MHLANGA TOWNSHIP DEVELOPMENT

PRELIMINARY SHALLOW SOIL ENGINEERING GEOLOGICAL INVESTIGATION FOR PLANNING PURPOSES, MHLANGA VILLAGE, UMTATA REGION, EASTERN CAPE PROVINCE

Basic Shallow Soil Investigation for Residential Planning

Project number: WF14066 **17 September 2014**

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PRELIMINARY SHALLOW SOIL ENGINEERING GEOLOGICAL INVESTIGATION FOR PLANNING PURPOSES, MHLANGA VILLAGE, UMTATA REGION, EASTERN CAPE PROVINCE

1. INTRODUCTION

WSM Leshika Consulting (Pty) Ltd. was appointed to conduct a basic shallow soil geotechnical assessment for the proposed housing units to be erected in the village known as Mhlanga, Umtata Region, Eastern Cape Province.

The area of interest is depicted in Figure 1 and Figure 2, Appendix A.

This report discusses the method of investigation, geotechnical conditions encountered with on-site material characteristics, recommendations and general considerations.

The level of information provided in this report is deemed suitable for planning purposes.

2. OBJECTIVES OF THE INVESTIGATION

The main objectives of the investigation were to:

- Identify and discuss the main on-site geotechnical constraints;
- Obtain the basic data concerning the use of in situ material;
- Comment on the excavation characteristics of the site soils;
- Comment on the potential for shallow seepage water conditions;
- Define the general ground conditions and provide site classifications including detailed soil profile and groundwater occurrences within the zone of influence of foundation work;
- Comment on the founding conditions;
- Provide the geotechnical basis for **planning** and **preliminary design** purposes.

3. INFORMATION USED DURING THE STUDY

The following information was available at the time of writing this report:

- Locality map;
- Approximate site boundaries;
- 1:50 000-scale 3129AC Topographical map;
- 1:250 000-scale 3128 UMTATA Geological Sheet;
- Existing GoogleEarth images.

Laboratory test results conducted on selectively retrieved soil horizons were also available at the time of writing this report. The laboratory tests consist of basic index tests and compaction tests conducted on a limited number of samples.

Localities for proposed units were not available and no tests for heave and/or collapse or consolidation quantification were conducted for the purposes of this basic investigation.

4. METHOD OF INVESTIGATION

The method of investigation can be summarized as:

- Desk study of available databases such as, aerial images and geological sheets;
- Field walkover survey;
- Excavation of a limited number of test pits with a TLB;
- Detailed soil profile descriptions;
- Soil profile photograph recordings;
- Selective soil sampling;
- Basic soil testing;
- Laboratory test results interpretation;
- Compilation of report with findings and recommendations.

Seven test pits were excavated by means of a JCB 3CX TLB in the area of interest down to refusal or to near refusal excavation conditions. The test pit positions are depicted in Figure 3, Appendix A.

A suitably qualified engineering geologist positioned and inspected the test pits. The soil profiles were recorded using the standard procedures as per the SANS633:2012 standards. The individual soil profile descriptions are attached as Appendix B with photographs attached as Appendix C.

Disturbed samples were selectively retrieved in order to determine the soil grading, compaction characteristics and general material properties. The samples were submitted to an SANAS accredited laboratory, ControLab South Africa (Pty) Ltd. for testing. The test results are attached as Appendix D.

5. GEOLOGY

5.1 Regional Geology

According to the 1:250 000-scale geological sheet 3128 Umtata, the area of interest is underlain by:

- "Jd" – Dolerite.
- "Pa" – Grey and brownish-red mudstone, sandstone.

The onsite rock/geology was interpreted as shale/siltstone.

The site is not underlain by potentially soluble dolomitic formations and a specialized dolomite stability investigation **is not required**.

The geology is depicted in Figure 4, Appendix A.

5.2 Site Specific Geology

Seven test pits were excavated by means of a TLB and terminated at between 0.87 to 3.00 m bngl (meters below natural ground level) in completely to highly weathered shale. Soft excavation conditions were encountered down to termination depth.

Based on the conditions encountered in the trial pits the site is seemingly covered with a moderately thick fine sandy silty clayey open structured stiff colluvium down to between 0.30 m and 0.55 m bngl.

The colluvial layer is underlain by a stiff to very stiff open structured silty clayey gravel pebble marker down to 0.40 m to 0.75 m bngl. The layer contains abundant iron and manganese nodules.

The colluvial layer is underlain by a medium dense to firm to dense to stiff silty clayey/clayey silty open and pinholed residual shale layer down to 0.65 m to 2.30 m bngl. The residual shale layer is underlain by slightly layered very dense silty completely weathered shale down to 0.87 m to 3.00 m bngl. The completely weathered shale is underlain by layered and jointed highly weathered soft rock shale down to 0.87 m to 3.00 m bngl.

A summary of the soil profiles are provided in Table 1a and Table 1b. The detailed soil profiles are attached as Appendix B with the relevant profile photographs as Appendix C.

Table 1a: Soil profiles summary (co-ordinates and soil textures)

Test pits	Latitude	Longitude	Elevation	Clay	Silt	Sand	Gravel
MH01	-31.437988°	29.014490°	1001	0.00-2.30	0.00-2.30	-	0.30-0.60
MH02	-31.441532°	29.011115°	972	0.00-0.65	0.00-1.20	-	0.00-0.40
MH03	-31.438348°	29.008805°	980	0.00-0.40	0.00-0.40	-	-
MH04	-31.433857°	29.012587°	1008	0.00-1.05	0.00-1.60	-	0.55-0.75
MH05	-31.433155°	29.017558°	1019	0.00-1.35	0.00-1.35	-	0.40-0.65
MH06	-31.429821°	29.011508°	1008	0.00-1.70	0.00-1.70	1.70-2.80	0.30-0.75
MH07	-31.430987°	29.006400°	990	0.00-0.90	0.00-1.40	0.90-1.40	0.30-0.75

Table 1b: Soil profiles summary (soil horizons and excavation)

Test pits	Colluvium	Pebble marker	Residuum	Pedogenic Formations	Completely Weathered Rock	Highly weathered rock	Termination depth	Excavatability up to termination depth	Excavatability at termination depth	Seepage
MH01	0.00-0.30	0.30-0.60	0.60-2.30	0.30-0.60	2.30-3.00	2.30-3.00	3	Soft	Soft	No
MH02	-	0.00-0.40	0.40-0.65	0.00-0.40	0.65-1.20	1.20-1.40	1.4	Soft	Hard	No
MH03	0.00-0.40	-	-	-	0.40-0.87	0.40-0.87	0.87	Soft	Hard	No
MH04	0.00-0.55	0.55-0.75	0.75-1.05	0.55-0.75	1.05-1.60	1.60-1.90	1.9	Soft	Intermediate to hard	No
MH05	0.00-0.40	0.40-0.65	0.65-1.35	0.40-0.65	1.35-1.80	1.80-2.10	2.1	Soft	Hard	No
MH06	0.00-0.30	0.30-0.75	0.75-1.70	0.30-0.75	1.70-2.80	-	2.8	Soft	Soft	No
MH07	0.00-0.30	0.30-0.55	0.55-0.90	0.30-0.75	0.90-1.70	1.40-1.70	1.7	Soft	Intermediate	No

6. SITE DESCRIPTION

6.1 Locality and Size

The site is situated 27 km north-east of the town of Umtata and 10 km north of Libode in the village of Mhlanga. The approximate size of the investigated area is 200 ha.

The approximate centre coordinates of the investigated area is as follows (Decimal Degrees, Datum: WGS84):
Latitude: -31.435456°
Longitude: 29.012806°

The locality is depicted in Figure 1 and Figure 2, Appendix A.

6.2 Vegetation, Topography, Drainage and Existing Structures

The site is mainly covered with natural grass, small to medium sized trees and informal mud houses. The remainder of the site is fairly open with slopes surrounding the village. No detailed contour map was provided/available at the time of writing this report. The regional topography as per the 1:50 000-scale topographical sheet is attached as Figure 5, Appendix A. The village is located on top of the limbs of a hilly area with moderate steep slopes from the center of the site decreasing to the edges of the site, the main/steepest slope direction is towards the river on the south-west side of the village. A drainage feature is present at the west side and north-east side of the village originating in the village and separated by a watershed. The drainage feature in the west is in a valley with intermediate steep slopes. See the elevation profile of the site from north-west to south-east in Figure 1 crossing the valley with the drainage feature and from south-west to north-east in Figure 2 below. Drainage channels are located in the valleys at the bases of these slopes.

Figure R1: Elevation profile from north-west to south-east cross cutting the drainage feature in the valley.

Figure R2: Elevation profile from south-west to north-east.

7. SHALLOW GROUNDWATER OR SEEPAGE WATER

Signs of seasonal shallow seepage water conditions are evident in the soil profiles excavated. Severe shallow seasonal seepage water are expected. Water is expected to occur mainly on but not limited to the contact between the shallow and completely to highly weathered shale. Concentration of flow will be from the top center of the village down slope to the sides of the village area especially towards the drainage features and river located south-west of the village.

Seasonal seepage water of less than 0.60 m below ground level will be a reality throughout the majority of the site; this is confirmed by the presence of iron and manganese nodules in the pebble marker at this depth. Localised areas of surface ponding conditions can also be expected and should be identified from the detailed ground contour survey data.

Typical seepage areas are generally more prominent in lower-lying areas. The site is situated on a watershed. Seepage is expected to mainly occur for short periods after heavy and/or prolonged rainfall events.

8. EXCAVATION CONDITIONS

Excavatability of materials can be classified in five different categories according to the SABS 1200 D-1988 standards. Table 2 below is a summary of the SABS standards (refer to SABS 1200D-1988 document for detailed classification):

Table 2: Excavation classes (Modified SABS 1200D)

Sample Position	Simplified description of typical material properties
Soft excavation	Material that can be efficiently removed or loaded, without prior ripping, by means of a bulldozer, tractor-scraper, track type front-end loader or back-acting excavator without the use of pneumatic tools such as paving breakers
Intermediate excavation	Material that can be efficiently ripped by a bulldozer fitted with a single-tine ripper or with a back-acting excavator of flywheel power exceeding 0,10 kW per mm of tined-bucket width or the use of pneumatic tools before removal by equipment equivalent to that specified above.
Hard rock excavation	Excavation in material that cannot, before removal, be efficiently ripped by a bulldozer. This is material that cannot be efficiently removed without blasting or without wedging and splitting.
Boulder excavation (Class A)	Excavation in material containing more than 40 % by volume boulders of size in the range of 0,03-20m3, in a matrix of soft material or smaller boulders.
Boulder excavation (Class B)	Excavation in material containing 40 % or less by volume boulders of size in the range of 0,03-20m3, in a matrix of soft material or smaller boulders and which require individual drilling and blasting in order to be loaded by a track type front-end loader or back-acting excavator .

The trial pits were excavated by means of a JCB 3CX TLB and the TLB excavatability in the upper excavated material and at termination depths with SABS excavatability correlations are summarized in Table 1b.

The test pits were excavated down to between 0.87 m to 3.00 m bngl with an average excavation depth of approximately 1.97 m bngl with a standard deviation of 0.75 m.

Refusal conditions were encountered in three of the test pits within highly weathered shale in test pit Mh02, Mh03 and Mh05 at 1.40 m, 0.87 m and 2.10 m bngl

respectively. Hard excavation conditions were encountered at these termination depths where refusal conditions were experienced on jointed and layered soft rock shale.

Excavation took place with a TLB in a confined trench; deeper excavation could be possible with a TLB in unconfined conditions and there is a possibility that the material may be rippable due to bedded and jointed nature. The materials are however expected to be excavatable with a larger excavator down to at least 2 m to 2.50 m bngl in confined trenches in the highly weathered shale.

Soft excavation was encountered down to termination depths for all the test pits.

The bedrock conditions are expected to be undulating with depths varying of 1.00 m to 2.00 m bngl over short distances due to the change in slope and location on the slope.

9. LABORATORY RESULTS AND GENERAL MATERIAL PROPERTIES

A number of disturbed soil samples were selectively retrieved and submitted to Controlab South Africa (Pty) Ltd. Umtata for testing.

Grading analysis, compaction testing, Atterberg Limit tests were conducted in order to determine the basic material properties for evaluation purposes. The laboratory test results are attached as Appendix D. The USCS (unified soil classification system) was not provided by the laboratory; the classifications used below where interpreted from the results received and should be used with caution as the classification may differ slightly. USCS (unified soil classification system) chart used to determine the classifications are attached in Appendix F as Chart C1 and C2.

9.1 Material Classifications and General Material Properties and Ratings

The material encountered and tested generally classifies as "**GM**"/"**GC**", "**SM**" and "**SC**" according to the Unified Soil Classification System. The Foundation Indicator test results conducted on selectively retrieved samples are summarized in Table 3.

TABLE 3: Foundation Indicator Test Results

Test pit no	Sample depth (m)	Material description	Soil composition				Atterberg Limits		LS (%)	GM	Class (USCS)	Class (USCS) 2
			Clay (%)	Silt (%)	Sand (%)	Gravel (%)	LL (%)	PI (%)				
Mh01	2.00-3.00	Completely to highly weathered shale	14	40.7	38.3	7	33	14	6.5	0.85	CL	0
Mh02	1.00-1.40	Highly weathered shale	2	11.3	40.7	46	27	9	4	0	GC	SC
Mh03	0.40-0.80	Highly weathered shale	1	10.6	19.4	69	21	7	2.5	2.43	GC	GM
Mh04	1.40-1.80	Completely to highly weathered shale	9	26.7	60.3	4	29	8	4	0	SM	SC
Mh06	1.70-2.00	Completely weathered shale	3	20.1	66.9	10	29	12	5	0	SC	0
Mh07	1.00-1.70	Completely to highly weathered shale	5	23.8	50.2	21	30	11	5	5	SM	SC

The following general descriptions can be assigned to the soil classes:

GM → Silty gravelly and poorly graded gravel and sand-silt mixtures.

GC → Clayey gravels, poorly graded gravel-sand-clay mixtures.

SM → Silty sands, poorly graded silt-sand mixtures.

SC → Clayey sands, poorly graded sand-clay mixtures.

Typical material properties for the above classifications are summarized in Table E1 and Table E2, Appendix F for guideline purposes.

10. GEOTECHNICAL EVALUATION

10.1 Soil Heave

The potential expansiveness of the material was evaluated based on the indicative laboratory test results and field observations. This included using the Plasticity Index and Linear Shrinkage of the material, Van der Merwe's Method and the material

structure to evaluate the potential heave of the material. The potential expansiveness of the materials is visually depicted in Chart 1.

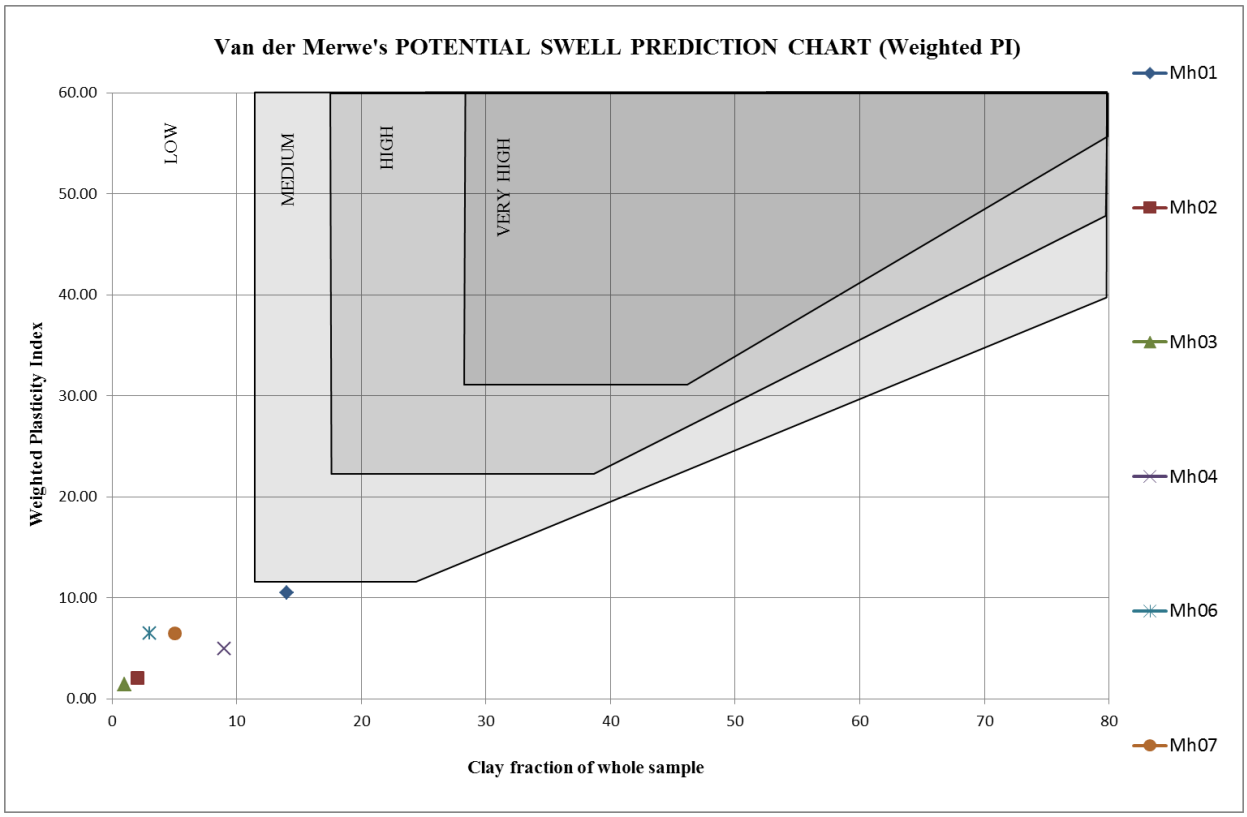


CHART 1: Swell Prediction Chart (Weighted PI and Clay Fraction of whole sample)

The indicator test results conducted on all the materials sampled indicate that the completely to highly weathered shale tested has a "Low" heave potential which confirms the visual interpretations taking into consideration the clay content and soil structure.

The completely to highly weathered shale in test pits Mh01, Mh03 and Mh07 at 2.00-3.00, 0.40-0.80 and 1.00-1.70 had a free swell percentage under 100 % MOD. AASHTO compaction effort of 0.99 %, 0.83 % and 1.38 % respectively. This is deemed a low heave percentage for the completely to highly weathered shale under compaction.

Medium soil heave corresponding to the SAICE (1995) site class designation "**H1**" (7.5 mm to 15 mm total range of expected soil movement, assumed 50% differential

movement) is expected in the colluvial and residual shale layer as identified from visual inspection.

Medium soil heave is only present in the overlying colluvium and residual shale layer; the underlying weathered rock has a low soil heave potential.

The grading analysis, Atterberg Limits and compaction test results for the materials are attached in Appendix D.

10.2 Collapsible and/or Compressible Material

The lower lying completely to highly weathered shale has a layered and jointed structure which may result in some settlement when loaded.

The colluvium, pebble marker and residual shale consist of medium amounts of fines present that can experience a degree of consolidation. These horizons have an open to very open structure that will result in a degree of consolidation corresponding to the SAICE class “C1”.

The layered and jointed completely to highly weathered shale has a slight collapse potential as for SAICE class “C” and “S” consolidation potential.

10.3 Erodability

The soils are considered to have a high susceptibility to erosion. Basic erosion protection measures will be recommended such as proper surface drainage in order to avoid concentrated water flow and potential erosion and undercutting of structures/floors and/or unwanted erosion of excavation/foundation/service trenches.

11. MAJOR GEOTECHNICAL CONSTRAINTS

Based on the conditions encountered during this investigation the major geotechnical constraints can be summarized as:

- Medium heave potential in colluvium and residual shale is a possibility;
- Severe shallow seasonal seepage water conditions and/or saturated soil profiles;
- Most favorable to intermediate steep slopes surrounding entire village 6 to 12 degrees;
- Excavation difficulty due to shallow bedrock, depending on location on slope.

12. SITE CLASSIFICATION

The site is classified based on the different geotechnical and founding conditions as per the SAICE 1995 classification (NHBRC classification as for single story residential/small type structures) and the SANS 634:2012 document of which the applicable tables are attached in Appendix F for reference purposes.

Two geotechnical zones have been assigned for the site for the purposes of this basic investigation:

Zone I: C1-H1 (R) / 2ABCDE (2FI)
Zone II: P (Drainage features and intermediate slopes) / 2I (Drainage features)

Where C, S and P before the / refer to:

C - Collapse settlement;
H - Expansive soils
(R) - Localised shallow rock.

The A-B-C-D-E-F-H-I after the / refer to:

A - Collapsible soils;
B - Seasonal shallow seepage water or saturated soil conditions;
C – Active soils;
D - Consolidation settlement;

E - Erodability of the soil horizons;

F - Excavation difficulty;

I - Steep slopes.

The classification in brackets (2FI) indicates localised occurrences for excavation difficulty and moderately steep slopes which has a highly likelihood.

Refer to Table 1, Table 2, Table 3, Table 4 and Table 5, Appendix F.

13. FOUNDATION AND GENERNAL RECOMMENDATIONS

For planning purposes the following foundation types/options can be considered for potential small size residential type structures (as for class “H1” and “C1” SAICE 1995 foundation options of which the appropriate tables are attached in Appendix F):

- Modified normal construction (As for class H1).
- Soil raft construction (As for class C1 or H1).

More conservative foundation options may be:

- Stiffened or cellular raft foundations (As for class H2).
- Split construction (As for class H2).

It is recommended that stiffened or cellular raft foundations are considered for planning purposes till more detailed investigations are conducted as required by the SANS634:2012 standards and accommodated with the necessary heave and consolidation quantification tests.

Modified normal construction to even normal construction may be suitable in areas. These foundation options however can only be considered if conditions are proven with more detailed investigations.

14. CONSTRUCTION MATERIALS

14.1 Soil Mattress and General Backfill

The basic requirements for material to be used for soil mattress construction can be summarized as:

- The material needs to be workable;
- The material needs to have good compaction characteristics;
- The material needs to have a low compressibility once properly compacted;
- The material needs to exhibit a low heave once properly compacted;
- The material needs to have suitable bearing capacity once properly compacted.

The on-site material is generally silty clays in the upper residual shale and colluvium. The completely to highly weathered shale crumbles to silt and rock fragments when excavated and compacted. The residual shale and completely to highly weathered shale material tested according to the USCS has the following workability rating:

• CL – Good to fair;
• SC – Good;
• SM – Fair;
• GC – Fair.

The completely to highly weathered shale material retrieved from test pit Mh01 and Mh07 at 2.00-3.00 m and 1.00-1.70 m has a maximum dry density of 1 802 kg/m^3 and 1 839 kg/m^3 with an optimum moisture content of 12.1 % and 12.5 % and a measured swell of 0.99 % and 1.38 % Mod. AASHTO compaction effort respectively. The CBR of the material increases from 1 to 2 to 3 at 90%, 95% and 100% Mod. AASHTO compaction efforts for both samples. The samples tested classifies as "G10" according to the TRH/COLTO classification.

The highly weathered shale material retrieved from test pit Mh03 at 0.40-0.80 m has a maximum dry density of 1 903 kg/m^3 with an optimum moisture content of 11.3 % and a measured swell of 0.83 % Mod. AASHTO compaction effort. The CBR of the material increases from 4 to 9 to 19 at 90%, 95% and 100% Mod. AASHTO compaction efforts. The samples tested classifies as "G10" according to the TRH/COLTO classification.

The completely to highly shale material from test pit Mh02 and Mh07 has poor compaction characteristics based on the increase in CBR values, CBR values acquired, achieved maximum dry densities and relatively low percentage swell measured. The highly weathered shale from test pit Mh03 has fair compaction characteristics.

The weathered shale is expected to have a low compressibility once properly compacted. The residual shale and upper fines are expected to have a medium to high compressibility even when properly compacted due to the abundance of fines.

The unweathered to moderately weathered shale is expected to have a low heave potential according to the test results received. The residual shale is expected to have a medium heave potential.

The typical fill rating of the material is represented in Table 5 below.

TABLE 5: Fill and Foundation Material

Test pit	Sample depth (m)	Material description	Unified Soil Class	Typical rating for use as general fill material	Typical rating for use as fill for foundation purposes	Expected Dry Density (kg/m3) (PROCTOR)
Mh01	2.00-3.00	Completely to highly weathered shale	CL	Average	Average (Swell?)	1 730 +/- 20
Mh02	1.00-1.40	Highly weathered shale	GC	Good	Excellent	> 1 840
Mh03	0.40-0.80	Highly weathered shale	GC	Good	Excellent	> 1 840
Mh04	1.40-1.80	Completely to highly weathered shale	SM	Average	Good (density important)	1 830 +/- 20
Mh06	1.70-2.00	Completely weathered shale	SC	Average	Good (density important)	1 840 +/- 20
Mh07	1.00-1.70	Completely to highly weathered shale	SM	Average	Good (density important)	1 830 +/- 20
0	0	0	0	#N/A	#N/A	#N/A

The weathered shale material in general (materials classifying as “GC”) are considered to have an excellent rating for typical fill for foundation purposes, whereas the material classifying as “SM” and “SC” has a good rating for typical fill. The colluvium and residual materials are deemed to have an average rating for typical fill.

14.2 Road Construction

A more detailed investigation should be conducted in order to comment the suitability of the on-site materials for pavement design. The colluvium and residual fines are expected to have a fair rating for subgrade construction and poor for sub-base and not suitable base construction. The lower weathered shale is expected to have a good rating for subgrade construction with possibly a good to fair rating for subbase construction. None of the on-site materials encountered are considered suitable for base construction. It is recommended that borrowpits is identified and that suitable materials are sourced for subbase and base construction.

15. CONCLUSIONS

The site is underlain by grey and brownish-red mudstone, sandstone; identified on site to be shale/siltstone.

No potentially soluble dolomitic or limestone formations are present and a dolomite stability investigation is not required.

The area is not undermined and no significant economic mineral deposits are indicated on the relevant geological sheet in the proposed development area that may affect the developability of the site.

Two geotechnical zones have been assigned for the site for the purposes of this basic investigation:

Zone I: C1-H1 (R) / 2ABCDE (2FI)

Zone II: P (Drainage features and intermediate slopes) / 2I (Drainage features)

For planning purposes one or a combination of the following foundation types/options can be considered:

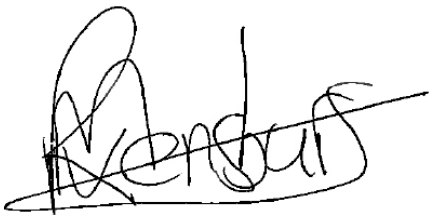
- Modified normal construction (As for class H1).
- Soil raft construction (As for class C1 or H1).
- Stiffened or cellular raft foundations (As for class H2).
- Split construction (As for class H2).

The stiffened or cellular raft foundations and split construction are considered the more conservative design approach. Proper surface, subsurface drainage and damp proofing will be essential in order to prevent or limit moisture damage to the floors and walls. Corrosion protection is recommended for any ferrous metals or services in contact with the soils. Termite and pesticide control will be recommended below all structures. Basic erosion protection will be highly recommended in order to prevent excessive erosion and potential undercutting of structures.

The report is deemed suitable for basic planning purposes. The standard engineering geological investigations associated with residential development with reference to the minimum requirements as outlined in the SANS634:2012 standards should be conducted for detailed planning, design and enrolment purposes.

16. REPORT PROVISIONS

The report is considered a basic investigation with level of detail considered suitable for basic planning purposes only. The report should be distributed in its full context in order to avoid miss-interpretation that may result from selective data distribution. The engineering geologist assumes no responsibilities for any damages or unforeseen circumstances resulting from any geotechnical hazard if detailed planning and/or design are based on this basic evaluation.



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Engineering Geologist

APPENDIX A

(Figures)

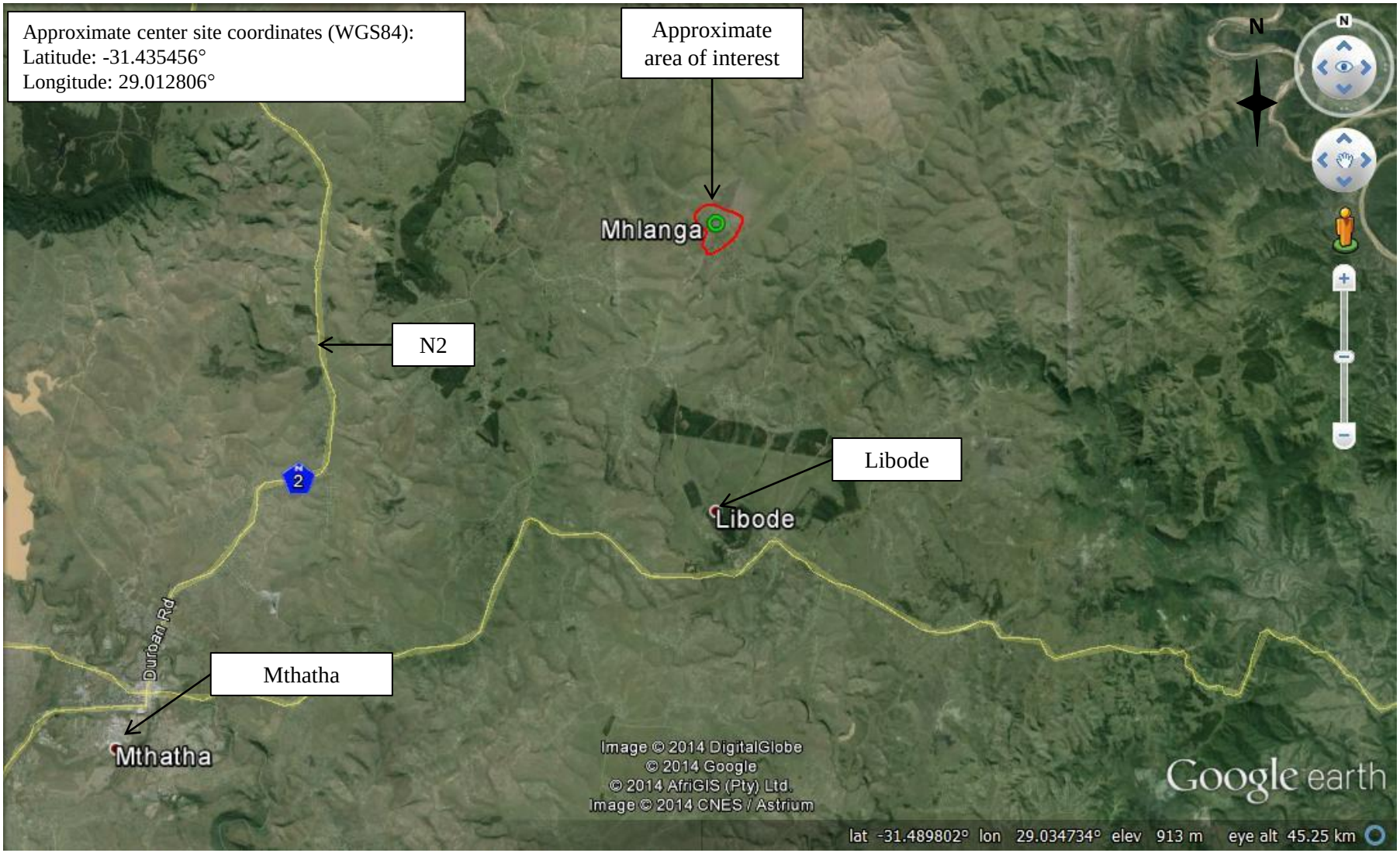


Figure 1: Locality map 1: Eastern Cape Housing (Mhlanga)

WSM LESHIKA CONSULTING (PTY) LTD

No: WF14066 © GoogleEarth 2014

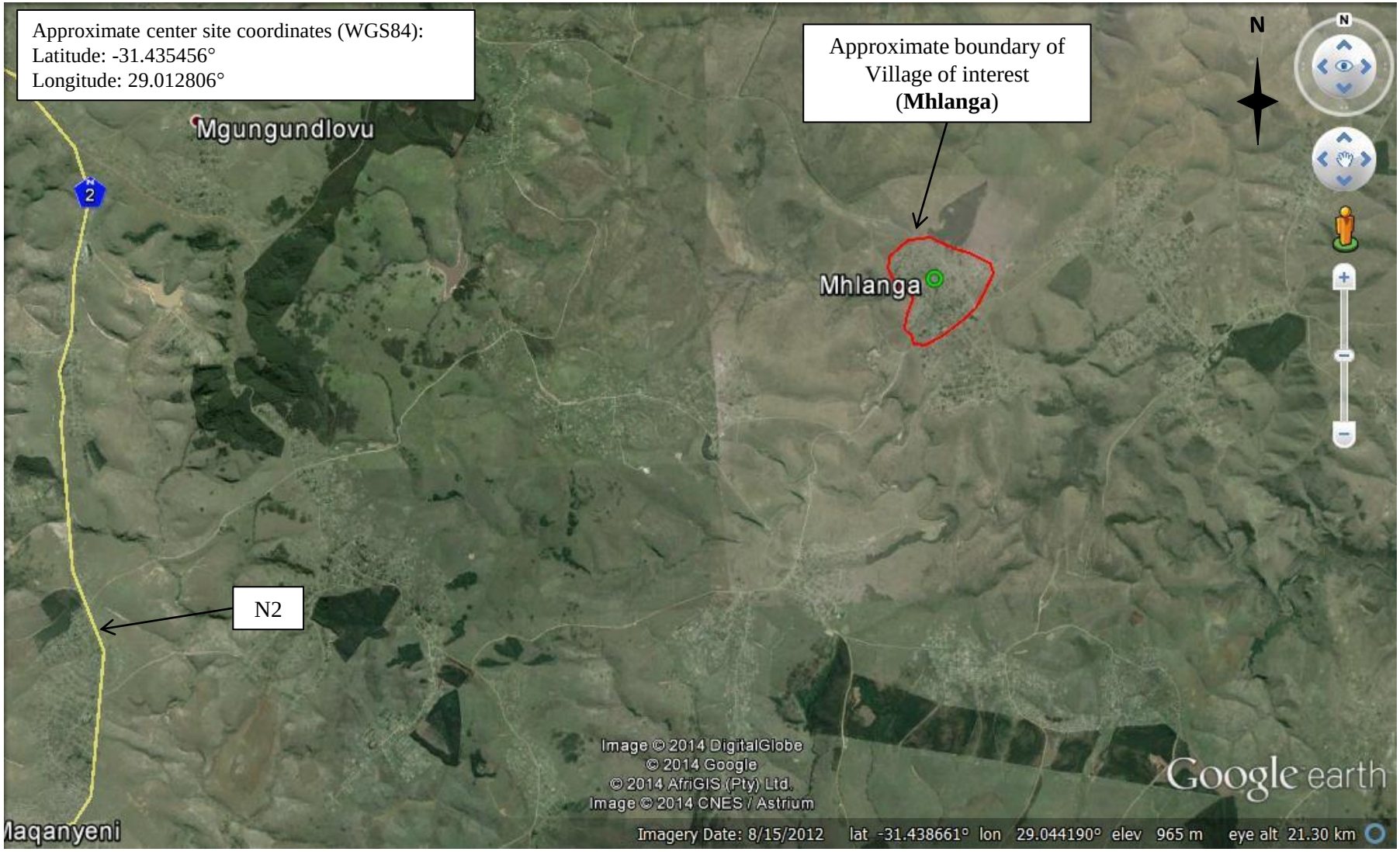


Figure 2: Locality map 2: Eastern Cape Housing (Mhlanga) WSM LESHIKA CONSULTING (PTY) LTD No: WF14066 © GoogleEarth 2014

Approximate center site coordinates (WGS84):
Latitude: -31.435456°
Longitude: 29.012806°

Approximate Area of Interest

Layered structure of soft rock shale

Highly weathered soft rock shale fragments excavated.

Iron and manganese nodules in top layers of test pit.

Jd — Dolerite ( ) / Doleriet ( )

Pa — Grys en bruinrooi moddersteen, sandsteen
Grey and brownish-red mudstone, sandstone

Google earth

eye alt 16.97 km

Figure 3: Geology map: Eastern Cape Housing (Mhlanga)

WSM LESHIKA CONSULTING (PTY) LTD

Project No: WF14066

Trial pit positions

Test Pit Mh02

Test Pit Mh03

Test Pit Mh06

Test Pit Mh07

Figure 4: Test Pit Positions: Eastern Cape Housing (Mhlanga)

WSM LESHIKA CONSULTING (PTY) LTD

Project no: WF14066

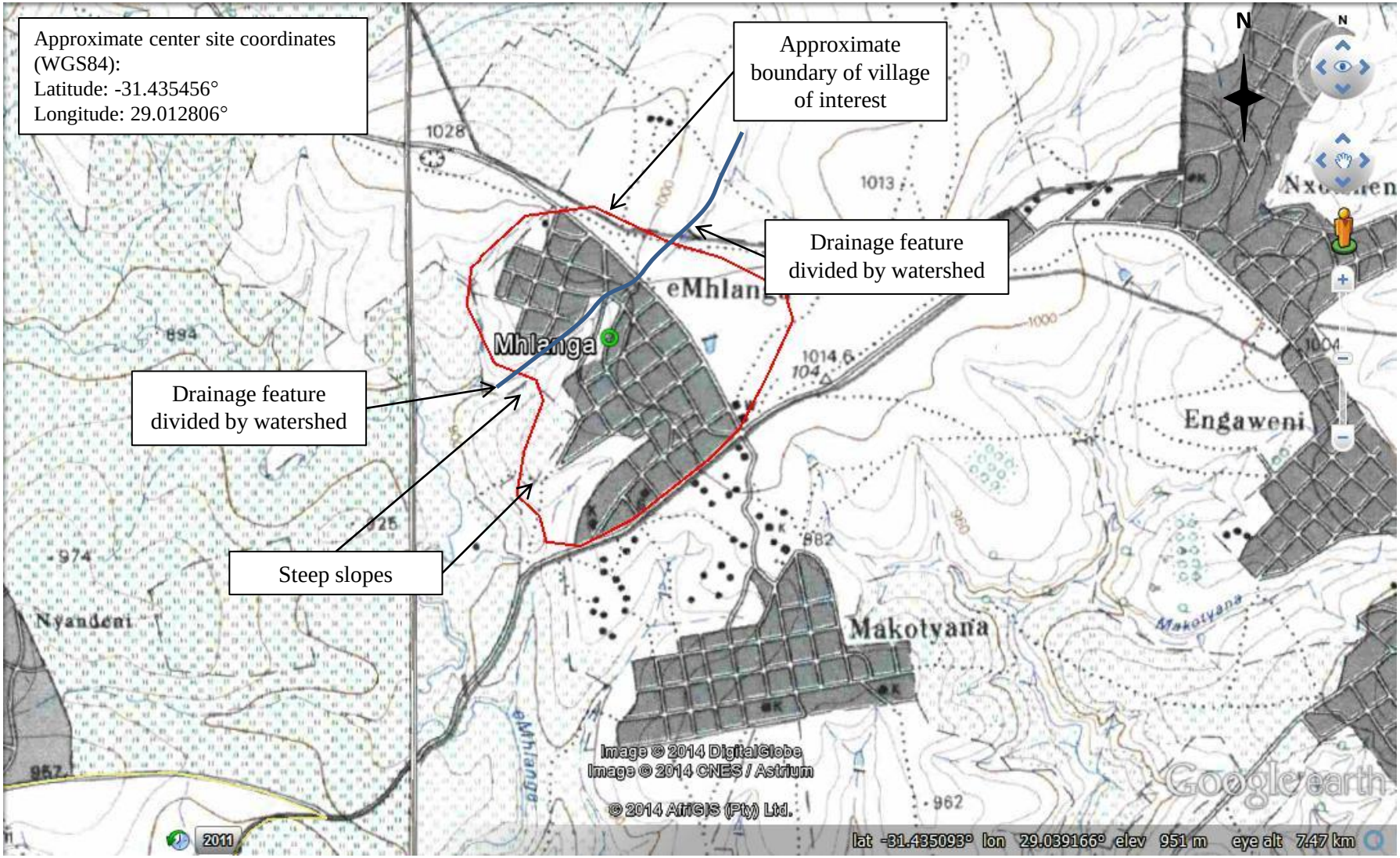
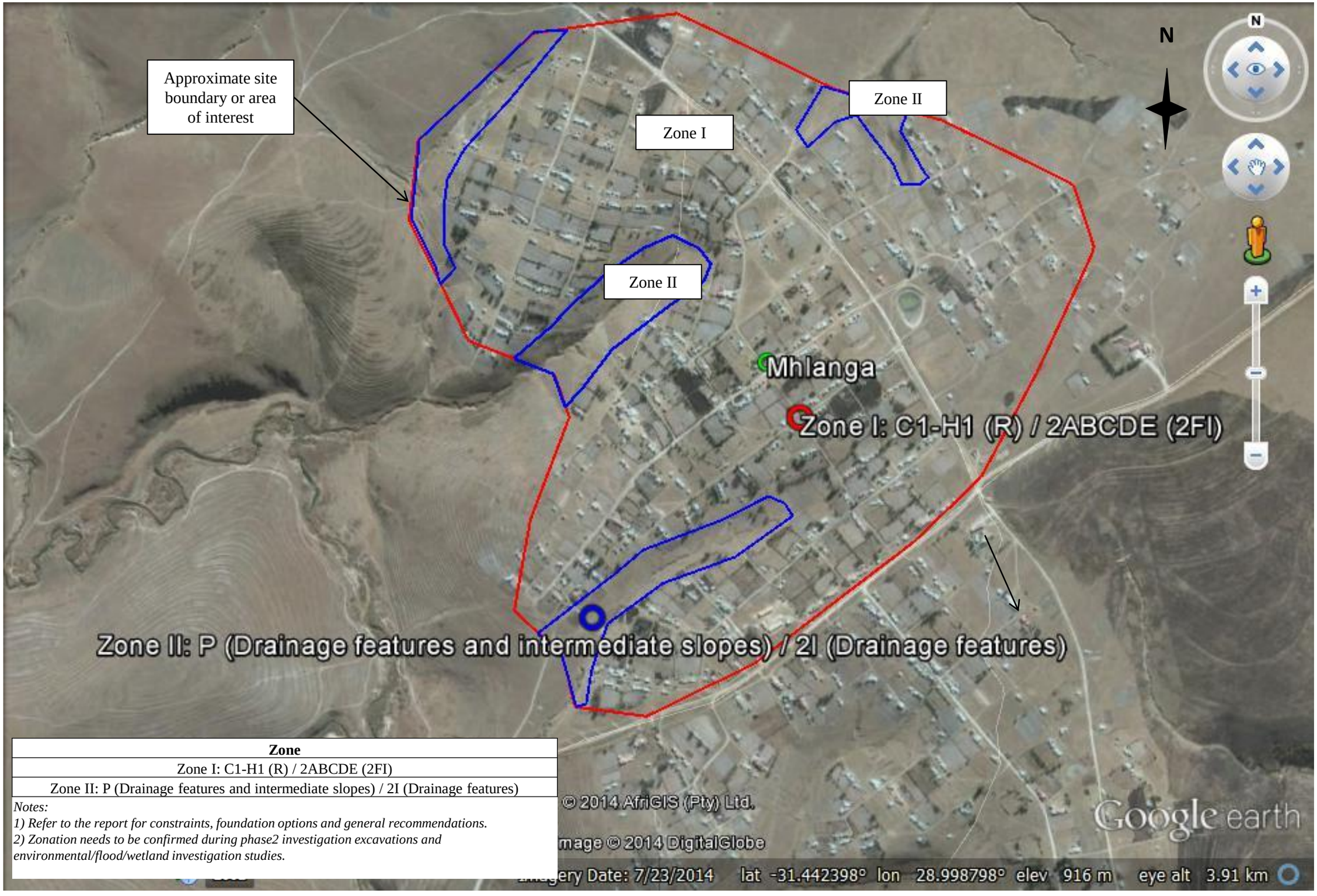


Figure 5: Topographical map: Eastern Cape Housing (Mhlanga)

WSM LESHIKA CONSULTING (PTY) LTD

No: WF14066 © The Government Printer



Zone
Zone I: C1-H1 (R) / 2ABCDE (2FI)
Zone II: P (Drainage features and intermediate slopes) / 2I (Drainage features)

Notes:
1) Refer to the report for constraints, foundation options and general recommendations.
2) Zonation needs to be confirmed during phase2 investigation excavations and environmental/flood/wetland investigation studies.

Figure 6: Geotechnical Zonation: Eastern Cape Housing (Mhlanga)

WSM LESHIKA CONSULTING (PTY) LTD

Project no: WF14066

APPENDIX B

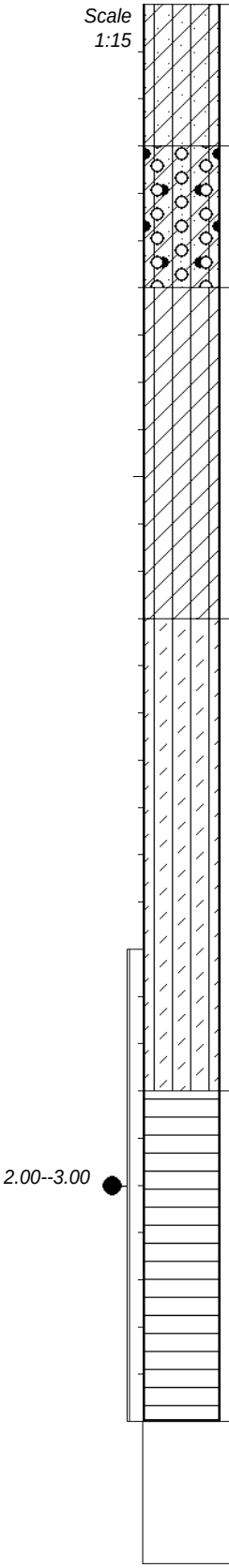
(Soil Profile Descriptions)

WSM LESHIKA CONSULTING (PTY) LTD

Housing project in Eastern Cape

HOLE No: Mh01
Sheet 1 of 1

JOB NUMBER: WF14066



0.00 Slightly moist, grey, stiff, **open structured**, sandy silty CLAY/ clayey SILT, colluvium.

0.30 Slightly moist, grey, stiff, **open structured**, sandy silty CLAY/ clayey SILT, with abundant fine gravel and iron and manganese nodules, pebble marker.

0.60 Moist, orange and yellow patched and streaked black, medium dense to firm, **open and pinholed**, clayey SILT/ silty CLAY, residual shale.

1.30 Moist, mustard yellow mottled orange and black, dense, **slightly layered**, clayey SILT, residual shale.

2.30 Mustard yellow stained black and red, **layered and jointed**, completely to highly weathered very soft rock shale.

3.00

NOTES

1) Hole stopped.

2) Sample: 2.00--3.00 m.

3) No seepage.

4) Hole stable during investigation.

CONTRACTOR :
MACHINE : TLB JCB
DRILLED BY :
PROFILED BY : HAM van Rensburg
TYPE SET BY :
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM :
DATE :
DATE : 2014/07/16-18
DATE : 11/09/14 12:08
TEXT : ..C:\DOTFILES\SP_DP.TXT

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: Mh01

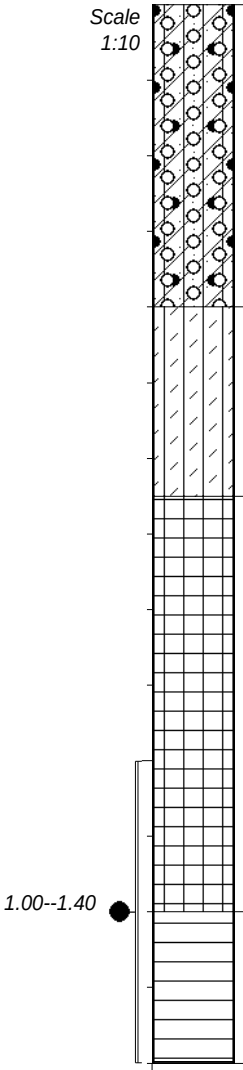
WSM LESHIKA CONSULTING (PTY) LTD

Housing project in Eastern Cape

HOLE No: Mh02
Sheet 1 of 1

JOB NUMBER: WF14066

Scale 1:10



0.00 Slightly moist, grey, stiff, **open structured**, sandy silty CLAY/ clayey SILT, with abundant fine gravel, pebble marker.

0.40 Slightly moist to moist, mottled orange black and grey, dense to stiff, **slightly pinholed**, clayey SILT, reworked residuum.

0.65 Slightly moist, mustard yellow mottled black, very dense, **slightly layered**, SILT, completely weathered shale.

1.00--1.40

1.20 Mustard yellow streaked black and red, **jointed and layered**, highly weathered soft rock shale.

1.40

NOTES

1) Refusal, TLB confined excavation.

2) Sample: 1.00--1.40 m.

3) No seepage.

4) Hole stable during investigation.

CONTRACTOR :
MACHINE : TLB JCB
DRILLED BY :
PROFILED BY : HAM van Rensburg
TYPE SET BY :
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM :
DATE :
DATE : 2014/07/16-18
DATE : 11/09/14 12:08
TEXT : ..C:\DOTFILES\SP_DP.TXT

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: Mh02

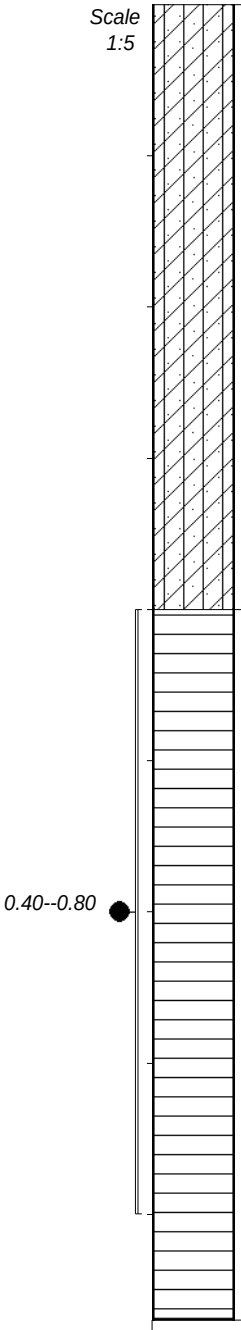
WSM LESHIKA CONSULTING (PTY) LTD

Housing project in Eastern Cape

HOLE No: Mh03
Sheet 1 of 1

JOB NUMBER: WF14066

Scale 1:5



0.00 Slightly moist, grey, stiff, **open structured**, sandy silty CLAY/ clayey SILT, colluvium.

0.40 Mustard yellow to dull grey streaked black, **layered jointed**, completely weathered becoming highly weathered soft rock shale.

0.40--0.80

0.87

NOTES

1) Refusal, TLB confined excavation.

2) Sample: 0.40--0.80 m.

3) No seepage.

4) Hole stable during investigation.

CONTRACTOR :
MACHINE : TLB JCB
DRILLED BY :
PROFILED BY : HAM van Rensburg
TYPE SET BY :
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM :
DATE :
DATE : 2014/07/16-18
DATE : 11/09/14 12:08
TEXT : ..C:\DOTFILES\SP_DP.TXT

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: Mh03

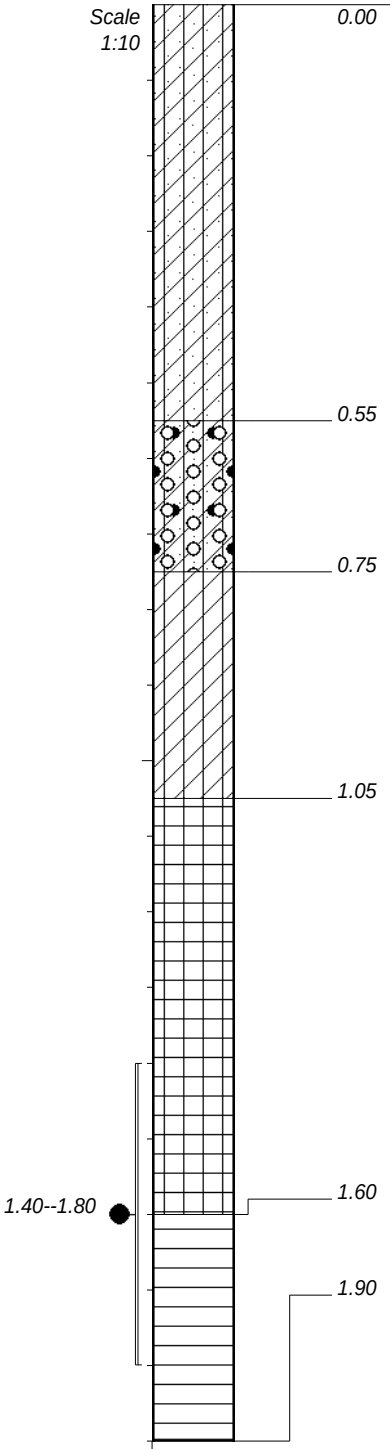
WSM LESHIKA CONSULTING (PTY) LTD

Housing project in Eastern Cape

HOLE No: Mh04
Sheet 1 of 1

JOB NUMBER: WF14066

Scale 1:10



0.00 Slightly moist, grey, stiff, **open structured**, sandy silty CLAY/ clayey SILT, colluvium.

0.55 Slightly moist, grey, stiff, **open structured**, sandy silty CLAY/ clayey SILT, with abundant Fe and Mn nodules as gravel, pebble marker.

0.75 Moist, orange and yellow patched and streaked black, medium dense to firm, **open and pinholed**, clayey SILT/ silty CLAY, residual shale.

1.05 Slightly moist, mustard yellow mottled black, very dense, **slightly layered**, SILT, completely weathered shale.

1.60 Mustard yellow streaked black and red, **jointed and layered**, highly weathered soft rock shale.

1.90

NOTES

1) Progressive Refusal, TLB confined excavation to Refusal, TLB confined excavation.

2) Sample: 1.40--1.80 m.

3) No seepage.

4) Hole stable during investigation.

CONTRACTOR :
MACHINE : TLB JCB
DRILLED BY :
PROFILED BY : HAM van Rensburg
TYPE SET BY :
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM :
DATE :
DATE : 2014/07/16-18
DATE : 11/09/14 12:08
TEXT : ..C:\DOTFILES\SP_DP.TXT

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: Mh04

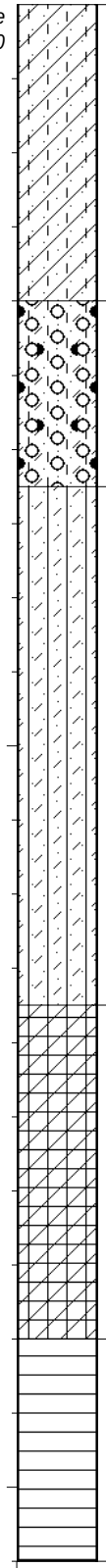
WSM LESHIKA CONSULTING (PTY) LTD

Housing project in Eastern Cape

HOLE No: Mh05
Sheet 1 of 1

JOB NUMBER: WF14066

Scale 1:10



0.00 Slightly moist, grey, very stiff, **open structured**, sandy silty CLAY, colluvium.

0.40 Slightly moist, grey, very stiff, **open structured**, sandy silty clayey GRAVEL, gravel of Fe and Mn nodules, pebble marker.

0.65 Moist, orange streaked grey and yellow, medium dense to soft, **slightly pinholed**, fine sandy clayey SILT, residual shale.

1.35 Slightly moist, mustard yellow mottled black, very dense, **slightly layered**, SILT with patches of grey clay, completely weathered shale.

1.80 Mustard yellow streaked black and red, **jointed and layered**, highly weathered very soft rock shale.

2.10

NOTES

1) Refusal, TLB confined excavation.

2) No sample.

3) No seepage.

4) Hole stable during investigation.

CONTRACTOR :
MACHINE : TLB JCB
DRILLED BY :
PROFILED BY : HAM van Rensburg
TYPE SET BY :
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM :
DATE :
DATE : 2014/07/16-18
DATE : 11/09/14 12:08
TEXT : ..C:\DOTFILES\SP_DP.TXT

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: Mh05

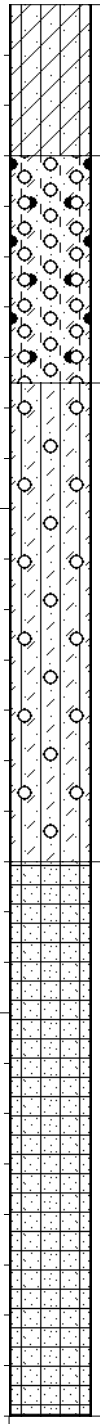
WSM LESHIKA CONSULTING (PTY) LTD

Housing project in Eastern Cape

HOLE No: Mh06
Sheet 1 of 1

JOB NUMBER: WF14066

Scale 1:15



0.00 Slightly moist, grey, very stiff, **open structured**, sandy silty CLAY/ clayey SILT, colluvium.

0.30 Slightly moist, grey, very stiff, **open structured**, sandy silty clayey fine GRAVEL of Fe and Mn nodules, pebble marker.

0.75 Slightly moist to moist, orange mottled yellow and black, medium dense to dense to stiff, **very open and pinholed**, sandy fine gravelly clayey SILT, reworked residual shale.

1.70 Moist, dull mustard yellow mottled orange and black, dense, **slightly layered jointed and pinholed**, fine sandy SILT/ silty fine SAND, completely weathered shale.

1.70--2.00

2.80

NOTES

1) Hole stopped.

2) Sample: 1.70--2.00 m.

3) No seepage.

4) Hole stable during investigation.

CONTRACTOR :
MACHINE : TLB JCB
DRILLED BY :
PROFILED BY : HAM van Rensburg
TYPE SET BY :
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM :
DATE :
DATE : 2014/07/16-18
DATE : 11/09/14 12:08
TEXT : ..C:\DOTFILES\SP_DP.TXT

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: Mh06

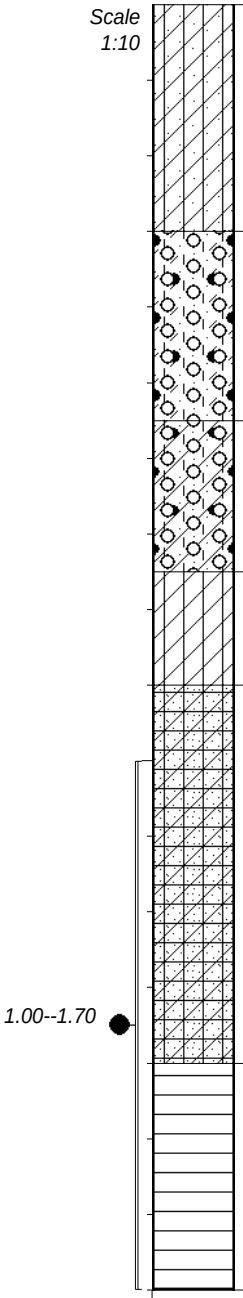
WSM LESHIKA CONSULTING (PTY) LTD

Housing project in Eastern Cape

HOLE No: Mh07
Sheet 1 of 1

JOB NUMBER: WF14066

Scale 1:10



0.00 Slightly moist, grey, very stiff, **open structured**, sandy silty CLAY/ clayey SILT, colluvium.

0.30 Slightly moist, grey streaked orange, very stiff, **open structured**, sandy silty clayey fine GRAVEL of Fe and Mn nodules, pebble marker.

0.55 Slightly moist, orange mottled black yellow and red, very stiff, **intact**, sandy gravelly silty CLAY, gravel of Fe and Mn nodules, reworked residuum.

0.75 Slightly moist, streaked yellow and black, very dense to very stiff, silt CLAY/ clayey SILT, residual shale.

0.90 Slightly moist, yellow patched and streaked black, very dense, **slightly layered**, fine sandy SILT/ silty fine SAND, with patches of black clay, completely weathered shale.

1.40 Mustard yellow, **layered and jointed**, completely to highly weathered soft rock shale.

1.70

NOTES

1) Progressive Refusal, TLB confined excavation.

2) Sample: 1.00--1.70 m.

3) No seepage.

4) Hole stable during investigation.

CONTRACTOR :
MACHINE : TLB JCB
DRILLED BY :
PROFILED BY : HAM van Rensburg
TYPE SET BY :
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM :
DATE :
DATE : 2014/07/16-18
DATE : 11/09/14 12:08
TEXT : ..C:\DOTFILES\SP_DP.TXT

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: Mh07

WSM LESHIKA CONSULTING (PTY) LTD

Housing project in Eastern Cape

LEGEND
Sheet 1 of 1

JOB NUMBER: WF14066

	GRAVEL	{SA02}
	GRAVELLY	{SA03}
	SAND	{SA04}
	SANDY	{SA05}
	SILT	{SA06}
	SILTY	{SA07}
	CLAY	{SA08}
	CLAYEY	{SA09}
	SHALE	{SA12}
	NODULAR FERRICRETE/ferricrete nodules/honeycomb ferric....	{SA24}
	SPARSE FERRICRETE NODULES/occasional ferricrete nodu....	{SA25}
	DISTURBED SAMPLE	{SA38}

Name ●

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY :
TYPE SET BY :
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM :
DATE :
DATE :
DATE : 11/09/14 12:08
TEXT : ..C:\DOTFILES\SP_DP.TXT

ELEVATION :
X-COORD :
Y-COORD :

LEGEND
SUMMARY OF SYMBOLS

APPENDIX C

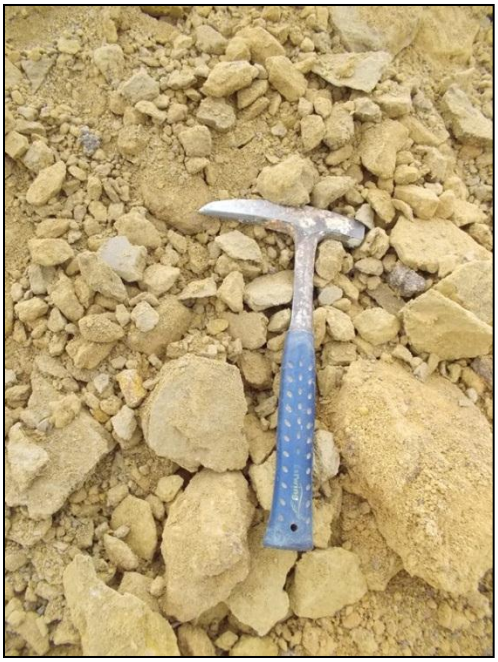
(Soil Profile Photographs)

PROJECT: Housing Project in Eastern Cape (Mhlanga) PROJECT no: WF14066

Test Pit number: Mh01

Note: Hole stopped TLB soft excavation.

Test Pit number: Mh01



Note: Very soft rock shale fragments.

Test Pit number: Mh01

Note: Clayey silty material excavated.

Test Pit number: Mh02

Note: Refusal of TLB on soft rock shale.

Test Pit number: Mh02

Note: Open structure in gravel of iron and manganese nodules.

Test Pit number: Mh02

Note: Soft rock shale fragments excavated.

Test Pit number: Mh03

Note: Refusal of TLB on highly weathered shale.

Test Pit number: Mh03

Note: Layered structure at base of test pit.

Test Pit number: Mh04

Note: Progressive refusal to refusal of TLB.

Test Pit number: Mh04

Note: Jointed and layered structure in soft rock shale at base.

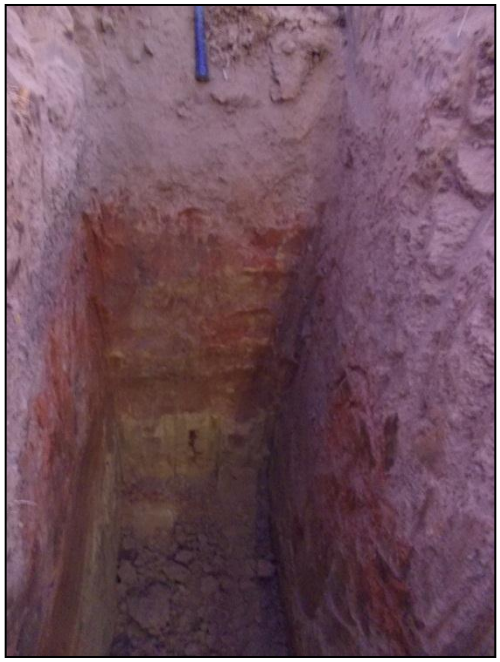
Test Pit number: Mh04

Note: Iron and manganese as gravel in test pit.

Test Pit number: Mh04

Note: Soft rock shale excavated.

Test Pit number: Mh05



Note: TLB refusal soft excavation till refusal.

Test Pit number: Mh05

Note: Soft rock shale excavated.

Test Pit number: Mh06

Note: Hole stopped TLB soft excavation.

Test Pit number: Mh06

Note: Silty fine sandy material excavated.

Test Pit number: Mh07

Note: Progressive refusal of TLB.

Test Pit number: Mh07

Note: Iron and manganese nodules in profile.

Test Pit number: Mh07

Note: Layered and jointed structure at base of test pit.

Test Pit number: Mh07

Note: View of down slope of village.

APPENDIX D

(Laboratory Test Results)

ControLab South Africa (Pty) Ltd

CIVIL ENGINEERING MATERIALS AND GEOTECHNICAL LABORATORY

2010/006/3907

www.controlab.co.za

HEAD OFFICE: 1 Alfred Road, Vincent 5247, Tel: 043 726 7659, Fax: 043 726 7426
CENTRAL LABORATORY : 10 St Pauls Road, East London, 5201, Tel: 043 722 5420 / 722 6585, Fax: 043 743 9942, P O Box 346, East London, 5200
OTHER BRANCH OFFICES: Cape Town, Kokstad, Mthatha, Port Elizabeth, Lusaka - Zambia

CLIENT:	WSM Leshika Consulting (PTY) Ltd	PROJECT:	HOUSING PROJECT IN E.C. MHLANGA VILL.
	P.O. Box 39942		
	Moreleta Park		
	PRETORIA 0044	DATE:	2014.08.14
ATT :	Mr M. Van Rensburg	REF:	MT 24750

O.N. WF 14066

FOUNDATION INDICATOR PREDICTION OF HEAVE

SAMPLE NO	3175	3176	3177	3178	3179	3180
POSITION	Mh 01	Mh 02	Mh 03	Mh 04	Mh 06	Mh 07
	MHLANGA	MHLANGA	MHLANGA	MHLANGA	MHLANGA	MHLANGA
DEPTH	2.00 - 3.00	1.00 - 1.40	0.40 - 0.80	1.40 - 1.80	1.70 - 2.00	1.00 - 1.70
DESCRIPTION	lt Ol Ms	lt Y P Ms	lt Ol Ms	lt Y cl Sdy	Blotch Y	Blotch Y
				st	Wth Ms	Wth Ms

SIEVE ANALYSIS

% PASSING							
75	mm		100	75			100
37.5	mm		95	54			89
19	mm	100	87	47	100	100	85
9.5	mm	98	74	38	99	96	83
4.75	mm	93	64	31	96	90	79
2.36	mm	87	39	26	85	79	73
1.18	mm	81	30	22	75	67	66
0.600	mm	77	25	21	66	58	61
0.425	mm	75	23	20	62	54	59
0.300	mm	75	22	20	60	52	57
0.150	mm	73	20	18	54	43	52
0.075	mm	54.7	13.3	11.6	35.7	23.1	28.8

MECHANICAL ANALYSIS

0.06	mm	49	12	10	31	20	25
0.02	mm	30	7	5	19	10	13
0.006	mm	18	3	2	12	5	7
0.002	mm	14	2	1	9	3	5

SOIL CONSTANTS

LIQUID LIMIT	33	27	21	29	29	30
PLASTICITY INDEX	14	9	7	8	12	11
LINEAR SHRINKAGE	6.5	4.0	2.5	4.0	5.0	5.0

PREDICTION OF HEAVE (VAN DER MERWE METHOD)

MOISTURE CONTENT %						
PI WHOLE SAMPLE	10.5	2.1	1.4	4.8	6.5	6.5
ACTIVITY						
POTENTIAL EXPANSIVENESS	LOW	LOW	LOW	LOW	LOW	LOW

The above test results are pertinent to the samples received and tested only.
While the tests are carried out according to recognized standards Controlab shall not be liable for erroneous testing or reporting thereof. This report may not be reproduced except in full without prior consent of Controlab.
Remarks:

For Controlab:

ConSR19

ControLab South Africa (Pty) Ltd

CIVIL ENGINEERING MATERIALS AND GEOTECHNICAL LABORATORY

www.controlab.co.za

HEAD OFFICE: 1 Alfred Road, Vincent 5247, Tel: 043 726 7859, Fax: 043 726 7426
CENTRAL LABORATORY : 10 St Pauls Road, East London, 5201, Tel: 043 722 5420 / 722 8565, Fax: 043 743 9942, P O Box 346, East London, 5200
OTHER BRANCH OFFICES: Cape Town, Kokstad, Mthatha, Port Elizabeth, Lusaka - Zambia

CLIENT: WSM Leshika Consulting (PTY) Ltd
P.O. Box 39942
Moreleta Park
PRETORIA, 0044
ATT: Mr. M. van Rensburg

PROJECT: HOUSING PROJECT IN E.C.
DATE RECEIVED: 2014.07.18
DATE TESTED: 2014.08.04
DATE REPORTED: 2014.08.19
TEST REPORT NO.: MT 24748

O.N. WF14066

MATERIALS TEST REPORT

SAMPLE NO:	3150	3151	3152	3153		
POSITION	Ma 03	Ma 06	Ma 08	Ma 13		
VILLAGE NAME	MARHUBENI VILLAGE					
DEPTH mm	1.00 - 2.00	1.50 - 2.50	1.50 - 2.80	1.30 - 2.30		
DESCRIPTION	lt R sty s	lt Y + lt G Ss	lt Y + P sdy	lt Y + lt R		
			cl	sdy cl		
CLASSIFICATION (TRH 14)	G 10	G 10	G 10	G 9		

Sieve Analysis (Wet Preparation) TMH1 - Method A1 (a)

% PASSING	75 mm						
	63 mm						
	53 mm						
	37.5 mm						
	26.5 mm						
	19 mm	100	100	100			
	13.2 mm	99	99	96	100		
	4.75 mm	98	98	85	98		
	2.00 mm	97	94	77	97		
	0.425 mm	94	75	67	90		
	0.075 mm	66.0	26.3	34.2	22.3		

Soil Mortar Analysis - TMH1 - Method A5

COURSE SAND (%)	3	20	13	7		
FINE SAND (%)	29	52	43	70		
SILT / CLAY (%)	68	28	44	23		
GRADING MODULUS	0.43	1.05	1.22	0.91		

Atterberg Limits - TMH1 - Methods A2, A3, A4

LIQUID LIMIT (%)	34	27	29	24		
PLASTICITY INDEX (%)	12	5	9	9		
LINEAR SHRINKAGE (%)	5.0	3	3.5	3.5		

Maximum Dry Density & Optimum Moisture Content - TMH1 - Method A7 / California Bearing Ratio - TMH1 - Method A8

Maximum Dry Density (kg/m^3)	1630	1778	1696	1805		
Optimum Moisture Content (%)	16.9	14.3	16.9	15.5		
C.B.R. @ 100% COMPACTION	3	21	5	25		
C.B.R. @ 98 % COMPACTION	2	17	4	19		
C.B.R. @ 95 % COMPACTION	2	11	3	13		
C.B.R. @ 93 % COMPACTION	2	9	3	10		
C.B.R. @ 90 % COMPACTION	1	6	2	7		
SWELL @ 100% COMP. (%)	1.67	1.57	2.47	0.91		

Lab Manager:

Remarks:
Sample Delivered by Customer
Sampled by Controlab [X]

ControLab South Africa (Pty) Ltd

CIVIL ENGINEERING MATERIALS AND GEOTECHNICAL LABORATORY

2012/006682/07

www.controlab.co.za

HEAD OFFICE: 1 Alfred Road, Vincent 5247, Tel: 043 726 7859, Fax: 043 726 7428
CENTRAL LABORATORY : 10 St Pauls Road, East London, 5201, Tel: 043 722 5420 / 722 8585, Fax: 043 743 9942, P O Box 346, East London, 5200
OTHER BRANCH OFFICES: Cape Town, Kokstad, Mthatha, Port Elizabeth, Lusaka - Zambia

CLIENT: WSM Leshika Consulting (PTY) Ltd
P.O. Box 39942
Moreleta Park
PRETORIA, 0044
ATT: Mr. M. van Rensburg

PROJECT: HOUSING PROJECT IN E.C.
DATE RECEIVED: 2014.07.18
DATE TESTED: 2014.08.04
DATE REPORTED: 2014.08.19
TEST REPORT NO.: MT 24750

O.N. WF14066

MATERIALS TEST REPORT

SAMPLE NO:	3175	3177	3180			
POSITION	Mh 01	Mh 03	Mh 07			
VILLAGE NAME	MHLANGA VILLAGE					
DEPTH mm	2.00 - 3.00	0.40 - 0.80	1.00 - 1.70			
DESCRIPTION	lt Ol Ms	lt Ol Ms	blotched Y			
			Wth Ms			
CLASSIFICATION (TRH 14)	G 10	G 10	G 10			

Sieve Analysis (Wet Preparation) TMH1 - Method A1 (a)

% PASSING							
75	mm		75	100			
63	mm		71	97			
53	mm		65	95			
37.5	mm		54	89			
26.5	mm		50	87			
19	mm	100	47	85			
13.2	mm	99	42	84			
4.75	mm	93	31	79			
2.00	mm	85	25	71			
0.425	mm	75	20	59			
0.075	mm	54.7	11.6	28.8			

Soil Mortar Analysis - TMH1 - Method A5

COURSE SAND (%)	12	20	17			
FINE SAND (%)	24	34	43			
SILT / CLAY (%)	64	46	41			
GRADING MODULUS	0.85	2.43	1.41			

Atterberg Limits - TMH1 - Methods A2, A3, A4

LIQUID LIMIT (%)	33	21	30			
PLASTICITY INDEX (%)	14	7	11			
LINEAR SHRINKAGE (%)	6.5	2.5	5.0			

Maximum Dry Density & Optimum Moisture Content - TMH1 - Method A7 / California Bearing Ratio - TMH1 - Method A8

Maximum Dry Density (kg/m^3)	1802	1903	1839			
Optimum Moisture Content (%)	12.1	11.3	12.5			
C.B.R. @ 100% COMPACTION	3	19	3			
C.B.R. @ 98 % COMPACTION	3	14	3			
C.B.R. @ 95 % COMPACTION	2	9	2			
C.B.R. @ 93 % COMPACTION	2	7	2			
C.B.R. @ 90 % COMPACTION	1	4	1			
SWELL @ 100% COMP. (%)	0.99	0.83	1.38			

Lab Manager:

Remarks:
Sample Delivered by Customer
Sampled by Controlab [X]

APPENDIX E

(Typical Material Properties)

TABLE E1: Typical material properties (Unified Soil Classification System)

Class:	Material description	Subgrade	Subbase	Base	Drainage when compacted	Compaction characteristics	Embankment material	Compressibility when compacted
GW	Well-graded gravel	Good to Excellent	Good	Fair to good	Excellent	Good	Reasonably stable	Low
GP	Poorly grade gravel (<5% fines)	Good to Excellent	Good	Fair to good	Excellent	Good	Reasonably stable	Low
GC	Clayey gravel (>12% fines)	Good	Fair	Poor to not suitable	Poor to practically impervious	Good to fair	Reasonably stable	Low
SP	Poorly graded sand (<5% fines)	Fair to good	Fair	Poor to not suitable	Excellent	Good	Reasonably stable	Low
SM	Silty sand (sand with fines PI<4)	Fair to good	Fair to good	Poor to not suitable	Fair to practically impervious to impervious	Good	Reasonably stable	Low
SC	Clayey sand (>12% fines PI>7)	Fair	Poor	Not suitable	Poor, impervious when compacted	Good to fair	Reasonably stable	Low
CL	Silts and clays (LL<50 & PI>7)	Fair to poor	Not suitable	Not suitable	Practically impervious	Good to fair	Good stability	Medium
ML	Silts and clays (LL<50 & PI<4)	Fair to poor	Not suitable	Not suitable	Semi-pervious to impervious	Good to poor	Poor stability	Medium
CH	Silts and clays (LL>50)	Poor to fair	Not suitable	Not suitable	Practically impervious	Fair to poor	Fair stability	Medium to high
MH	Silts and clays (LL>50)	Poor	Not suitable	Not suitable	Fair to poor, semi-pervious to pervious	Fair to poor	Poor stability	Medium to high

TABLE E2: Material properties after NAVFAC DM7 (1971)

Group symbol	Soil type	Max yd	Optimum moisture (%)	Typical strength characteristics			
				Cu (kPa)	C` (kPa)	ϕ` (deg.)	tan ϕ`
GW	Well-graded clean gravels, gravel-sand mixtures	19.7-21.2	11-8	0	0	>38	>0.78
GC	Clayey gravels, poorly graded gravel-sand-clay	18.1-20.5	14-9	0	0	>31	>0.60
SM	Silty sands, poorly graded sand-silt mixtures	17.3-19.7	16-11	50	5	34	0.67
SC	Clayey sands poorly graded sand-clays	16.5-19.7	19-11	75	10	31	0.60
CL	Inorganic clays of low to medium plasticity	15.0-18.9	24-12	85	12	28	0.54
ML	Inorganic silts and clayey silts	15.0-18.9	24-12	65	10	32	0.62
CH	Inorganic clays of high plasticity	11.8-16.5	36-19	100	12	19	0.35

yd – Dry density; Cu – Undrained cohesion; C` - Drained cohesion; ϕ`(deg.) – Shearing resistance

APPENDIX F

(Classification Tables)

TABLE C1. GEOTECHNICAL CLASSIFICATION FOR URBAN DEVELOPMENT (after Partridge, Wood and Brink 1993)

CONSTRAINT		Most favourable (1)	Intermediate (2)	Least favourable (3)
A	Collapsible Soil	Any collapsible horizon or consecutive horizons totalling a depth of less than 750 mm in thickness.*	Any collapsible horizon or consecutive horizons with a depth of more than 750 mm in thickness.	A least favourable situation for this constraint does not occur.
B	Seepage	Permanent or perched water table more than 1,5 m below ground surface.	Permanent or perched water table less than 1,5 m below ground surface	Swamps and marshes.
C	Active soil	Low soil-heave potential predicted. *	Moderate soil heave potential predicted.	High soil-heave potential predicted.
D	Highly compressible soil	Low soil compressibility expected.*	Moderate soil compressibility expected.	High soil compressibility expected.
E	Erodability of soil	Low.	Intermediate.	High.
F	Difficulty of excavation to 1,5 m depth	Scattered or occasional boulders less than 10% of the total volume.	Rock or hardpan pedocretes between 10 and 40 % of the total volume.	Rock or hardpan pedocretes more than 40 % of the total volume.
G	Undermined ground	Undermining at a depth greater than 100 m below surface (except where total extraction mining has not occurred.)	Old undermined areas to a depth of 100m below surface where stope closure has ceased.	Mining within less than 100 m of surface or where total extraction mining has taken place.
H	Instability in areas of soluble rock	Possibly unstable.	Probably unstable.	Known sinkholes and dolines
I	Steep slopes	Between 2 and 6 degrees (all regions).	Slopes between 6 and 18 degrees and less than 2 degrees (Natal and Western Cape). Slopes between 6 and 12 degrees and less than 12 degrees (all other regions).	More than 18 degrees (Natal and Western Cape). More than 12 degrees (all other regions).
J	Areas of unstable natural slopes	Low risk.	Intermediate risk.	High risk (especially in areas subject to seismic activity).
K	Areas subject to seismic activity	10% probability of an event less than 100 cm/s^2 within 50 years	Mining-induced seismic activity more 100 cm/s^2.	Natural seismic activity more than 100 cm/s^2.
L	Areas subject to flooding	A “most favourable” situation for this constraint does not occur.	Areas adjacent to a known drainage channel or floodplain with slope less than 1%.	Areas within a known drainage channel or floodplain.

* These areas are designated as 1A, 1C, 1D, or 1F where localised occurrences of the constraint may arise.

TABLE C2: RESIDENTIAL SITE CLASS DESIGNATIONS (SAICE, 1995)

TYPICAL FOUNDATION MATERIAL	CHARACTER OF FOUNDING MATERIAL	EXPECTED RANGE OF TOTAL SOIL MOVEMENTS (mm)	ASSUMED DIFFERENTIAL MOVEMENT (% OF TOTAL)	SITE CLASS
Rock (excluding mud rocks which exhibit swelling to some depth)	STABLE	NEGLIGIBLE	-	R
Fine-grained soils with moderate to very high plasticity (clays, silty clays, clayey silts and sandy clays)	EXPANSIVE SOILS	< 7,5 7,5 – 15 15 – 30 > 30	50% 50% 50% 50%	H H1 H2 H3
Silty sands, sands, sandy and gravelly soils	COMPRESSIBLE AND POTENTIALLY COLLAPSIBLE SOILS	< 5,0 5,0 – 10 > 10	75% 75% 75%	C C1 C2
Fine-grained soils (clayey silts and clayey sands of low plasticity), sands, sandy and gravelly soils	COMPRESSIBLE SOIL	< 10 10 – 20 > 20	50% 50% 50%	S S1 S2
Contaminated soils Controlled fill Dolomitic areas Land fill Marshy areas Mine waste fill Mining subsidence Reclaimed areas Very soft silt/silty clays Uncontrolled fill	VARIABLE	VARIABLE		P

NOTES:

1. The classifications C, H, R and S are not intended for dolomitic area sites unless specific investigations are carried out to assess the stability (risk of sinkholes and doline formation) of the dolomites. Where this risk is found to be acceptable, the site shall be designated as Class P (dolomitic areas).
2. Site classes are based on the assumption that differential movements, experienced by single-storey residential buildings, expressed as a percentage of the total movements are equal to about 50% for soils that exhibit expansive or compressive characteristics and 75% for soils that exhibit both compressible and collapse characteristics. Where this assumption is incorrect or inappropriate, the total soil movements must be adjusted so that the resultant different movements implied by the table are equal to that which is expected in the field.
3. In some instances, it may be more appropriate to use a composite description to describe a site mote fully e.g. C1/H2 or S1 and/or H2. Composite Site Classes may lead to higher differential movements and result in design solutions appropriate to a higher range of differential movement e.g. a Class R/C1 site. Alternatively, a further site investigation may be necessary since the final design solution may depend on the location of the building on a particular site.
4. Where it is not possible to provide a single site designation and a composite description is inappropriate, sites may be given multiple descriptions to indicate the range of possible conditions e.g. H-H1-H2 or C1-C2.
5. Soft silts and clays usually exhibit high consolidation and low bearing characteristics. Structures founded on these horizons may experience high settlements and such sites should be designated as being Class S1 or S2 as relevant and appropriate.
6. Sites containing contaminated soils include those associated with reclaimed mine land, land down-slope of mine tailings and old land fills.
7. Where a site is designated as Class P, full particulars relating to the founding conditions on the site must be provided.
8. Where sites are designated as being Class P, the reason for such classification shall be placed in brackets immediately after the suffix – i.e. P(contaminated soils). Under certain circumstances, composite description may be more appropriate – e.g. P(dolomite areas)-C1.
9. Certain fills may contain contaminates which present a health risk. The nature of such fill should be evaluated and should be clearly demarcated as such.

TABLE C3: FOUNDATION DESIGN, BUILDING PROCEDURES AND PRECAUTIONARY MEASURES FOR SINGLE-STOREY RESIDENTIAL BUILDINGS FOUNDED ON HORIZONS SUBJECT TO CONSOLIDATION SETTLEMENT (SAICE, 1995)

SITE CLASS	ESTIMATED TOTAL SETTLEMENT (mm)	CONSTRUCTION TYPE	FOUNDATION DESIGN AND BUILDING PROCEDURES
S	**<10**	Normal	- Normal construction (strip footing or slab-on-the-ground foundations) - Good site drainage
S1	**10-20**	Modified normal	- Reinforced strip footings - Articulation joints at some internal and all external doors - Light reinforcement in masonry - Site drainage and service/plumbing precautions - Foundation pressure not to exceed 50 kPa
		Compaction of in situ soils below individual footings	- Remove in situ material below foundations to a depth and width of 1,5 times the foundation width or to a competent horizon and replace with material compacted to 93% MOD AASHTO density at –1% to +2% of optimum moisture content. - Normal construction with lightly reinforced strip foundations and light reinforcement in masonry.
		Deep strip foundations	- Normal construction with drainage requirements. - Founding on a competent horizon below the problem horizon
		Soil raft	- Remove in situ material to 1,0m beyond perimeter of building to a depth and width of 1,5 times the widest foundation or to a competent horizon and replace with material compacted to 93% MOD AASHTO density at –1% to +2% of optimum moisture content. - Normal construction with lightly reinforced strip footings and light reinforcement in masonry.
S2	**>20**	Stiffened strip footings, stiffened or cellular raft	- Stiffened strip footing or stiffened or cellular raft with articulation joints or solid lightly reinforced masonry. - Bearing pressure not to exceed 50kPa. - Fabric reinforcement in floor slabs. - Site drainage and service/plumbing precautions.
		Deep strip foundations	- As for S1 but with fabric reinforcement in floor slabs
		Compaction of in-situ soils below individual footings	- As for S1.
		Piled or pier foundations	- Reinforced concrete ground beams or solid slabs on piled or pier foundations. - Ground slabs with fabric reinforcement. - Good site drainage.
		Soil raft	- As for S1.

NOTES:

1. Differential settlement assumed to equal 50% of total settlement.
2. The relaxation of some of these requirements, e.g. the reduction or omission of steel or articulation joints, may result in a Category 2 level of expected damage.
3. Account must be taken on sloping site since differential fill heights may lead to greater differential settlements.
4. Settlements induced by loads imposed by deep filling beneath surface beds may necessitate the adoption of a construction type appropriate to a more severe site class.

TABLE C4: FOUNDATION DESIGN, BUILDING PROCEDURES AND PRECAUTIONARY MEASURES FOR SINGLE-STOREY RESIDENTIAL BUILDINGS FOUNDED ON HORIZONS SUBJECT TO BOTH CONSOLIDATION AND COLLAPSE SETTLEMENT
(SAICE, 1995)

SITE CLASS	ESTIMATED TOTAL SETTLEMENT (mm)	CONSTRUCTION TYPE	FOUNDATION DESIGN AND BUILDING PROCEDURES
C	**<5**	Normal	- Normal construction (strip footing or slab-on-the-ground foundations) - Good site drainage
C1	**5 – 10**	Modified normal	- Reinforced strip footings - Articulation joints at some internal and all external doors - Light reinforcement in masonry - Site drainage and service/plumbing precautions - Foundation pressure not to exceed 50 kPa
		Compaction of in situ soils below individual footings	- Remove in situ material below foundations to a depth and width of 1,5 times the foundation width or to a competent horizon and replace with material compacted to 93% MOD AASHTO density at –1% to +2% of optimum moisture content. - Normal construction with lightly reinforced strip foundations and light reinforcement in masonry.
		Deep strip foundations	- Normal construction with drainage requirements. - Founding on a competent horizon below the problem horizon
		Soil raft	- Remove in situ material to 1,0m beyond perimeter of building to a depth and width of 1,5 times the widest foundation or to a competent horizon and replace with material compacted to 93% MOD AASHTO density at –1% to +2% of optimum moisture content. - Normal construction with lightly reinforced strip footings and light reinforcement in masonry.
C2	**>10**	Stiffened strip footings, stiffened or cellular raft	- Stiffened strip footing or stiffened or cellular raft with articulation joints or solid lightly reinforced masonry. - Bearing pressure not to exceed 50kPa. - Fabric reinforcement in floor slabs. - Site drainage and service/plumbing precautions.
		Deep strip foundations	- As for C1 but with fabric reinforcement in floor slabs
		Compaction of in situ soils below individual footings	- As for C1.
		Piled or pier foundations	- Reinforced concrete ground beams or solid slabs on piled or pier foundations. - Ground slabs with fabric reinforcement. - Good site drainage.
		Soil raft	- As for C1.

NOTES:
1. Differential settlement assumed to equal 75% of total settlement
2. The relaxation of some of these requirements, e.g. the reduction or omission of steel or articulation joints, may result in a Category 2 level of expected damage.

TABLE C5: FOUNDATION DESIGN, BUILDING PROCEDURES AND PRECAUTIONARY MEASURES FOR SINGLE-STOREY RESIDENTIAL BUILDINGS FOUNDED ON HORIZONS SUBJECT TO HEAVE (SAICE, 1995)

SITE CLASS	ESTIMATED TOTAL EXPANSION (mm)	CONSTRUCTION TYPE	FOUNDATION DESIGN AND BUILDING PROCEDURES
H	**<7,5**	Normal	- Normal construction (strip footing or slab-on-the-ground foundations) - Good site drainage and service/plumbing precautions recommended.
H1	**7,5 – 15**	Modified normal	- Lightly reinforced strip footings - Articulation joints at all internal/external doors - Light reinforcement in masonry - Site drainage and service/plumbing precautions
		Soil raft	- Remove in situ material to 1,0m beyond perimeter of the structure and replace with inert backfill, compacted to 93% MOD AASHTO density at –1% to +2% of optimum moisture content. - Normal construction with lightly reinforced strip footings and light reinforcement in masonry if residual movements are <7,5mm, or construction type appropriate to residual movements. - Site drainage and plumbing/service precautions.
H2	**15-30**	Stiffened or cellular raft	- Stiffened or cellular raft with articulation joints or lightly reinforced masonry. - Site drainage and plumbing/service precautions.
		Piled construction	- Piled foundations with suspended floor slabs with or without ground beams. - Site drainage and plumbing/service precautions.
		Split construction	- Combination of reinforced brickwork/block work and full movement joints. - Suspended floors of fabric-reinforced ground slabs acting independently from the structure. - Site drainage and plumbing/service precautions.
		Soil raft	- As for H1.
H3	**>30**	Stiffened or cellular raft	- As for H2.
		Piled construction	- As for H2.
		Soil raft	- As for H1.

NOTES:

1. Differential settlement assumed to equal 50% of total settlement
2. The relaxation of some of these requirements, e.g. the reduction or omission of steel or articulation joints, may result in a Category 2 level of expected damage.

CHART C1: USCS MATERIAL DESIGNATION CHART

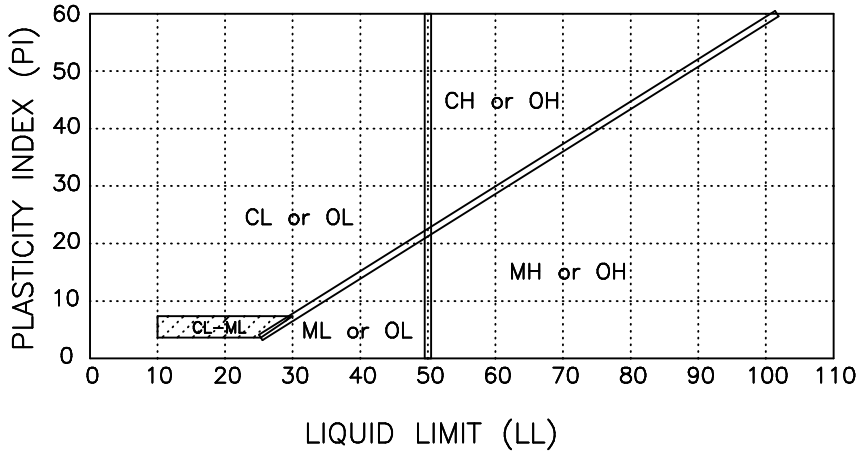
UNIFIED SOIL CLASSIFICATION SYSTEM

Soils are visually classified by the United Soil Classification System (USCS) on the boring logs presented in this report. Grain size analysis and Atterberg limits tests are often performed on selected samples to aid in classification. The classification system is briefly outlined on this chart. For a more detailed description of the system, see "The Unified Soil Classification System" Corps of Engineers, US Army Technical Memorandum No. 3–357 (Revised April 1960) or ASTM Designation: D2487–66T.

MAJOR DIVISIONS				GROUP SYMBOL	TYPICAL NAMES
COARSE – GRAINED SOILS (Less than 50% passes No. 200 sieve)	GRAVELS (50% or less of coarse fraction passes No. 4 sieve)	CLEAN GRAVELS (Less than 5% passes No. 200 sieve)		GW	Well graded gravels, gravel–sand mixtures, or sand–gravel–cobble mixtures.
				GP	Poorly graded gravels, gravel–sand mixtures, or sand–gravel–cobble mixtures.
		GRAVELS WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below the "A" line & hatched zone on plasticity chart	GM	Silty gravels, gravel–sand–silt mixtures.
			Limits plot above the "A" line & hatched zone on plasticity chart	GC	Clayey gravels, gravel–sand–clay mixtures.
	SANDS (More than 50% of coarse fraction passes No. 4 sieve)	CLEAN SANDS (Less than 5% passes No. 200 sieve)		SW	Well graded sands, gravelly sands.
				SP	Poorly graded sands, gravelly sands.
		SANDS WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below the "A" line & hatched zone on plasticity chart	SM	Silty sands, sand–silt mixtures.
			Limits plot above the "A" line & hatched zone on plasticity chart	SC	Clayey sands, sand–clay mixtures.
FINE – GRAINED SOILS (50% or more passes No. 200 sieve)	SILTS (Limits Plot Below "A" Line & hatched Zone on Plasticity Chart)	SILTS OF LOW PLASTICITY (Liquid Limit Less Than 50)		ML	Inorganic silts, non–plastic or slightly plastic.
		SILTS OF HIGH PLASTICITY (Liquid Limit More Than 50)		MH	Inorganic silts, micaceous or diatomaceous silty soils, elastic silts.
	CLAYS (Limits Plot Above "A" Line & hatched Zone on Plasticity Chart)	CLAYS OF LOW PLASTICITY (Liquid Limit Less Than 50)		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		CLAYS OF HIGH PLASTICITY (Liquid Limit More Than 50)		CH	Inorganic clays of high plasticity, fat clays, sandy clays of high plasticity.

NOTE:
Coarse grained soils with between 5% & 12% passing the No. 200 sieve and fine grained soils with Atterberg limits plotting in the hatched zone on the plasticity chart shall have dual symbol. In Arizona, local streams contain sand, gravel & cobble type material, which are locally known as SGC or riverrun material. The USCS is not used to divide and symbolize this material.

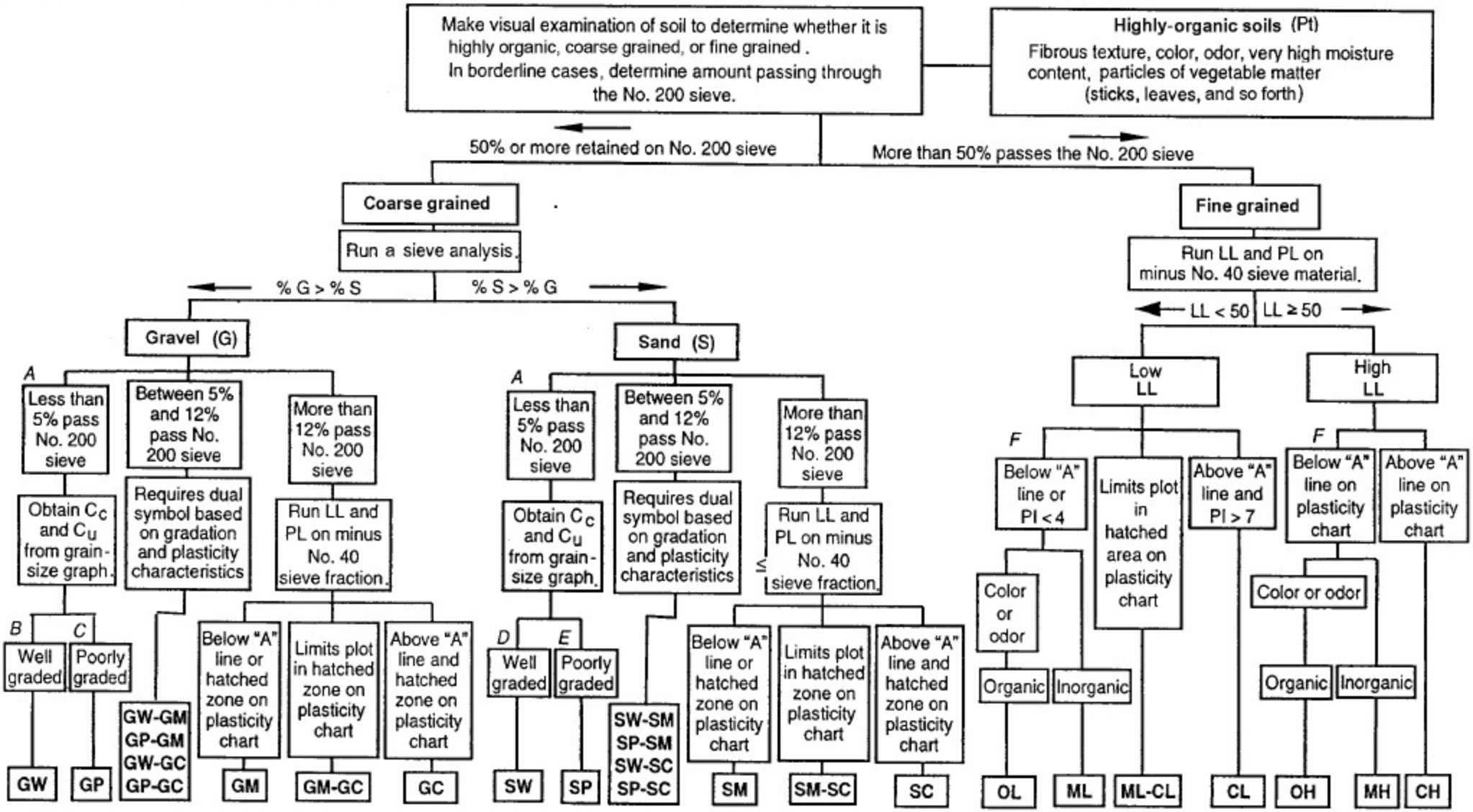
PLASTICITY CHART



DEFINITIONS OF SOIL FRACTIONS

SOIL COMPONENT	PARTICLE SIZE RANGE
Cobbles	Above 3 in.
Gravel	3 in. to No. 4 sieve
Coarse gravel	3 in. to 3/4 in.
Fine gravel	3/4 in. to No. 4 sieve
Sand	No. 4 to No. 200
Coarse	No. 4 to No. 10
Medium	No. 10 to No. 40
Fine	No. 40 to No. 200
Fines (silt & clay)	Below No. 200 sieve
Clay	Smaller than 2 microns
Colloid	Smaller than 5 microns

CHART C2: USCS DESIGNATION FLOW CHART



A If fines interfere with free-draining properties, use a double symbol such as GW-GM.

B For well-graded gravel, the C_U must be > 4 and the C_C must be ≥ 1 and ≤ 3.

C For poorly graded gravel, the C_U must be ≤ 4 and/or the C_C is < 1 or > 3.

D For well graded sand, the C_U must be > 6 and the C_C must be ≥ 1 and ≤ 3.

E For poorly graded sand, the C_U must be ≤ 6 and/or the C_C is < 1 or > 3.

F In cases where organic material can't be determined by color or odor, a LL and PL test must be conducted on a sample of natural moisture content and a sample that has been oven-dried. Organic soils will show a radical drop in plasticity for the oven-dried sample compared to the retained-moisture sample. Inorganic soils generally fall within ± 1 or 2 percent of each other.