-	G7/G8[1]	7,64	78	Extremely corrosive
Silty CLAY with frequent scattered coarse grained sand in profile. Residual norite.	TH15	DS8	0,0-1,5	1,50	0,35	24	97	23,3	42,1	Medium to high	-	-	-	>G10	-	-	-
Fine to medium grained silty and gravelly SAND. Residual norite.	TH15	DS9	1,5-2,6	1,10	1,98	9	36	3,2	3,3	Low	-	-	-	G7/G8[1]	-	-	-
	TH08	DS10	1,2-2,1	0,90	2,59	10	11	1,1	-	Low	7	11	13	G9	-	-	-
Silty CLAY with frequent scattered coarse grained sand in profile. Residual norite.	TH41	DS11	0,0-1,05	1,05	0,46	24	94	22,6	42,5	Medium	-	-	-	>G10	7,79	113	Extremely corrosive
Fine to medium grained silty and gravelly SAND. Residual norite.	TH41	DS12	1,05-1,8	0,75	1,96	4	25	1,0	1,5	Low	-	-	-	G7/G8[1]	8,05	19	Mildly corrosive

[1]Estimated TRH 14 classification. We strongly recommend that confirmation quality assurance testing be carried out to confirm the above material classification for construction purposes.

All oversize material was removed during sampling process to provide a representative laboratory test result for re-use consideration purposes.

Summary of road building related laboratory test results

All oversize and organic material ***must*** be removed prior to re-use though.

Therefore, all **G5**, **G6** and **G7** shortfall (base, subbase/engineered fill/selected road and surface bed layer works) material will have to be imported from commercial resources, when required.

We strongly recommend that confirmation quality assurance testing be carried out to confirm the noted material classifications for construction stage re-use considerations.

We trust that our report meets with your expectations. Should you wish to discuss the above in any further detail, please do not hesitate to contact the undersigned.

Yours faithfully,

Petrus van Straten
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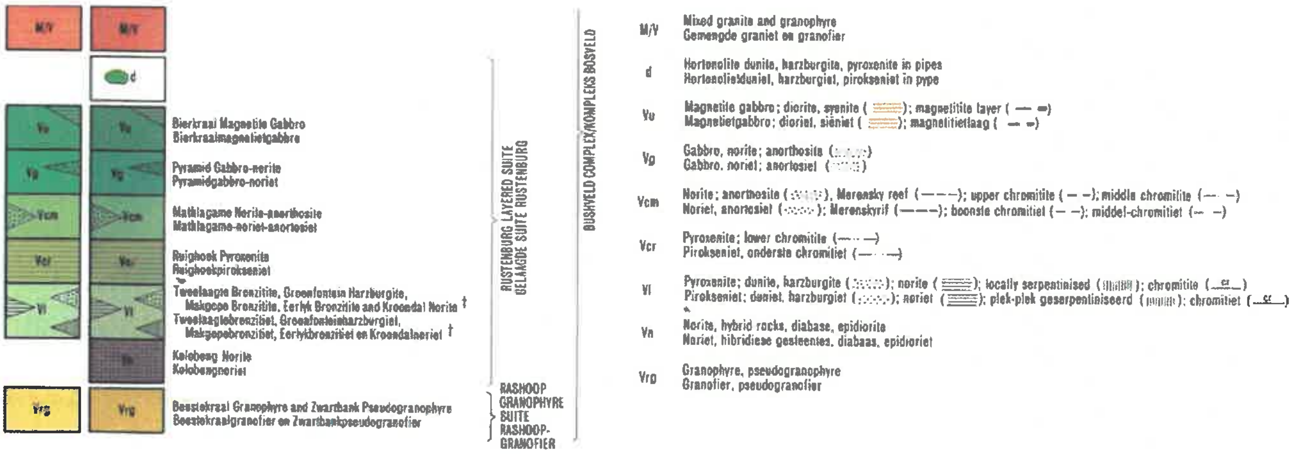
ANNEXURE A:

DRAWINGS

(REGIONAL GEOLOGY, SITE LOCATION, TEST POSITIONS AND GEOTECHNICAL ZONING)

Regional geology

Where:



LOCALITY MAP

TEST POSITIONS

TEST HOLE DATA:

TH 01 TLB TEST HOLE NUMBER & POSITION	TH 01	TH 02	TH 03	TH 04	TH 05	TH 06	TH 07	TH 08	TH 09	TH 10	TH 11	TH 12	TH 13	TH 14	TH 15	TH 16	TH 17	TH 18	TH 19	TH 20
TEST HOLE DEPTH (m)	1.60 m	1.50 m	1.90 m	1.80 m	1.80 m	2.00 m	1.40 m	2.10 m	1.90 m	1.90 m	1.50 m	1.50 m	1.80 m	2.30 m	2.60 m	1.50 m	3.30 m	1.70 m	1.50 m	1.50 m
TEST HOLE REFUSAL DEPTH (m)	1.60 m	1.50 m	1.90 m	1.80 m	1.80 m	2.00 m	1.40 m	2.10 m	1.90 m	1.90 m	1.50 m	1.50 m	1.80 m	2.30 m	2.60 m	1.50 m	Not Encountered	1.70 m	1.50 m	1.50 m
GROUNDWATER SEEPAGE,(m)	Not Encountered																			

Note:
- All measurements taken below Ground Level at Geotechnical Investigation stage (GGL) m
- Groundwater seepage = Depth below GGL (m)

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PROJECT:
PRELIMINARY GEOTECHNICAL INVESTIGATION FOR THE PROPOSED TOWNSHIP DEVELOPMENT MARIKANA EXTENSION 14 - NORTH WEST PROVINCE

FIGURE 1:
SITE LOCATION AND TEST POSITIONS

REVISIONS:

PREPARED: PvS
APPROVED: PvS
DATE: 10 - DEC - 2019
DRAWING No.: G403-DRW01-REV.00

LOCALITY MAP

TEST POSITIONS

TEST HOLE DATA:

TLB TEST HOLE NUMBER & POSITION (TH 01)	TH 21	TH 22	TH 23	TH 24	TH 25	TH 26	TH 27	TH 28	TH 29	TH 30	TH 31	TH 32	TH 33	TH 34	TH 35	TH 36	TH 37	TH 38	TH 39	TH 40	TH 41
TEST HOLE DEPTH (m)	2.60 m	2.10 m	2.10 m	2.10 m	1.40 m	1.70 m	1.70 m	1.50 m	1.70 m	2.40 m	2.10 m	2.40 m	1.00 m	2.20 m	1.40 m	0.90 m	1.10 m	1.30 m	1.40 m	0.80 m	1.80 m
TEST HOLE REFUSAL DEPTH (m)	2.60 m	2.10 m	2.10 m	2.10 m	1.40 m	1.70 m	1.70 m	1.50 m	1.70 m	2.40 m	2.10 m	2.40 m	1.00 m	2.20 m	1.40 m	0.90 m	1.10 m	1.30 m	1.40 m	0.80 m	1.80 m
GROUNDWATER SEEPAGE,(m)	Not Encountered																				

Note:
- All measurements taken below Ground Level at Geotechnical Investigation stage (GGL) m
- Groundwater seepage = Depth below GGL (m)

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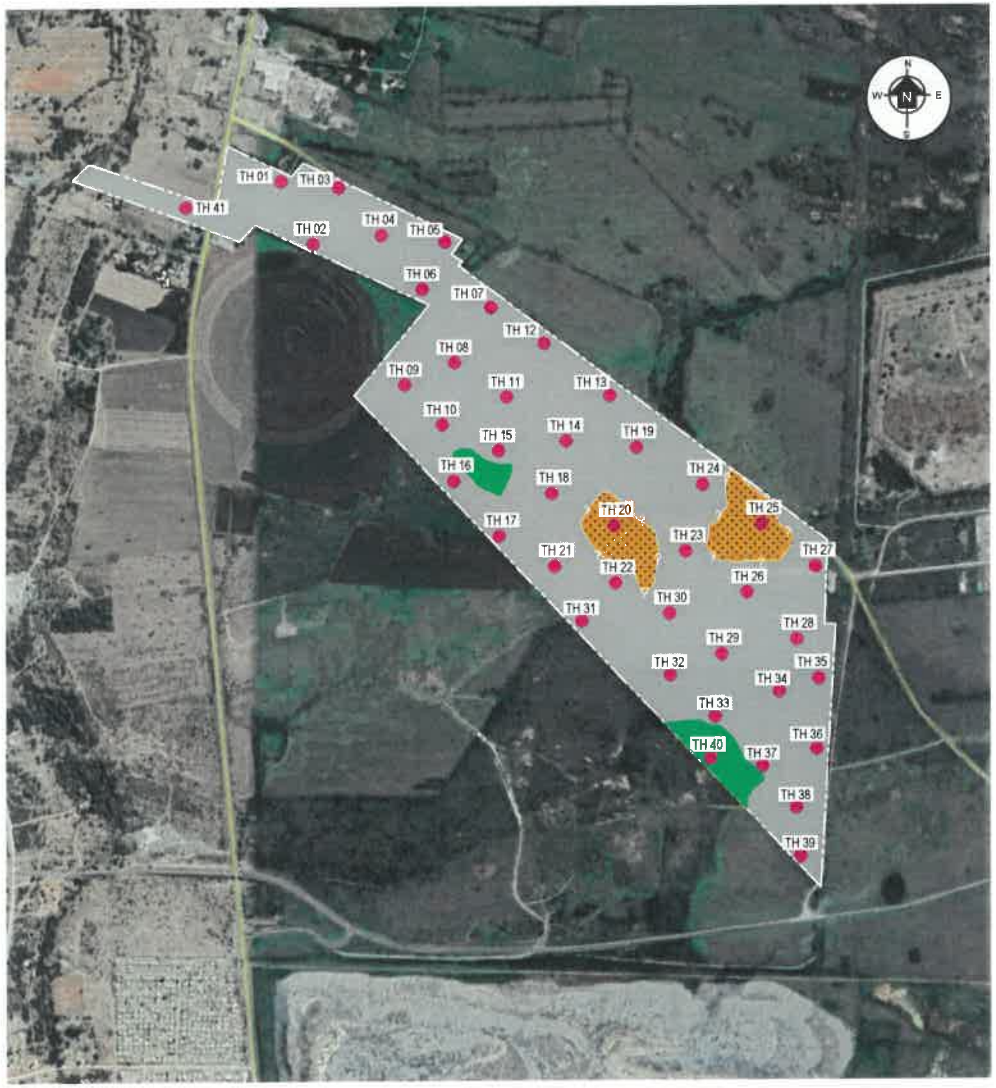
FIGURE 2:
SITE LOCATION AND TEST POSITIONS

REVISIONS:

PREPARED: PvS
APPROVED: PvS
DATE: 10 - DEC - 2019
DRAWING No.: G403-DRW02-REV.00



NOTES:

1. Demarcation of zones is approximate and should be confirmed during construction.
2. Refer to text of report for detailed foundation recommendations.
3. GGL = Ground level at geotechnical investigation fieldwork stage
4. Site class designation:

Geotechnical zone	Descriptions	Class
Zone A	Potentially expansive silty CLAY, residual norite, underlain by potentially compressible (in some places) silty and gravelly SAND, residual norite and ultimately underlain by norite bedrock.	H2 / S2 / R
Zone B	Near surface norite bedrock and/or outcrops, sporadically overlain by a thin layer of potentially expansive silty CLAY, residual norite and potentially compressible silty and gravelly SAND, residual norite.	R / H2 / S2
Zone C	Non-engineered fill, comprising of a thin layer of potentially expansive silty CLAY, followed by fine to coarse grained GRAVEL, COBBLES AND BOULDERS (up to 0.8m in dia) in a fine to coarse grained silty sand matrix with an expected highly variable in-situ soil consistency and associated stiffness.	P (Uncontrolled fill) / S2 / H2

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FIGURE 3:
GEOTECHNICAL ZONING

REVISIONS:

PREPARED: PvS
APPROVED: PvS
DATE: 10 - DEC - 2019
DRAWING No.: G403-DRW03-REV.00