GEOTECHNICAL INVESTIGATION
For United Nations Development Programme (UNDP)
Medical Stores Limited's Regional Warehouse Hubs
MPIKA

FINAL REPORT

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Table of Contents

Contents

Table of Contents 3
1. Introduction 4
2. Technical Standards 4
3. General Description of Project Area 5
4. Geology 5
6. Results of field work 6
6.1 SPT 6
6.1.1 Analysis of SPT results 7
6.2 Trial Pits 8
7. Results of laboratory testing 9
8. Conclusions 11
Appendix A – Map A-1
Appendix B – SPT test records B-1
Appendix C – SPT and Test Pits Logging C-1
Appendix D - Sieve Analysis Results D-1
Appendix E - Atterberg Limit Results E-1
Appendix F – Moisture Content Results F-1
Appendix G – MDD Test Results G-1
Appendix H – CBR Test Results H-1

1. Introduction

Rankin Engineering Consultants was contracted by the United Nations Development Programme (UNDP) 18th August 2016 to carry out geo-technical investigations at the proposed sites for Mongu, Choma, Mansa, Mpika and Chipata Medical Stores Limited's Regional Warehouse Hubs. This report presents the findings based on the tests carried out in the field and laboratory testing.

Field testing included test pit, DPSH and SPT's.

Laboratory testing of samples included Sieve Analysis, Atterberg Limits, Moisture Content, MDD and CBR.

Field investigation was carried out over the period of 7th to 15th September 2016.

The map of the investigation area is included in Appendix A.

2. Technical Standards

The following technical standards were applied to this project:

BS EN 1997-2:2007 Geotechnical Design – Ground Investigation and testing

BS 1377-9:1990 Methods of test for Soils for Civil Engineering Purposes – In-situ tests

SANS 3001-GR1: 2013 Wet preparation and particle size analysis

BS 1377-2: 1990 Tests 1.2, 1.3 and 1.4 Liquid Limit, Plastic Limit & Plasticity Index, Linear Shrinkage

SANS 3001-GR30: 2013 Determination of the maximum dry density and optimum moisture content

SANS 3001-GR40: 2013 Determination of the California bearing ratio

BS 1377-2: 1990 Moisture Content

3. General Description of Project Area

The investigated area is rural, dominated by grass vegetation, with some small vegetable farms developed.

The whole area is covered by moist reddish brown soft sandy clay in the upper layers and moist light reddish brown soft to firm gravelly sandy clay at depth.

4. Geology

The geology of the Mpika is of Precambrian in age. The geological succession shown in three main lithological units: quartzites and sandstones of the Kibaran System mainly occurring in the north-west but also dominating the Mpika-lsoka Ridge Land Region; granite in a central zone north-east to south-west but also surrounding the Luangwa Valley in the extreme east; and the shales, siltstones, mudstones and sandstones of the Kundelungu System, which is found both along the Luapula Valley where it is known as the Luapula Beds and in the south-east of the Chambesi-Bangweulu Plain Land Region where it is called the Luitikila Beds. Zambia was subjected to at least two periods of granitic intrusion (Reeve, 1963); the granite found in the project area, however, seems to belong to the older intrusion. Apart from some very small and scattered basic outcrops, igneous rocks can also be found surrounding the Kibaran System in the north-west of the project area, as an intermittent volcanic or hypabyssal suite. The geological map of the project area (Figure 1) is based on a revision of the 1:1 000 000 Geological Map of Zambia published by the Geological Survey of Zambia (formerly Northern Rhodesia) in 1960. North of Mpika, there is a basaltic mesa and further basaltic outcrops found to the south-west of this mesa, which give rise to smectoid (or more active) clays. The folded rocks of the Kibaran System attain their maximal width north of Mpika where 'the quartzite formations are repeated six or seven times from north-west to south-east by major folds' (Marten, 1968a). The folding decreases in width north-east and south-west from this area. [1]

[1] Land Resources of the Northern and Luapula Provinces, Zambia reconnaissance assessment. Volume 4 The biophysical environment.

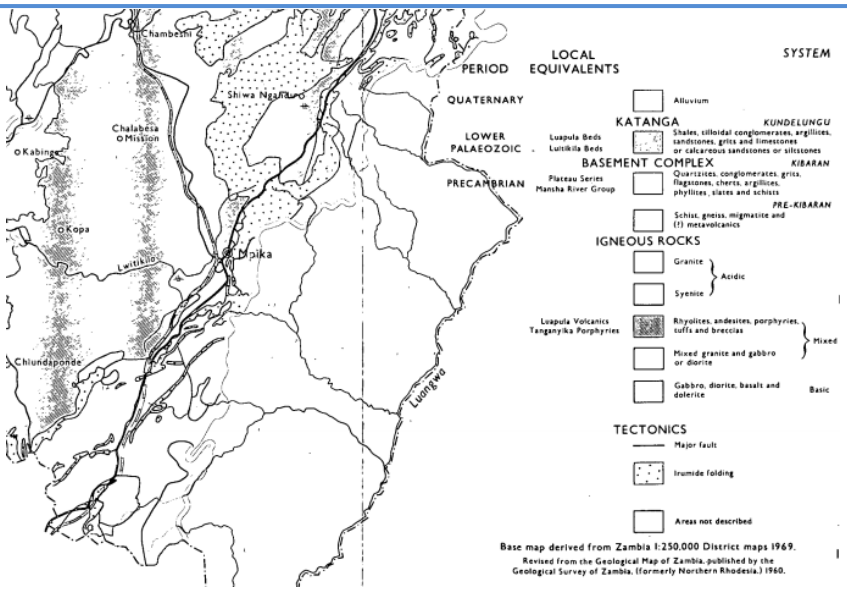


Figure 1: Map of Mpika Terrane

5. Methodology

The field work comprised a combination of soil profiling using undisturbed methods to extract samples of the soil to 5.0 metres depth where conditions allowed, combined with In-situ testing using Standard Penetration Test (SPT) 'down the hole' at every 1m level. Laboratory testing was done to classify the soil types encountered and to determine their engineering characteristics. Test pitting was also carried out on one point.

6. Results of field work

6.1 SPT

A total of 4 SPT tests were carried out at the test locations as shown on the map in Appendix A. The SPT test was performed using a split cone, with a 150mm seating blow. This test is used to directly determine the allowable bearing capacity under in-situ conditions. The number of blows required to advance the cone through the final 300mm of a 450mm test range is reported as the 'N' value. The SPT test records are included in Appendix B. A summary and interpretation is given in Table 1.

The allowable bearing capacity is a function of the foundation size and depth. Without knowing these in advance, an approximation of bearing capacity for various widths at the top of the excavation has been used.

It should be borne in mind that conditions at the time of testing may not be the worst condition that can be experienced over the life of the foundation, particularly with respect to saturated conditions in soils which are highly susceptible to softening under moisture. Reference should therefore also be made to soil classification results.

6.1.1 Analysis of SPT results

The SPT values recorded were processed using relationships developed by Bowles based on Meyer-hof relationships. Calculated values for the site are given in the table below.

Mpika						
Point ID	Depth	N Value	Proposed founding depth (m)	Possible foundation width (m)	Average SPT in zone of influence	Allowable bearing capacity (kPa)
SPT1	1	6	2.0	0.8	11	135
	2	15		1	11	135
	3	10		1.5	11	130
	4	9		2	11	130
	5	14				
SPT2	1	5	2.0	0.8	10	125
	2	7		1	10	125
	3	17		1.5	9	110
	4	7		2	9	110
	5	10				
SPT3	1	12	2.0	0.8	8	95
	2	9		1	8	95
	3	9		1.5	10	115
	4	6		2	10	115
	5	12				
SPT4	1	3	2.0	0.8	9	100
	2	11		1	9	100
	3	31		1.5	13	160
	4	6		2	13	160
	5	15				

Table 1: Bearing Capacity based on SPT N Values

The results indicate that on Mpika site, an allowable bearing capacity of 100kPa at a minimum founding depth of 2.0 metres below the ground surface may be appropriate.

At the site, the materials in the proposed founding layer are moist reddish brown yellowish gravelly sand-clay mixture. The soil matrix itself appears firm.

As the field testing was done during the dry season, it is anticipated that lower results would have been achieved during the rainy season. Reference is therefore made to the laboratory results.

6.2 Trial Pits

A total of 1 Trial Pits tests were carried out at the test locations as shown on the map in Appendix A.

Conditions on site allowed excavation as deep as 3.0m due to presence of moist reddish brown yellowish gravelly sand-clay mixture.

The soil profiles (Appendix C) in trial pit revealed that the whole area is covered by moist reddish brown sandy clay in the upper layers.

Point ID	GPS Coordinates		Photo
	E	N	Tested Sample
1	328727	8692313	
	Sample: Moist reddish brown yellowish gravelly sand-clay mixture (Residual)		
	Depth: 0.8-3.0m		

7. Results of laboratory testing

Laboratory testing was used to classify materials and to corroborate the results of the SPT testing. The tests included Sieve Analysis, Atterberg Limits, Moisture Content, MDD and CBR.

A total of 4 undisturbed samples from the SPT borings were obtained for testing.

Soils were cohesive with low plasticity and moisture contents ranging from 13.4% to 19.7%. The materials exhibit low shrinkage. The CBR of the material was 81%.

The actual lab test results are presented in Appendices D to H.

Table 2: Laboratory test summary

Mpika

Lab #	ID #	Visual Description	Depth (m)	USCS classification	Moisture Content (%)	Linear Shrinkage	Sieve analysis % passing sieve size (mm) 0,075	0,425	2,0	5,0	28,0	50,0	63,0	PI	Shrinkage Product	Grading Co-efficient	Plasticity Modulus	Grading Modulus	Proctor MDD (Kg/m^3)	Proctor OMC (%)	CBR 93%	CBR 95%	CBR 98%
3269	TP1	Moist reddish brown sandy clay (Residual)	0.8-3.0	CL															2041	15.3	88	81	-
3270	SPT1	Moist reddish brown soft sandy clay (Residual)	0-1.3	CL	19.7	9.29	76.3	92.6	97.8	99.6	100	100	100	20.6	860	7	1572	0.3					
3271	SPT2	Moist light reddish brown soft gravelly sandy clay (Residual)	3.4-5.0	CL	14.5	5.21	50.3	62.6	74.2	93	100	100	100	18.4	326	35	926	1.1					
3272	SPT3	Moist reddish brown yellowish soft gravelly sand-clay mixture (Residual)	1.0-3.1	SC	18.2	5.21	48.7	63.7	75.8	93.1	100	100	100	17.3	332	34	843	1.1					
3273	SPT4	Moist reddish brown yellowish firm gravelly clayey sand with fragments of sandstone and quartzitic stone (Residual)	1.4-3.7	SC	13.4	6.0	32.5	42.1	53.7	72.1	92.8	100	100	16.6	253	37	540	1.7					

CL Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays

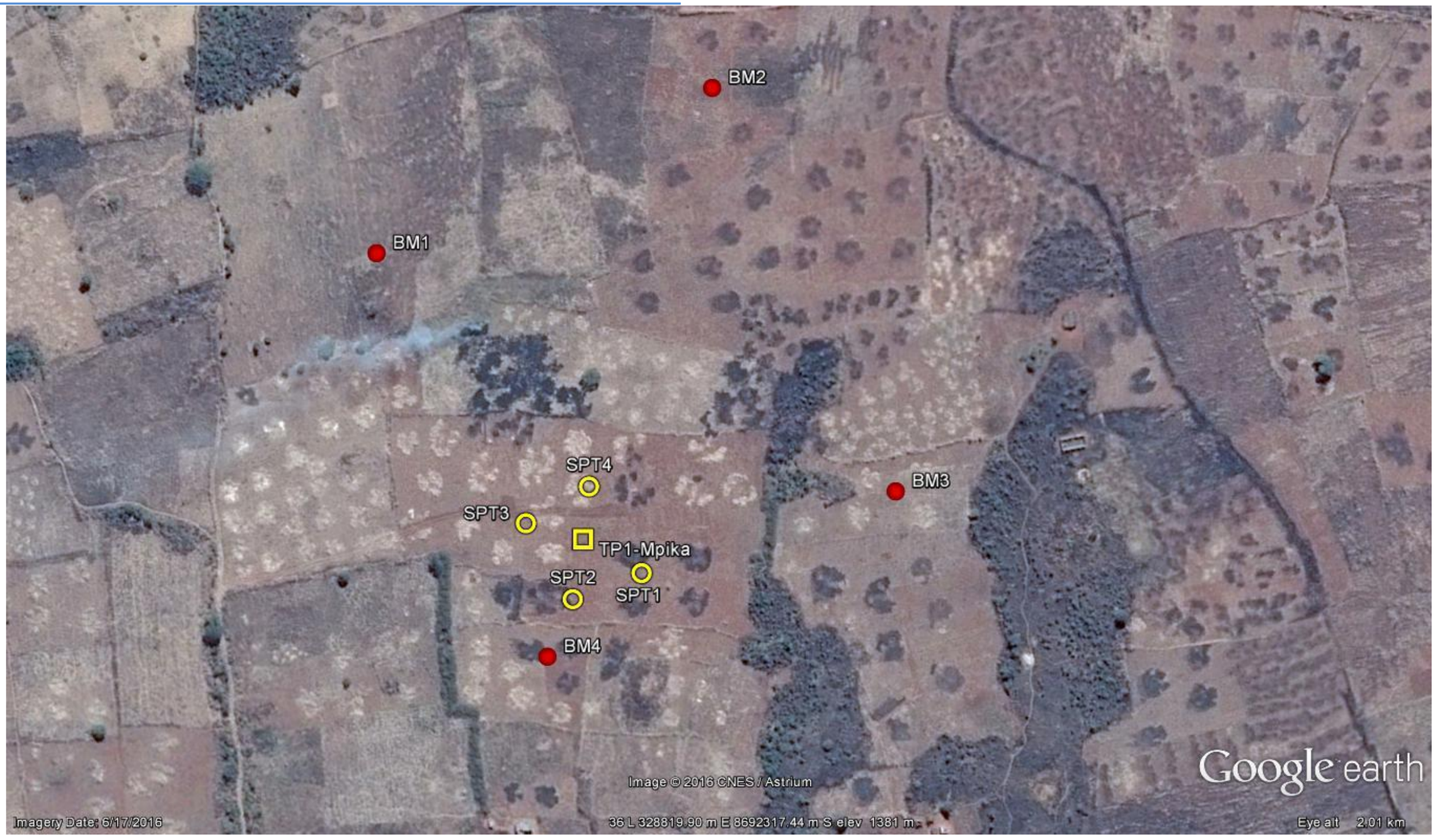
SC Clayey sands, poorly graded sand-clay mixtures

8. Conclusions

From the investigation carried out, the following conclusions can be drawn:

- An allowable bearing capacity of 100kPa would be the maximum recommended.
- The soil at this site is mostly moist reddish brown soft sandy clay in the upper layers and moist light reddish brown soft to firm gravelly sandy clay at depth with occurrence of sand-stone and quartz fragments in depth of 3.0-3.5m.
- SPT'N' Values reveal that soil stratum is soft to firm from ground level up to investigated depth.
- Groundwater was not encountered within the boreholes up to 5.0m depth during investiga-tion.
- A minimum foundation depth of 2.0m is proposed.
- In-situ materials can be used as fill and as road pavement layers. Compacted to 95% MDD, a CBR of at least 80 is expected.
- All foundations for a single structure should be placed in the same strata and therefore should be at the same level.

Appendix A – Map


BM2
BM1
SPT4
BM3
SPT3
TP1-Mpika
SPT2
SPT1
BM4
Image © 2016 CNES / Astrium
Google earth
Imagery Date: 6/17/2016
36 L 328819.90 m E 8692317.44 m S elev 1381 m
Eye alt 2.01 km

Appendix B – SPT test records

RECORD FOR SUBSURFACE EXPLORATION			
TYPE OF BORING:	SPT 1	DATE OF BORING:	13/09/2016
PROJECT NAME:	UNDP-Geotechnical Survey for Medical Store Limited's Regional Hubs (Mpika)	BORING No :	BH-1
OPERATOR'S NAME:	CH		
LOCATION:	328740 8692281	Elevation:	1375m

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DESCRIPTION	PROFILE	DEPTH m	BLOWS	SAMPLE	N	WC	γ	REMARKS
Moist reddish brown soft sandy clay (Residual)			3					
			3					
			3					
		1.0	6	↓	6			
			6					
			7					
Moist reddish brown yellowish firm gravelly sand-clay mixture (Residual)			8					
		2.0	15	↓	15			
			6					
			6					
			4					
		3.0	10	↓	10			
			3					
			4					
			5					
		4.0	9	↓	9			
Moist light reddish brown firm gravelly sandy clay (Residual)			4					
			5					
			9					
		5.0	14	↓	14			No Ground Water Level Found
Moist light reddish brown firm gravelly sandy clay (Residual)	DPSH	5.1	2					
		5.2	5					
		5.3	2					
		5.4	3					
		5.5	7					
		5.6	7					
		5.7	9					
		5.8	8					
		5.9	11					
		6.0	12					
		6.1	19					

		BULK SAMPLE	•	B
GROUND LEVEL	⏚	DISTURBED SAMPLE	•	D
WATER LEVEL	▽	UNDISTURBED SAMPLE	■	U
S.P.T	↓	WATER SAMPLE	•	W

SKETCH MAP OF BORING HOLE

RECORD FOR SUBSURFACE EXPLORATION			
TYPE OF BORING:	SPT 2	DATE OF BORING:	13/09/2016
PROJECT NAME:	UNDP-Geotechnical Survey for Medical Store Limited's Regional Hubs (Mpika)	BORING No :	BH-2
OPERATOR'S NAME:	CH		
LOCATION:	328704 8692292	**Elevation:**	1375m

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DESCRIPTION	PROFILE	DEPTH m	BLOWS	SAMPLE	N	WC	γ	REMARKS
Moist reddish brown soft sandy clay (Residual)			3					
			2					
			3					
		1.0	5	↓	5			
			2					
			3					
			4					
		2.0	7	↓	7			
Moist reddish brown yellowish firm gravelly sand-clay mixture (Residual)			5					
			7					
			10					
		3.0	17	↓	17			
			3					
			4					
Moist light reddish brown soft gravelly sandy clay (Residual)			5					
		4.0	9	↓	9			
			2					
			4					
			6					
		5.0	10	↓	10			No Ground Water Level Found
Moist light reddish brown soft gravelly sandy clay (Residual)	DPSH	5.1	2					
		5.2	4					
		5.3	5					
		5.4	5					
		5.5	6					
		5.6	7					
		5.7	9					
		5.8	9					
		5.9	10					
		6.0	11					

		BULK SAMPLE	•	B
GROUND LEVEL	⏚	DISTURBED SAMPLE	•	D
WATER LEVEL	▽	UNDISTURBED SAMPLE	■	U
S.P.T	↓	WATER SAMPLE	•	W

SKETCH MAP OF BORING HOLE

RECORD FOR SUBSURFACE EXPLORATION									
TYPE OF BORING:		SPT 3			DATE OF BORING:	13/09/2016			
PROJECT NAME:		UNDP-Geotechnical Survey for Medical Store Limited's Regional Hubs (Mpika)			BORING No : BH-3				
OPERATOR'S NAME:		CH							
LOCATION:	328709	8692337			**Elevation:**	1374m			

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DESCRIPTION	PROFILE	DEPTH m	BLOWS	SAMPLE	N	WC	Y	REMARKS
Moist reddish brown firm sandy clay (Residual)			8					
			6					
			6					
		1.0	12	↓	12			
Moist reddish brown yellowish soft gravelly sand-clay mixture (Residual)			4					
			4					
			5					
		2.0	9	↓	9			
			3					
			4					
			5					
		3.0	9	↓	9			
Moist light reddish brown soft to firm gravelly sandy clay (Residual)			1					
			3					
			3					
		4.0	6	↓	6			
			3					
			5					
			7					
		5.0	12	↓	12			No Ground Water Level Found
Moist light reddish brown soft to firm gravelly sandy clay (Residual)	DPSH	5.1	1					
		5.2	2					
		5.3	4					
		5.4	5					
		5.5	6					
		5.6	5					
		5.7	6					
		5.8	7					
		5.9	8					
		6.0	9					

		BULK SAMPLE	•	B
GROUND LEVEL	↓	DISTURBED SAMPLE	•	D
WATER LEVEL	↓	UNDISTURBED SAMPLE	■	U
S.P.T	↓	WATER SAMPLE	•	W

SKETCH MAP OF BORING HOLE

RECORD FOR SUBSURFACE EXPLORATION			
TYPE OF BORING:	SPT 4	DATE OF BORING:	14/09/2016
PROJECT NAME:	UNDP-Geotechnical Survey for Medical Store Limited's Regional Hubs (Mpika)	BORING No :	BH-4
OPERATOR'S NAME:	CH		
LOCATION:	328746 8692332	**Elevation:**	1375m

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DESCRIPTION	PROFILE	DEPTH m	BLOWS	SAMPLE	N	WC	γ	REMARKS
Moist reddish brown very soft sandy clay (Residual)			2					
			1					
			2					
		1.0	3	↓	3			
			4					
			5					
Moist reddish brown yellowish firm gravelly clayey sand with fragments of sandstone and quartzitic stone (Residual)			6					
		2.0	11	↓	11			
			16					
			21					
			10					
		3.0	31	↓	31			
			2					
			3					
			3					
Moist light reddish brown firm gravelly sandy clay (Residual)		4.0	6	↓	6			
			4					
			7					
			8					
		5.0	15	↓	15			No Ground Water Level Found
Moist light reddish brown firm gravelly sandy clay (Residual)	DPSH	5.1	1					
		5.2	3					
		5.3	4					
		5.4	4					
		5.5	6					
		5.6	6					
		5.7	7					
		5.8	7					
		5.9	8					
		6.0	9					

		BULK SAMPLE	•	B
GROUND LEVEL	⏚	DISTURBED SAMPLE	•	D
WATER LEVEL	▽	UNDISTURBED SAMPLE	■	U
S.P.T	↓	WATER SAMPLE	•	W

SKETCH MAP OF BORING HOLE

Appendix C – SPT and Test Pits Logging

Figure 2*: SPT Logging*

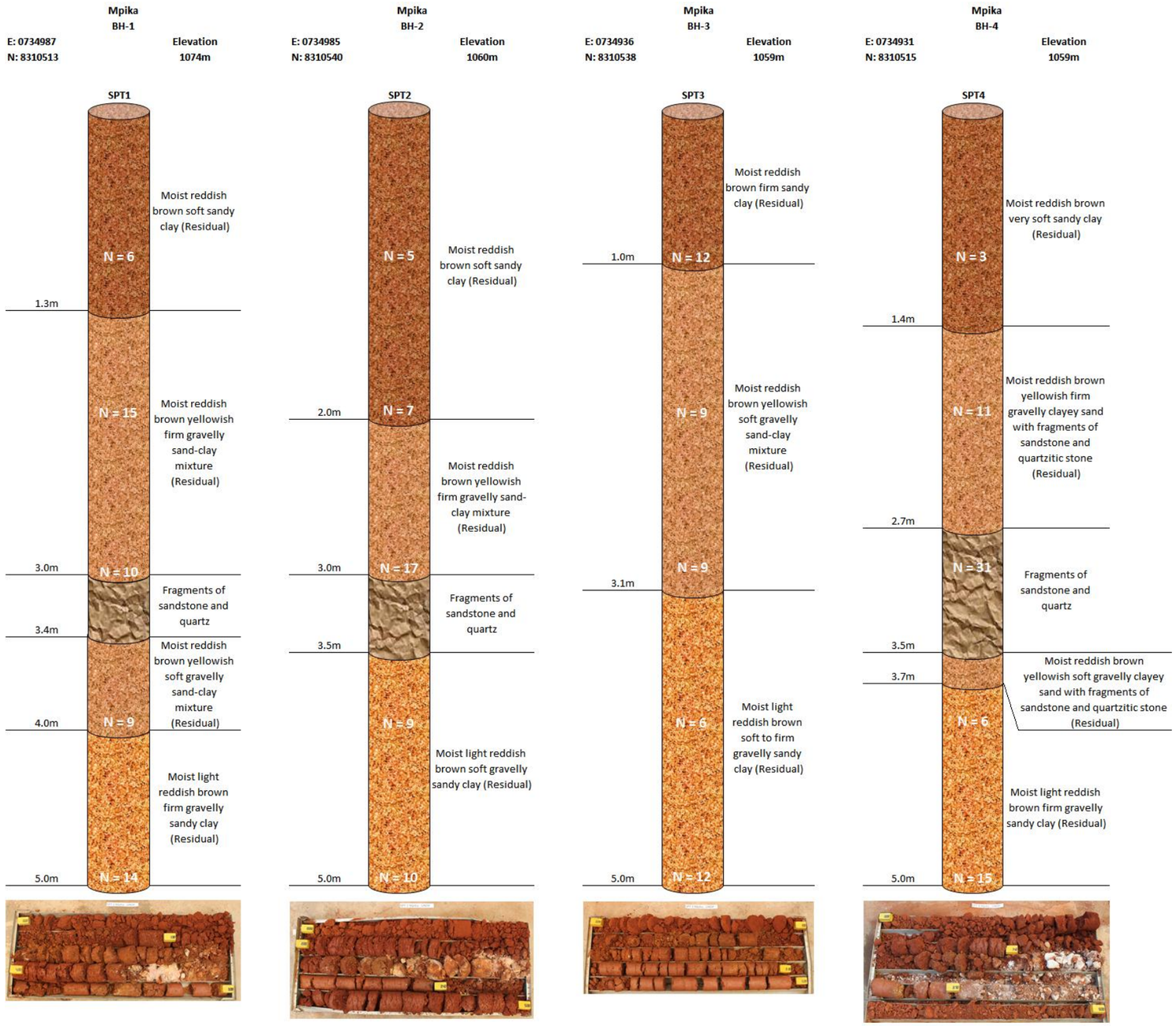
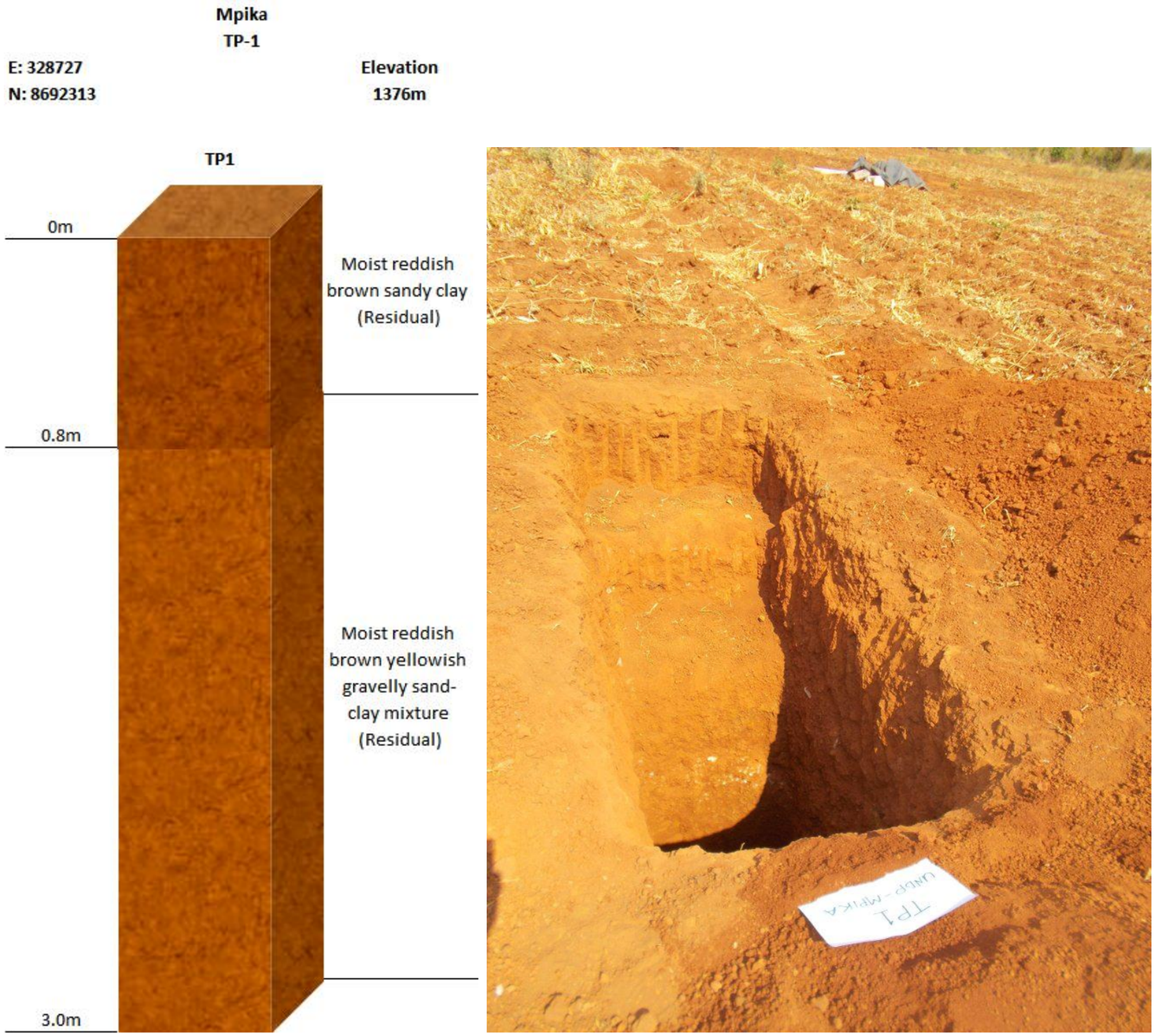


Figure 3*: Test Pits Logging*



Appendix D - Sieve Analysis Results

WET SIEVE ANALYSIS — FORM: SANS 3001-GR1: 2013

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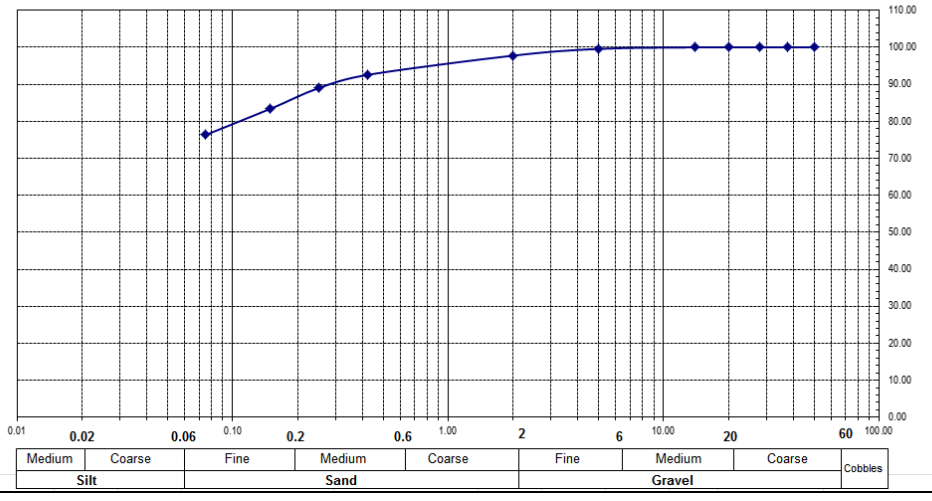
CLIENT:	United Nations Development Programme (UNDP)		
PROJECT:	Medical Store Limited's Regional Hubs-Mpika		
SUPERVISOR:	DL	DATE:	19/09/2016
OPERATOR	BZ	SAMPLE SOURCE:	SPT 1 (0 - 1.30m)
DATE OF SOAKING:	19/09/2016	Soil Description	Moist reddish brown soft sandy clay (Residual)
DATE OF TESTING:	19/09/2016	Lab No.	3270

Initial Dry Mass (m_1) **2413.4** g

Sieve Opening (mm)	Mass Retained (g) Actual	Mass Retained (g) Corrected	% Retained (m)*100 / (m_1)	% Passing (p)	Cumulative % passing
75.0	0			100.0	100
63.0	0	0	0.0	100.0	100
50.0	0	0	0.0	100.0	100
37.5	0	0	0.0	100.0	100
28.0	0	0	0.0	100.0	100
20.0	0	0	0.0	100.0	100
Passing 20 mm (m_2)	2413.4	2413.4			
total (checked with m_1)	**2413.4**				
riffled (m_3)	631.7				
riffled and washed (m_4)	156.2				
Correction factor $\frac{m_2}{m_3}$		3.82			
14.0	0	0	0.0	100.0	100
5.0	2.7	10	0.4	99.6	100
2.0	11.5	44	1.8	97.8	98
0.425	32.7	125	5.2	92.6	93
0.250	22.8	87	3.6	89.0	89
0.150	35	134	5.5	83.4	83
0.075	44.8	171	7.1	76.3	76
<0.075 (+ 475.5	482.2	1842	76.3		
TOTAL		2413.4			

Grading Modulus: GM = (300 -%<2mm-%<0.425mm-%<0.075mm)/100	0.3
Grading Coefficient: GC= (%<28.0-%<0.425) x (%<5.0mm)/100	7.4
USCS classification	CL

SIEVE SIZE BY LOG SCALE



WET SIEVE ANALYSIS — FORM: SANS 3001-GR1: 2013

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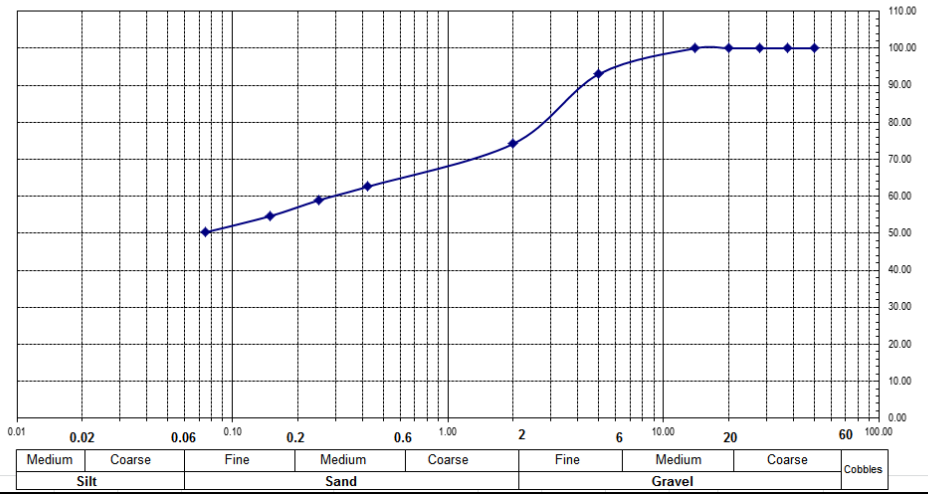
CLIENT:	United Nations Development Programme (UNDP)		
PROJECT:	Medical Store Limited's Regional Hubs-Mpika		
SUPERVISOR:	DL	DATE:	19/09/2016
OPERATOR	BZ	SAMPLE SOURCE:	SPT 2 (3.4 - 5.0m)
DATE OF SOAKING:	19/09/2016	Soil Description	Moist light reddish brown soft gravelly sandy clay (Residual)
DATE OF TESTING:	19/09/2016	Lab No.	3271

Initial Dry Mass (m_1) **1539.4** g

Sieve Opening (mm)	Mass Retained (g) Actual	Mass Retained (g) Corrected	% Retained (m)*100 / (m_1)	% Passing (p)	Cumulative % passing
75.0	0			100.0	100
63.0	0	0	0.0	100.0	100
50.0	0	0	0.0	100.0	100
37.5	0	0	0.0	100.0	100
28.0	0	0	0.0	100.0	100
20.0	0	0	0.0	100.0	100
Passing 20 mm (m_2)	1539.4	1539.4			
total (checked with m_1)	**1539.4**				
riffled (m_3)	431.6				
riffled and washed (m_4)	217.1				
Correction factor $\frac{m_2}{m_3}$		3.57			
14.0	0	0	0.0	100.0	100
5.0	30.1	107	7.0	93.0	93
2.0	81.4	290	18.9	74.2	74
0.425	49.8	178	11.5	62.6	63
0.250	16.1	57	3.7	58.9	59
0.150	18.2	65	4.2	54.7	55
0.075	19	68	4.4	50.3	50
<0.075 (+ 214.5	217	774	50.3		
TOTAL		1539.4			

Grading Modulus: GM = (300 -%<2mm-%<0.425mm-%<0.075mm)/100	1.1
Grading Coefficient: GC= (%<28.0-%<0.425) x (%<5.0mm)/100	34.8
USCS classification	CL

SIEVE SIZE BY LOG SCALE



WET SIEVE ANALYSIS — **FORM: SANS 3001-GR1: 2013**

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Lusaka, Zambia
Tel/Fax: 260-1-291195

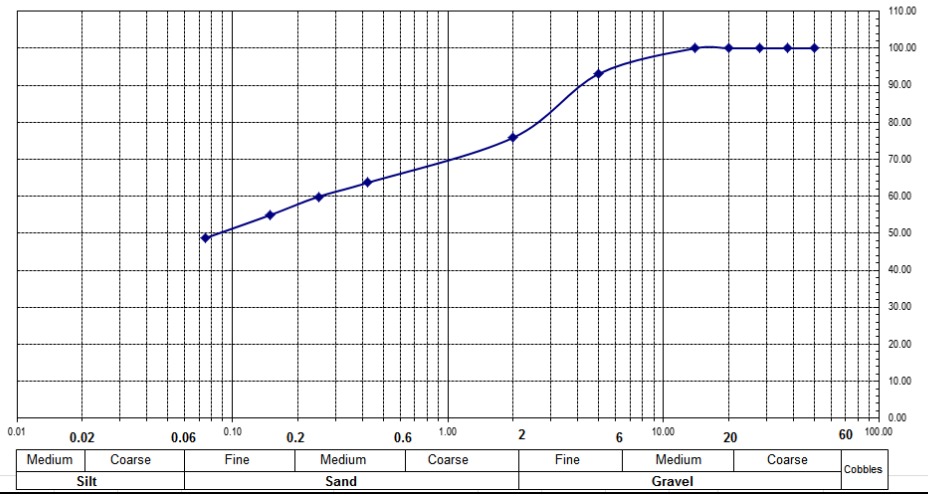
CLIENT:	United Nations Development Programme (UNDP)		
PROJECT:	Medical Store Limited's Regional Hubs-Mpika		
SUPERVISOR:	DL	DATE:	19/09/2016
OPERATOR	BZ	SAMPLE SOURCE:	SPT 3 (1.0 - 3.1m)
DATE OF SOAKING:	19/09/2016	Soil Description	Moist reddish brown yellowish soft gravelly sand-clay mixture (Residual)
DATE OF TESTING:	19/09/2016	Lab No.	3272

Initial Dry Mass (m_1) **1288.4** g

Sieve Opening (mm)	Mass Retained (g) Actual	Mass Retained (g) Corrected	% Retained (m)*100 / (m_1)	% Passing (p)	Cumulative % passing
75.0	0			100.0	100
63.0	0	0	0.0	100.0	100
50.0	0	0	0.0	100.0	100
37.5	0	0	0.0	100.0	100
28.0	0	0	0.0	100.0	100
20.0	0	0	0.0	100.0	100
Passing 20 mm (m_2)	1288.4	1288.4			
total (checked with m_1)	**1288.4**				
riffled (m_3)	316				
riffled and washed (m_4)	164.2				
Correction factor $\frac{m_2}{m_3}$		4.08			
14.0	0	0	0.0	100.0	100
5.0	21.8	89	6.9	93.1	93
2.0	54.6	223	17.3	75.8	76
0.425	38.3	156	12.1	63.7	64
0.250	12	49	3.8	59.9	60
0.150	15.6	64	4.9	55.0	55
0.075	19.7	80	6.2	48.7	49
<0.075 (+ 151.8	154	628	48.7		
TOTAL		1288.4			

Grading Modulus: GM = (300 -%<2mm-%<0.425mm-%<0.075mm)/100	1.1
Grading Coefficient: GC= (%<28.0-%<0.425) x (%<5.0mm)/100	33.8
USCS classification	SC

SIEVE SIZE BY LOG SCALE



WET SIEVE ANALYSIS — **FORM: SANS 3001-GR1: 2013**

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Lusaka, Zambia
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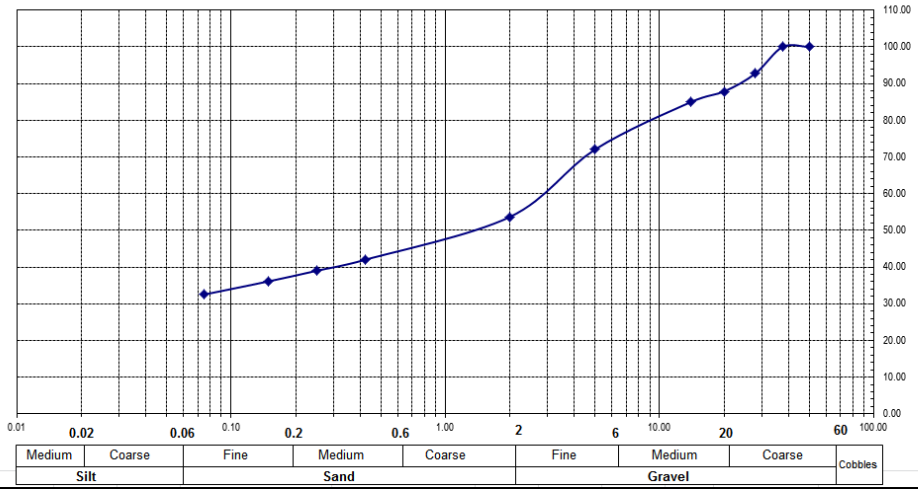
CLIENT:	United Nations Development Programme (UNDP)		
PROJECT:	Medical Store Limited's Regional Hubs-Mpika		
SUPERVISOR:	DL	DATE:	19/09/2016
OPERATOR	BZ	SAMPLE SOURCE:	SPT 4 (1.4 - 3.7m)
DATE OF SOAKING:	19/09/2016	Soil Description	Moist reddish brown yellowish firm gravelly clayey sand with fragments of sandstone and quartzitic stone (Residual)
DATE OF TESTING:	19/09/2016	Lab No.	3273

Initial Dry Mass (m_1) **3170.2** g

Sieve Opening (mm)	Mass Retained (g) Actual	Mass Retained (g) Corrected	% Retained (m)*100 / (m_1)	% Passing (p)	Cumulative % passing
75.0	0			100.0	100
63.0	0	0	0.0	100.0	100
50.0	0	0	0.0	100.0	100
37.5	0	0	0.0	100.0	100
28.0	229.4	229	7.2	92.8	93
20.0	155.7	156	4.9	87.9	88
Passing 20 mm (m_2)	2785.1	2785.1			
total (checked with m_1)	**3170.2**				
riffled (m_3)	716.5				
riffled and washed (m_4)	454.1				
Correction factor $\frac{m_2}{m_3}$		3.89			
14.0	23.4	91	2.9	85.0	85
5.0	105.2	409	12.9	72.1	72
2.0	150.1	583	18.4	53.7	54
0.425	94.8	368	11.6	42.1	42
0.250	25	97	3.1	39.0	39
0.150	23.2	90	2.8	36.1	36
0.075	29.4	114	3.6	32.5	33
<0.075 (+ 262.4	265.4	1032	32.5		
TOTAL		3170.2			

Grading Modulus: GM = (300 -%<2mm-%<0.425mm-%<0.075mm)/100	1.7
Grading Coefficient: GC= (%<28.0-%<0.425) x (%<5.0mm)/100	36.6
USCS classification	SC

SIEVE SIZE BY LOG SCALE



Appendix E - Atterberg Limit Results

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CONE PENETROMETER

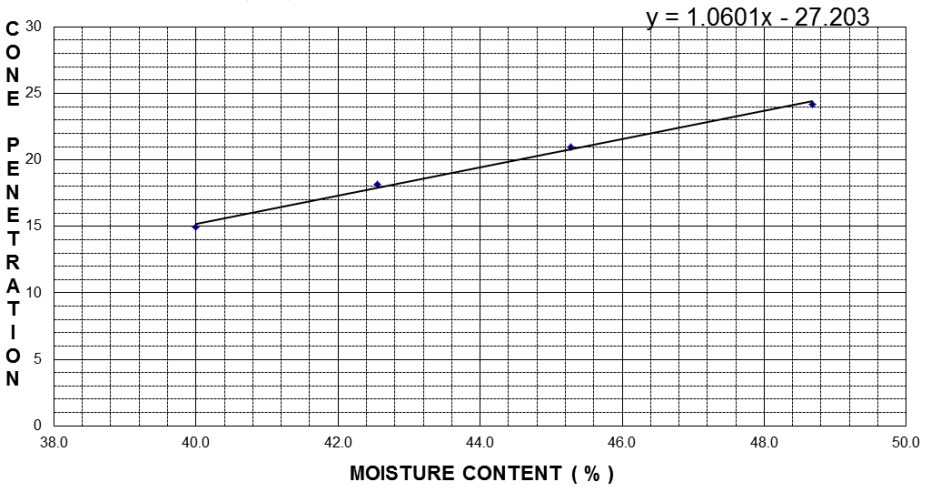
Liquid and Plastic Limits

Linear Shrinkage and Shrinkage Product

PROJECT :	Medical Store Limited's Regional Hubs-Mpika		DESCRPTN :	SPT1 (0 - 1.30m) Moist reddish brown soft sandy clay (Residual)	
CLIENT :	United Nations Development Programme (UNDP)		LAB No :	3270	DATE : 19/09/2016
RESPONSIBLE TECHNICIAN :	TK		CHECKED :	DL	APPROVED : SR

TEST METHOD — TESTS 1.2, 1.3 and 1.4 , ref. BS 1377 : Part 2 : 1990

		LIQUID LIMIT				PLASTIC LIMIT		
TEST NO.		1	2	3	4	1	2	Average
Initial gauge reading	mm	0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0			
Final gauge reading	mm	15.0 14.9	18.3 18.0	21.0 21.0	24.2 24.2			
Average penetration	mm	15.0	18.2	21.0	24.2			
Container Number		RNK37	RNK12	RNK4	RNK2	IV	J14	
Mass of wet soil & container	g	25.5	27.5	29.5	31.1	12.8	12.8	
Mass of dry soil & container	g	22.3	23.5	24.7	25.6	11.7	11.8	
Mass of container	g	14.3	14.1	14.1	14.3	7.2	7.5	
Mass of dry soil	g	8.0	9.4	10.6	11.3	4.5	4.3	
Mass of moisture	g	3.2	4.0	4.8	5.5	1.1	1.0	
Moisture content	%	40.0	42.6	45.3	48.7	24.4	23.3	23.9



Sample preparation :
a) As received
b) Airdried : ° C
c) Washed on 425 µm
d) Oven dried : ° C
e) Not known

Proportion passing on 425 µm sieve :		
93		
LIQUID LIMIT		
LL =	44.5	%
PLASTIC LIMIT		
PL =	23.9	%
PLASTICITY INDEX		
PI =	20.6	%

LINEAR SHRINKAGE and SHRINKAGE PRODUCT						
Specimen reference			1	2	3	4	5
Initial Length	L_0	mm	140				
Oven dried length	L_D	mm	127				
Linear Shrinkage, LS = 100* (1-(L_D/L_O))		%	9.29				
Shrinkage Product, SP = LS* % <425um			859.86				

1 of 1

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CONE PENETROMETER

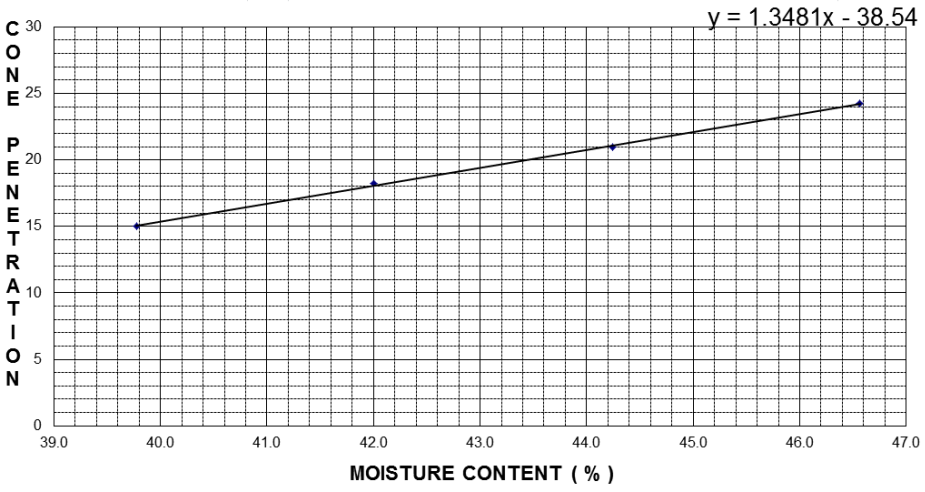
Liquid and Plastic Limits

Linear Shrinkage and Shrinkage Product

PROJECT :	Medical Store Limited's Regional Hubs-Mpika	DESCRPTN :	SPT1 (3.4 - 5.0m) Moist light reddish brown soft gravelly sandy clay (Residual)		
CLIENT :	United Nations Development Programme (UNDP)	LAB No :	3271	DATE :	20/09/2016
RESPONSIBLE TECHNICIAN :	TK	CHECKED :	DL	APPROVED :	SR

TEST METHOD — TESTS 1.2, 1.3 and 1.4 , ref. BS 1377 : Part 2 : 1990

		LIQUID LIMIT				PLASTIC LIMIT		
TEST NO.		1	2	3	4	1	2	Average
Initial gauge reading	mm	0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0			
Final gauge reading	mm	15.0 15.0	18.3 18.2	21.0 21.0	24.2 24.3			
Average penetration	mm	15.0	18.3	21.0	24.3			
Container Number		x	DOC9	127	AB6	DX	2B1	
Mass of wet soil & container	g	26.3	28.5	30.7	33.3	13.3	13.8	
Mass of dry soil & container	g	22.8	24.3	25.7	27.2	12.1	12.5	
Mass of container	g	14.0	14.3	14.4	14.1	7.4	7.2	
Mass of dry soil	g	8.8	10.0	11.3	13.1	4.7	5.3	
Mass of moisture	g	3.5	4.2	5.0	6.1	1.2	1.3	
Moisture content	%	39.8	42.0	44.2	46.6	25.5	24.5	25.0



Sample preparation :	
a) As received	
b) Airdried :	° C
c) Washed on 425 µm	
d) Oven dried :	° C
e) Not known	
Proportion passing on 425 µm sieve :	
63	
LIQUID LIMIT	
LL = 43.4	%
PLASTIC LIMIT	
PL = 25.0	%
PLASTICITY INDEX	
PI = 18.4	%

LINEAR SHRINKAGE and SHRINKAGE PRODUCT							
Specimen reference			1	2	3	4	5
Initial Length	L_0	mm	140				
Oven dried length	L_D	mm	132.7				
Linear Shrinkage, LS = 100* (1-(L_D/L_O))		%	5.21				
Shrinkage Product, SP = LS* % <425um			326.41				

1 of 1

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CONE PENETROMETER

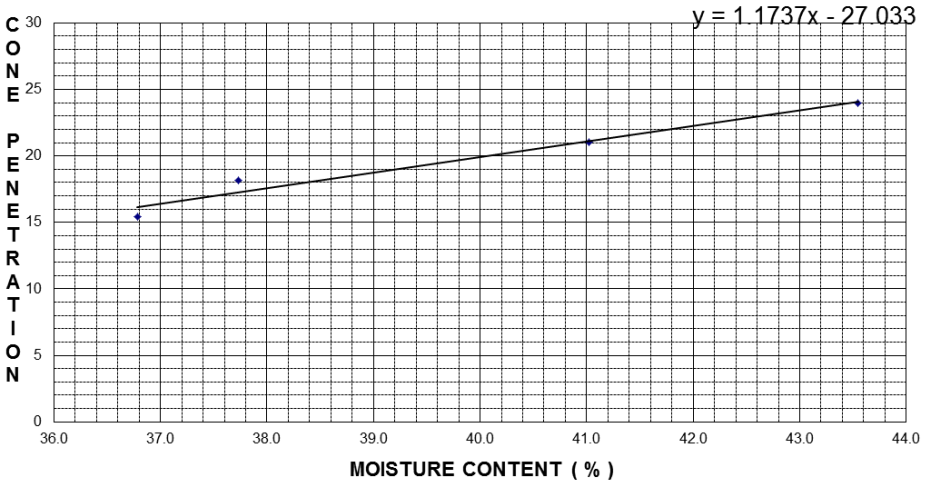
Liquid and Plastic Limits

Linear Shrinkage and Shrinkage Product

PROJECT :	Medical Store Limited's Regional Hubs-Mpika	DESCRPTN :	SPT3 (1.0 - 3.1m) Moist reddish brown yellowish soft gravelly sand-clay mixture (Residual)		
CLIENT :	United Nations Development Programme (UNDP)	LAB No :	3272	DATE :	20/09/2016
RESPONSIBLE TECHNICIAN :	TK	CHECKED :	DL	APPROVED :	SR

TEST METHOD — TESTS 1.2, 1.3 and 1.4 , ref. BS 1377 : Part 2 : 1990

		LIQUID LIMIT				PLASTIC LIMIT		
TEST NO.		1	2	3	4	1	2	Average
Initial gauge reading	mm	0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0			
Final gauge reading	mm	15.6 15.2	18.1 18.2	21.0 21.1	24.0 24.0			
Average penetration	mm	15.4	18.2	21.1	24.0			
Container Number		JK1	RNK4	SN2	RNK2	J14	IV	
Mass of wet soil & container	g	26.2	28.7	30.4	32.1	12.3	12.5	
Mass of dry soil & container	g	23.0	24.7	25.6	26.7	11.43	11.5	
Mass of container	g	14.3	14.1	13.9	14.3	7.5	7.2	
Mass of dry soil	g	8.7	10.6	11.7	12.4	3.9	4.3	
Mass of moisture	g	3.2	4.0	4.8	5.4	0.9	1.0	
Moisture content	%	36.8	37.7	41.0	43.5	22.1	23.3	22.7



Sample preparation :	
a) As received	
b) Airdried :	° C
c) Washed on 425 µm	
d) Oven dried :	° C
e) Not known	

Proportion passing on 425 µm sieve :		
64		
LIQUID LIMIT		
LL =	40.0	%
PLASTIC LIMIT		
PL =	22.7	%
PLASTICITY INDEX		
PI =	17.3	%

LINEAR SHRINKAGE and SHRINKAGE PRODUCT							
Specimen reference			1	2	3	4	5
Initial Length	L_0	mm	140				
Oven dried length	L_D	mm	132.7				
Linear Shrinkage, LS = 100* (1-(L_D/L_O))		%	5.21				
Shrinkage Product, SP = LS* % <425um			332.15				

1 of 1

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CONE PENETROMETER

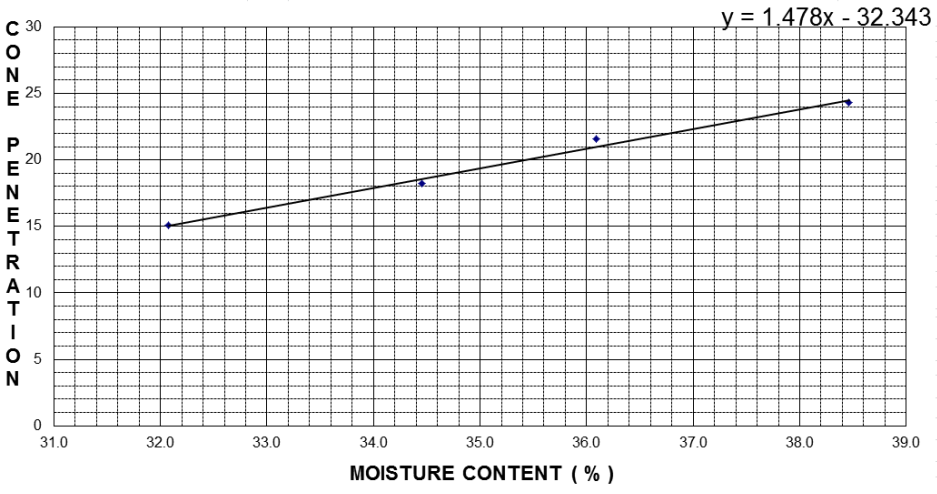
Liquid and Plastic Limits

Linear Shrinkage and Shrinkage Product

PROJECT :	Medical Store Limited's Regional Hubs-Mpika	DESCRPTN :	SPT4 (1.4 - 3.7m) Moist reddish brown yellowish firm gravelly clayey sand with fragments of sandstone and quartzitic stone (Residual)		
CLIENT :	United Nations Development Programme (UNDP)	LAB No :	3273	DATE :	20/09/2016
RESPONSIBLE TECHNICIAN :	TK	CHECKED :	DL	APPROVED :	SR

TEST METHOD — TESTS 1.2, 1.3 and 1.4 , ref. BS 1377 : Part 2 : 1990

		LIQUID LIMIT				PLASTIC LIMIT		
TEST NO.		1	2	3	4	1	2	Average
Initial gauge reading	mm	0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0			
Final gauge reading	mm	15.0 15.2	18.3 18.1	21.6 21.5	24.3 24.3			
Average penetration	mm	15.1	18.2	21.6	24.3			
Container Number		RK4	RNK12	MG1	RNK37	TAO	LB	
Mass of wet soil & container	g	28.3	30.1	32.4	34.1	13	12.7	
Mass of dry soil & container	g	24.9	26.0	27.6	28.6	12.1	11.8	
Mass of container	g	14.3	14.1	14.3	14.3	7.2	7.1	
Mass of dry soil	g	10.6	11.9	13.3	14.3	4.9	4.7	
Mass of moisture	g	3.4	4.1	4.8	5.5	0.9	0.9	
Moisture content	%	32.1	34.5	36.1	38.5	18.4	19.1	18.8



Sample preparation :	
a) As received	
b) Airdried :	° C
c) Washed on 425 µm	
d) Oven dried :	° C
e) Not known	
Proportion passing on 425 µm sieve :	
42	
LIQUID LIMIT	
LL = 35.4	%
PLASTIC LIMIT	
PL = 18.8	%
PLASTICITY INDEX	
PI = 16.6	%

LINEAR SHRINKAGE and SHRINKAGE PRODUCT							
Specimen reference			1	2	3	4	5
Initial Length	L_0	mm	140				
Oven dried length	L_D	mm	131.6				
Linear Shrinkage, LS = 100* (1-(L_D/L_O))		%	6.00				
Shrinkage Product, SP = LS* % <425um			252.60				

1 of 1

Appendix F – Moisture Content Results

MOISTURE CONTENT		FORM M1
CLIENT:	United Nations Development Programme (UNDP)	
PROJECT:	Medical Store Limited's Regional Hubs-Mpika	
TECHNICIAN:	TK	DATE 16/09/2016
SAMPLE SOURCE:	SPT1 (0 - 1.3m) Moist reddish brown soft sandy clay (Residual)	
	Lab # 3270	

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TEST ref: BS 1377: Part 2 : 1990

Container Number	K9	AB6	H
Mass of wet soil & container (g) (m_2)	42.1	49.0	50.3
Mass of dry soil & container (g) (m_3)	37.5	43.3	44.4
Mass of container (g) (m_1)	14.0	14.1	14.1
Mass of dry soil (g) (m_3 - m_1)	23.4	29.2	30.4
Mass of moisture (g) (m_2 - m_3)	4.6	5.8	5.9
Moisture content (%)	19.8%	19.8%	19.5%
AVERAGE	19.7%		

CHECKED BY: DL

DATE: DATE 16/09/2016

MOISTURE CONTENT		FORM M1
CLIENT:	United Nations Development Programme (UNDP)	
PROJECT:	Medical Store Limited's Regional Hubs-Mpika	
TECHNICIAN:	TK	DATE 17/09/2016

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SAMPLE SOURCE:	SPT2 (3.4 - 5.0m) Moist light reddish brown soft gravelly sandy clay (Residual)
	Lab # 3271

TEST ref: BS 1377: Part 2 : 1990

Container Number	RK15	K13	BBB
Mass of wet soil & container (g) (m_2)	61.8	48.6	52.9
Mass of dry soil & container (g) (m_3)	55.5	44.1	48.4
Mass of container (g) (m_1)	14.2	13.9	14.0
Mass of dry soil (g) (m_3 - m_1)	41.2	30.2	34.4
Mass of moisture (g) (m_2 - m_3)	6.4	4.5	4.5
Moisture content (%)	15.4%	14.8%	13.2%
AVERAGE	14.5%		

CHECKED BY:	DL
DATE:	DATE 17/09/2016

MOISTURE CONTENT			FORM M1					
CLIENT:	United Nations Development Programme (UNDP)							
PROJECT:	Medical Store Limited's Regional Hubs-Mpika							
TECHNICIAN:	TK		DATE 16/09/2016					
SAMPLE SOURCE:	SPT3 (1.0 - 3.1m) Moist reddish brown yellowish soft gravelly sand-clay mixture (Residual)							
	Lab # 3272							
TEST ref: BS 1377: Part 2 : 1990								
Container Number		F06	RNK32	RK2				
Mass of wet soil & container (g) (m_2)		69.1	60.1	46.4				
Mass of dry soil & container (g) (m_3)		60.7	53.0	41.4				
Mass of container (g) (m_1)		13.8	14.4	14.3				
Mass of dry soil (g) (m_3 - m_1)		46.9	38.6	27.1				
Mass of moisture (g) (m_2 - m_3)		8.4	7.1	5.0				
Moisture content (%)		18.0%	18.3%	18.3%				
AVERAGE		18.2%						
CHECKED BY:	DL							
DATE:	DATE 16/09/2016							

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MOISTURE CONTENT		FORM M1
CLIENT:	United Nations Development Programme (UNDP)	
PROJECT:	Medical Store Limited's Regional Hubs-Mpika	
TECHNICIAN:	TK	DATE 16/09/2016
SAMPLE SOURCE:	SPT4 (1.4 - 3.7m) Moist reddish brown yellowish firm gravelly clayey sand with fragments of sandstone and quartzitic stone (Residual)	
	Lab # 3273	

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TEST ref: BS 1377: Part 2 : 1990

Container Number	F4	A2	100
Mass of wet soil & container (g) (m_2)	87.5	76.1	77.5
Mass of dry soil & container (g) (m_3)	78.8	69.1	69.7
Mass of container (g) (m_1)	14.1	13.9	14.2
Mass of dry soil (g) (m_3 - m_1)	64.6	55.2	55.5
Mass of moisture (g) (m_2 - m_3)	8.8	6.9	7.8
Moisture content (%)	13.6%	12.6%	14.1%
AVERAGE	13.4%		

CHECKED BY:	DL
DATE:	DATE 16/09/2016

Appendix G – MDD Test Results

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Working Sheet

Compaction Test

Compaction Test, Test Method CML 1.9
Ref. BS1377:Part4:1990

LAB No. 3269

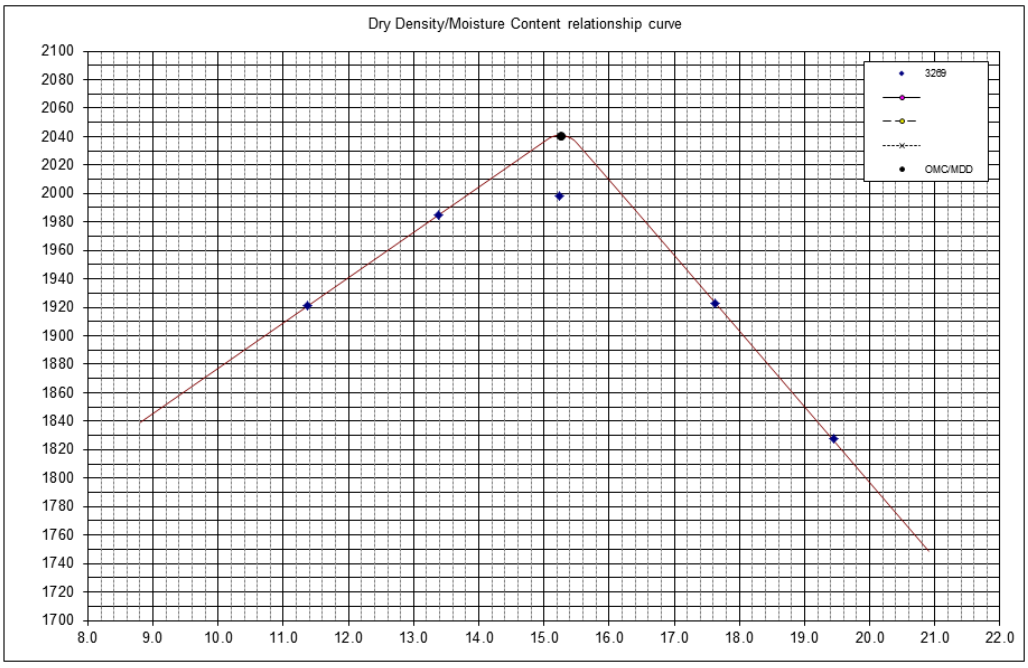
Client UNDP **Project:** Medical Store Limited's Regional Hubs-Mpika

Date Sampled: 13/9/2016 **Sampled By:** **Sample Description:** Moist reddish brown sandy clay (Residual)

Sample St.: **Offset from ¢ (m):** **Lane:** **Work Area:** 0.8-3.0m **Source:** TP1

Compaction type:

Mould no.	30		Mass		4866 g		Volume	2305	(m^3)		
WATER ADDED			0	2	4	6	8				
Weight of mould + sample		g	9798.0	10054.0	10174.0	10079.0	9898.0				
Weight of sample		g	4932.0	5188.0	5308.0	5213.0	5032.0				
Wet Density		kg/m^3	2140	2251	2303	2262	2183.1				
Dry Density		kg/m^3	1921	1985	1998	1923	1828				
Factor of mould:											
Moisture Container no.			OM39	OM22	OM8	OM14	OM38				
Weight of wet soil+ container		g	655	699	690	674	652				
Weight of dried soil + container		g	607	638	626	600	575				
Weight of container		g	185	182	206	180	179				
Weight of dry soil		g	422.0	456.0	420.0	420.0	396.0				
Moisture Content		%	11.4	13.4	15.2	17.6	19.4				



Optimum Moisture Content:	**OMC**	15.3	%
Maximum Dry Density:	**MDD**	2041	kg/m^3

Remarks:

For the Engineers

	Signature	Date
Checked by	DL	16/9/2016
Approved by	SR	16/9/2016

Appendix H – CBR Test Results

Rankin Engineering

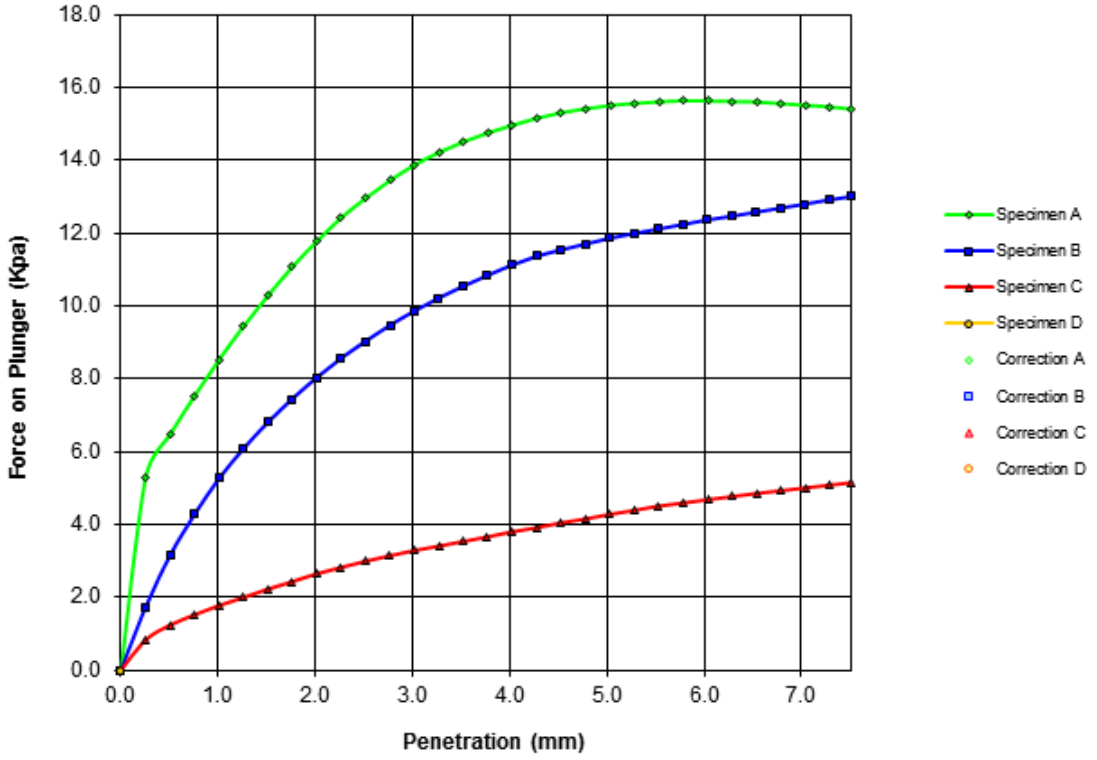
California Bearing Ratio Test Report

Date 26/09/2016 — Checked By DL

Date 26/09/2016 — Computed By CM

Tested By CM

Load Penetration Curve



CBR Results

Results	A	B	C	
2.54 mm Pen.	98.1	68.3	22.6	
5.08 mm Pen.	77.5	59.3	21.4	
Moisture (%)	15.07	15.27	15.28	%Swell 0.1
Density (g/cm3)	1.844	2.006	1.809	
%Compaction	90.37	98.27	88.65	

Project Information

Project Num				Sample Location	
Project	Mpika UNDP			Specimen A	TP1(0.8 - 3.0m)
Date				Specimen B	TP1(0.8 - 3.0m)
Client	United Nations Development Programme (UNDP)			Specimen C	TP1(0.8 - 3.0m)
				Specimen D	TP1(0.8 - 3.0m)
				Test Variables	
Job Ref.				Liquid Limit:	-
Sample Num.	Lab#3269			Plastic Limit:	-
Remarks	%Compaction	93	95	98	
	%CBR	88	81	-	