

TRANSALLOYS, EMALAHLENI

GEOTECHNICAL INVESTIGATION FINAL REPORT



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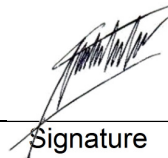
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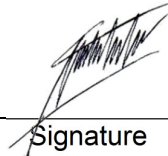
12 December 2016

Date

Approved by :

J van Tonder

Initials & Surname



Signature

12 December 2016

Date

TRANSALLOYS, EMALAHLENI

GEOTECHNICAL INVESTIGATION FINAL REPORT

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TRANSALLOYS, EMALAHLENI

GEOTECHNICAL INVESTIGATION FINAL REPORT

1. INTRODUCTION

Knight Piésold Consulting (KP) was appointed by Transalloys to conduct a geotechnical investigation to identify possible borrow pit areas, from which suitable cover and capping material may be obtained. A large quantity of capping material is required for a proposed slag dump for its rehabilitation.

The geotechnical investigation was conducted to identify areas that are underlain by cohesive (clayey or silty) soils to delineate potential borrow pit areas. This report provides the results of the geotechnical investigation and the evaluation of the results.

2. GEOLOGY & SITE DESCRIPTION

Transalloys' silicomanganese plant is located approximately 2km south of the N4 highway, 10km west of eMalahleni (refer to Figure 1 for the site locality). The Brugspruit River (a tributary of the Olifants River) flows on the eastern part of the terrain in a northern direction. The investigated area for borrow pits (from here-on referred to as the "site") is located east of the plant infrastructure towards the river.

The landscape is undulating with rolling hills and valleys typical of Mpumalanga, with regional drainage taking place by means of sheetwash towards the river. A regional low point occurs in the valley at the river and the terrain climbs steeply towards the east and west on either side of the river, with an elevation difference of 35m.

According to the published geological map of the area (2628 East Rand), the site is underlain by shale, sandstone, gritstone, and conglomerate of the Ecca Formation, Karoo Supergroup. Refer to Figure 2 for a geological map of the area. These formations are often interlayered between themselves, exposing successions of stratigraphy along the slopes. Large quartzitic sandstone outcrops were observed directly west of the river.

The vegetation on site generally comprises Savannah Grassland, while trees and shrubs are limited to the river area.

According to Weinert's climatic N-value, the site falls in an area classified as N<5 where the predominant weathering mode is chemical alteration as opposed to mechanical disintegration. Chemical alteration in deeply weathered residual shale soil profiles would generally contain high fines content as opposed to weathering in sandstone soil profiles.

3. METHOD OF INVESTIGATION

The fieldwork was conducted on 29 September 2016 and comprised the excavation of twelve test pits (TP1 to TP12) with a Tractor Loaded Backhoe (TLB).

The test pits were profiled by an engineering geologist according to the recommended standard procedures. The soil profile logs are provided in Appendix A.

Representative soil samples were taken from selected soil horizons and submitted to *Geostrada* to determine soil particle size distribution, Atterberg Limits and its density and permeability characteristics. The laboratory test results will be provided in the final letter report.

The positions of the test pits were recorded with a handheld GPS (accuracy of 5m) with coordinates provided on each soil profile, in WGS84 datum, South African grid.

4. SOIL PROFILE RESULTS

Figure 3 indicates the positions of the test pits excavated, while the results of the soil profiles are summarised in Table 1. The test pit logs are contained in Appendix A. The typical soil profile is described as follows.

- Fill material occurs at TP1 from surface to a depth of 2,3m, which was possibly excavated from a local nearby source. The fill material comprises clayey sand and is underlain by residual sandstone.
- The remainder of the site is covered by a thin topsoil horizon or colluvial soil. The colluvial soil consists of clayey sand or clayey gravelly sand that varies in thickness of between 0,3m to 2,7m. It appears that the variation in thickness corresponds with the topography, where areas located at higher elevations is covered by thick colluvial soils, while at the low-level areas the colluvium is relatively thin.
- The colluvium is either underlain by residual sandstone or by residual shale. The residual sandstone comprises a coarse-grained soil and extends to a depth of between 0,5m and more than 2,3m, where excavation was stopped on soft rock sandstone bedrock.
- The residual shale, especially in the areas of TP4 and TP10 to TP12, comprises predominantly fine-grained material. The total thickness of the residual shale is unknown, since the TLB stopped excavation at its maximum reach before encountering refusal on bedrock.
- No groundwater seepage was encountered in any of the test pits.

5. LABORATORY RESULTS

The detailed results of the geotechnical laboratory tests are provided in Appendix B and are summarised in Table 2. The Laboratory test results classify the soils as follows:

- Residual sandstone comprises gravelly sand with a low fines content and has a Grading Modulus (GM) of 1,6.
- Colluvial soil varies from medium-grained to coarse-grained, where the GM varies between 1 and 2. At TP9 the clay content varies from 5% to 20% between the upper and lower horizons. At TP4 the colluvium has a clay content of 11%.
- Residual shale at TP4 comprises 90% fines with a clay content of 25%. The soil has a grading modulus of 0,1.

Standard Proctor compaction tests on the colluvial soil yielded a maximum dry density of 2132 kg/m³ with an optimum moisture content of 8%. Falling head permeability tests were conducted on samples compacted to 95% of Proctor compaction yielded a coefficient of permeability (k-value) of 3,7 x 10⁻⁶ cm/s.

The residual shale soil has a maximum dry density of 1652kg/m³ with an optimum moisture content of 14%. The residual shale has a coefficient of permeability of 1 x 10⁻⁶ cm/s.

6. GEOTECHNICAL EVALUATION

The capping material required for the installation of cover at the slag dumps, requires a fine-grained impermeable soil to prohibit the flow of surface water into the dump.

The results of the investigation indicate that three types of soil are present on the site, which includes the following:

- Colluvial soil that varies from a fine- to coarse-grained.
- Residual sandstone soil that is coarse-grained and has a variable distribution and thickness and;
- Residual shale that comprises a fine-grained material with a low coefficient of permeability.

It is evident that the residual shale soil is suitable to utilize for the capping material. The residual shale is predominantly present at the area delineated by test pits TP4 and TP10 to TP12. Colluvium covers the area to depths of between 1m and 2,4m, which should be removed. The variation in the colluvium indicates that the material should rather be discarded since the variability in the clay content provides variable permeability characteristics of the soil.

The area delineated by these test pits has an approximate size of 25 000m², where the residual shale is generally thicker than 2m and should be able to produce a volume of at least 50 000m³.

TABLE 1: SUMMARY OF SOIL PROFILES

Test Pit No	Total Depth	Depths of Layers (m) – (m)					
		Soils					Rock
		Topsoil	Fill	Colluvium	Residual Shale	Residual Sandstone	Soft Rock Sandstone
TP1	2,3	–	0,0 – 2,3	–		2,3+	–
TP2	1,9	–	–	0 – 1,9	–	1,9+	–
TP3	1,8	–	–	0 – 1,5	–	1,5 – 1,8	1,8 + R
TP4	3,0	–	–	0 – 2,0	2,0 – 3,0+	–	–
TP5	0,5	–	–	0 – 0,3	–	0,3 – 0,5	0,5 + R
TP6	0,5	–	–	0 – 0,5	–	–	0,5 + R
TP7	1,6	0 – 0,1	–	0,1 – 0,8	–	0,8 – 1,6	1,6 + R
TP8	1,2	–	–	0 – 0,3	–	0,3 – 1,2	1,2 + R
TP9	3,1	0 – 0,3	–	0,3 – 2,7	2,7 – 3,1+	–	–
TP10	3,0	0 – 0,1	–	0,1 – 2,2	2,2 – 3,0+	–	–
TP11	3,0	0 – 0,3	–	0,3 – 2,4	2,4 – 3,0+	–	–
TP12	3,0	0 – 0,1	–	0,1 – 1,8	1,8 – 3,0+	–	–

R Denotes Refusal

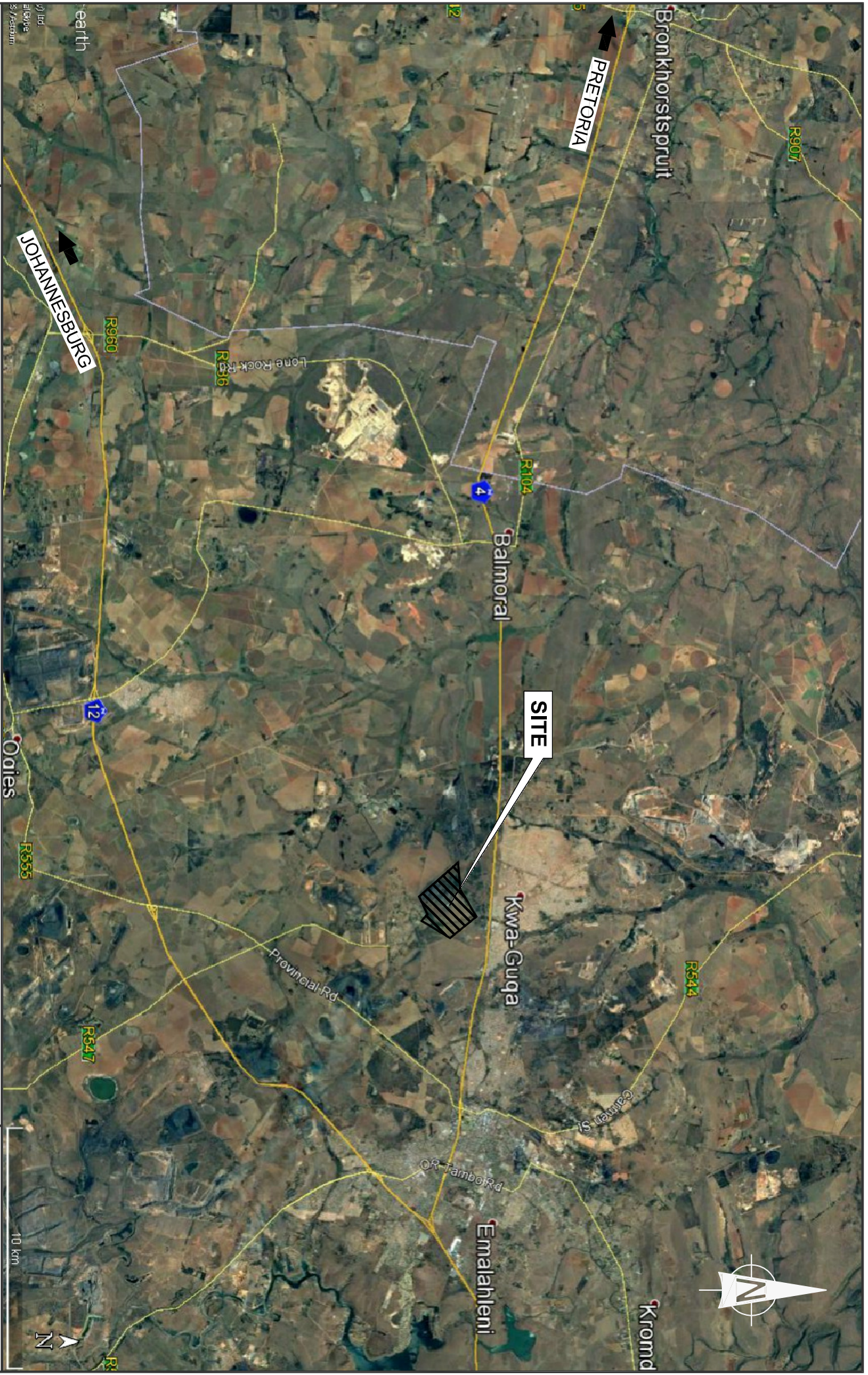
TABLE 2 : SUMMARY OF LABORATORY TEST RESULTS

Sample		Grading %				Atterberg Limits %			GM	PE	USC	Std. Proctor Compaction		Falling Head Permeability (k-value) (cm/s)	Material
No.	Depth (m - m)	Gravel	Sand	Silt	Clay	LL	PI	LS				MDD (kg/m ³)	OMC (%)		
TP3/1	1,5 - 1,7	31	47	13	9	22	9	4.5	1.55	Low	SC	-	-	-	Residual Sandstone
TP4/1 + TP4/2	0,4 - 2,0	39	41	9	11	22	12	5.0	1.69	Low	SC	2132	8	3,7 x 10 ⁻⁶	Colluvium
TP4/3 + TP4/4	2,0 - 3,0	1	10	64	25	42	17	7.5	0.1	Medium	CL	1652	14	1 x 10 ⁻⁶	Residual Shale
TP9/1	0,3 - 1,4	51	36	8	5	21	10	5.0	1.99	Low	SC	-	-	-	Colluvium
TP9/2	1,4 - 2,7	19	41	20	20	32	16	7.0	1.03	Low	SC	-	-	-	Colluvium

ABBREVIATION

LL	:	Liquid Limit	OMC	:	Optimum Moisture Content
PI	:	Plasticity Index	PE	:	Potential Expansiveness
LS	:	Linear Shrinkage	CL	:	Clayey soils with low to medium plasticity
USC	:	Unified Soil Classification	SC	:	Clayey sands – poorly graded
GM	:	Grading Modulus	MDD	:	Maximum Dry Density

FIGURES

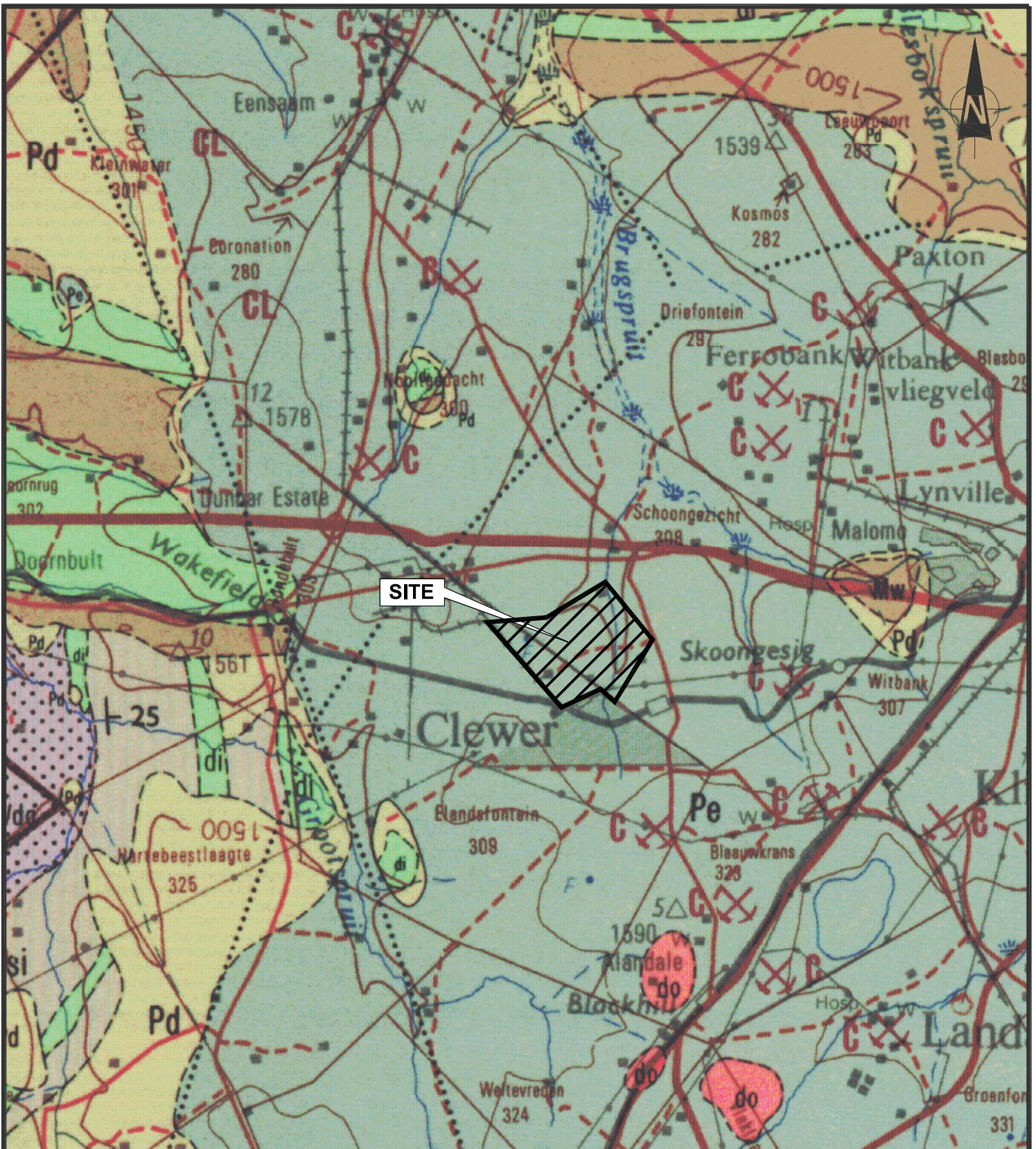


Knight Piésold
CONSULTING

TRANSALLOYS, MIDDELBURG
GEOTECHNICAL INVESTIGATION
LOCALITY PLAN

PROJECT NO: 30200047/04
FIGURE NO 1
SCALE N.T.S.

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GEOLOGICAL LEGEND:

- d : Dolerite of the Waterberg Group.
- Pe : Shale, shaly sandstone, grit, sandstone, conglomerate and coal of the Ecca Formation, Karoo Supergroup.
- Pd : Tillite and shale of the Dwyka Formation, Karoo Supergroup.
- Mw : Sandstone, quartzitic in places, conglomerate of the Wilgerivier Formation, Waterberg Group.
- Vsi : Shale, carbonaceous in places of the Silverton Formation, Pretoria Group.

REFERENCE MAP
 1:250 000 SCALE
 GEOLOGICAL SERIES
 SHEET: 2528 PRETORIA
 NOT TO ORIGINAL SCALE

Knight Piésold
 CONSULTING

**TRANSALLOYS, MIDDELBURG
 GEOTECHNICAL INVESTIGATION**

GEOLOGY MAP

PROJECT NO: 30200047/04
 FIGURE NO 2
 SCALE N.T.S.

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LEGEND
TEST PITS
TP1



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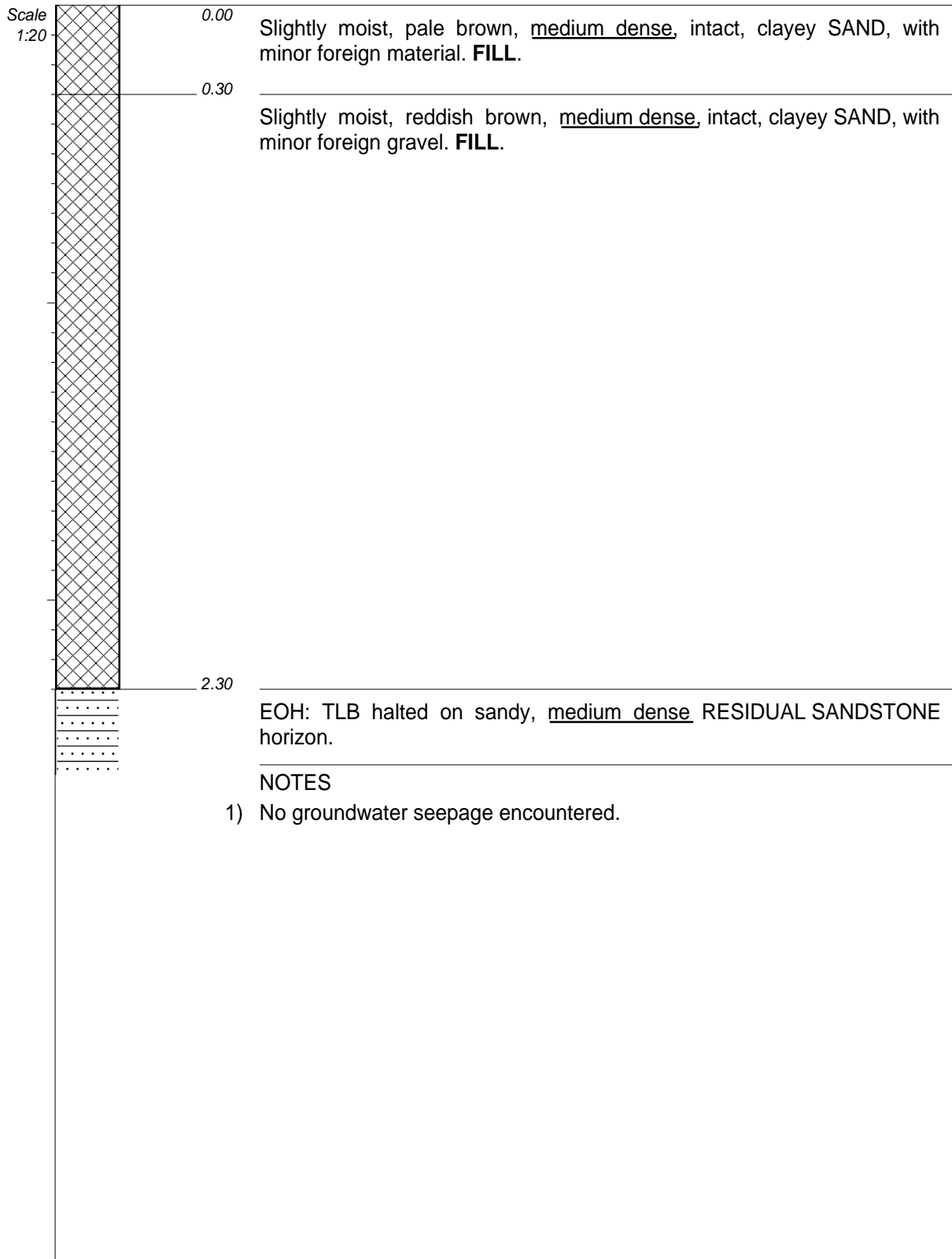
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**TRANSALLOYS, MIDDLEBURG
GEOTECHNICAL INVESTIGATION
SITE LAYOUT WITH TEST PIT POSITIONS**

PROJECT NO: 30200047/04
FIGURE NO 3
SCALE N.T.S.

APPENDIX A

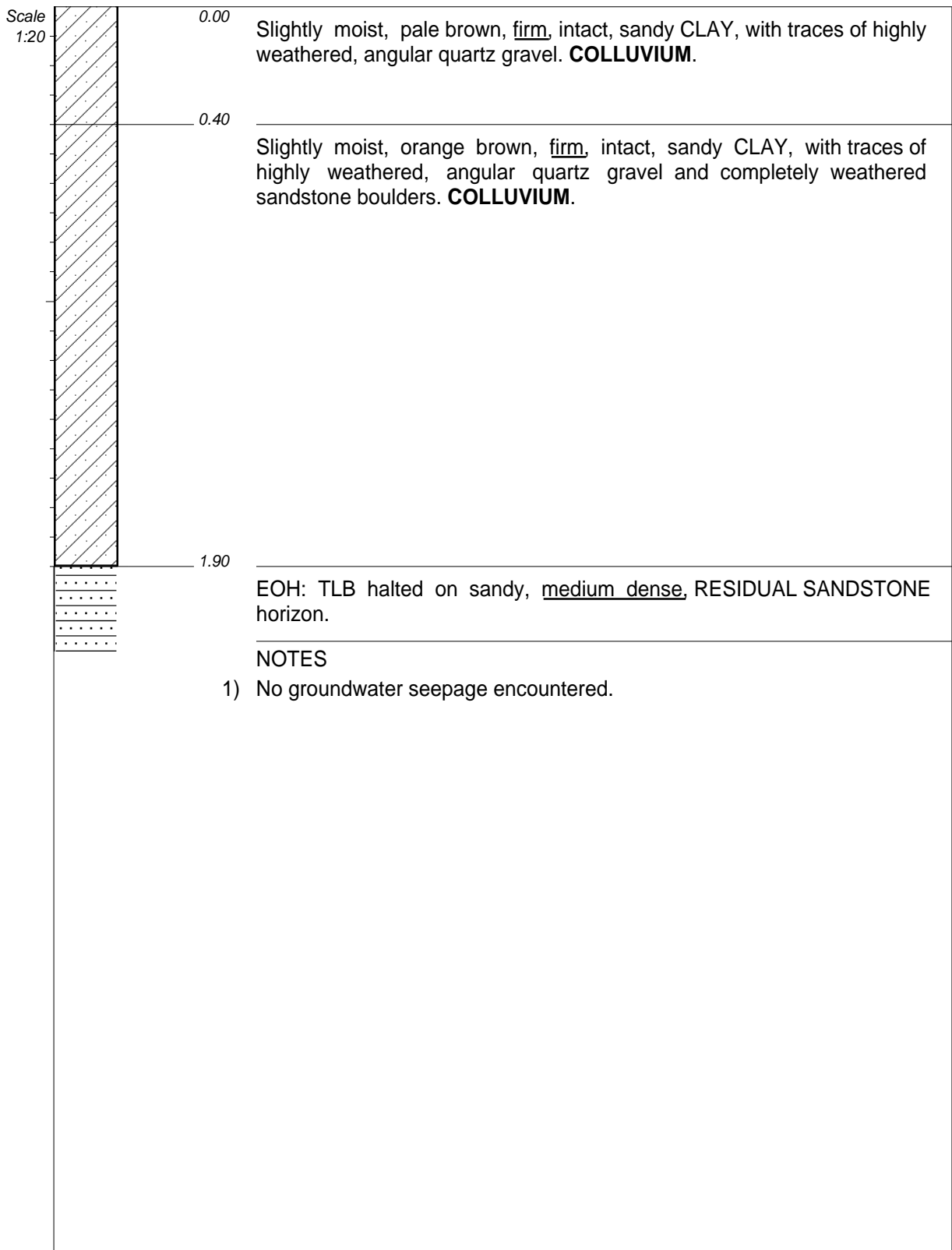
SOIL PROFILE LOGS



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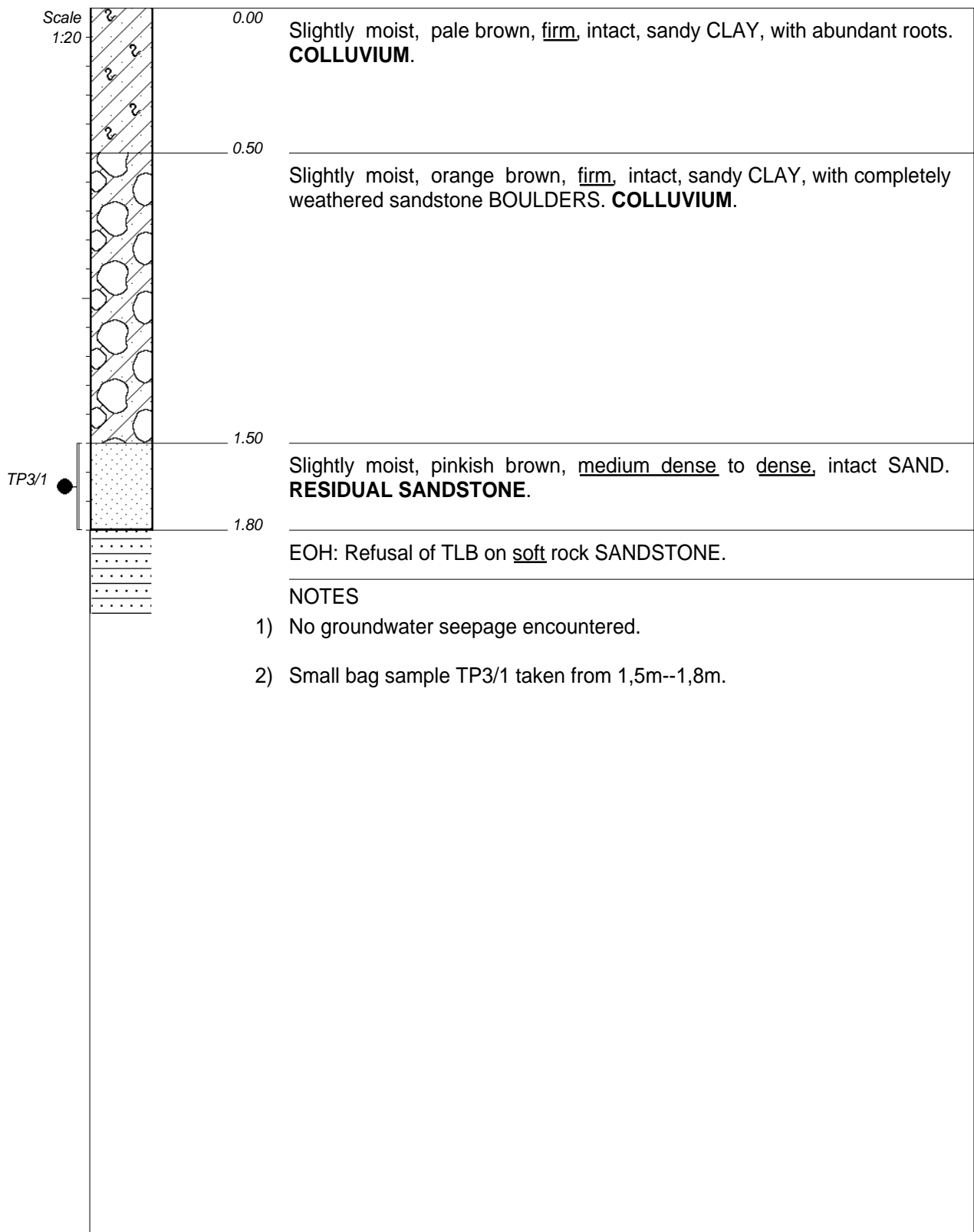
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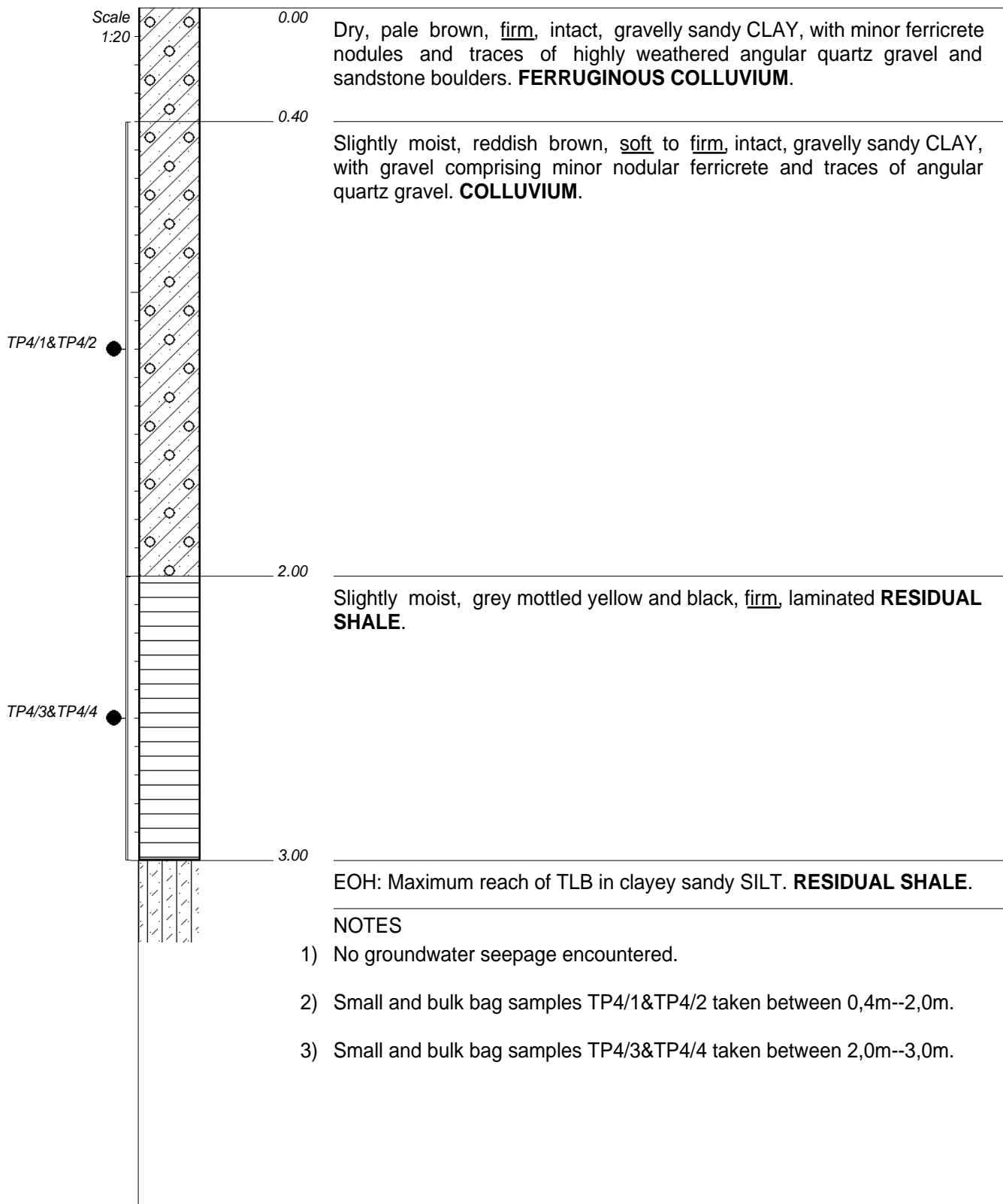
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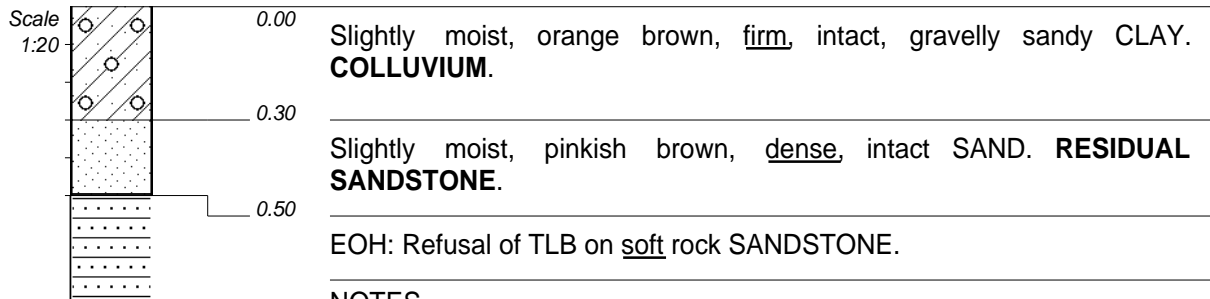
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NOTES

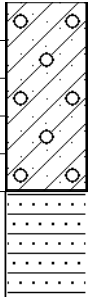
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Scale
1:20



0.00

Slightly moist, orange brown, firm, intact gravelly sandy CLAY.
COLLUVIUM.

0.50

EOH: Slightly weathered, soft rock quartzitic SANDSTONE.

NOTES

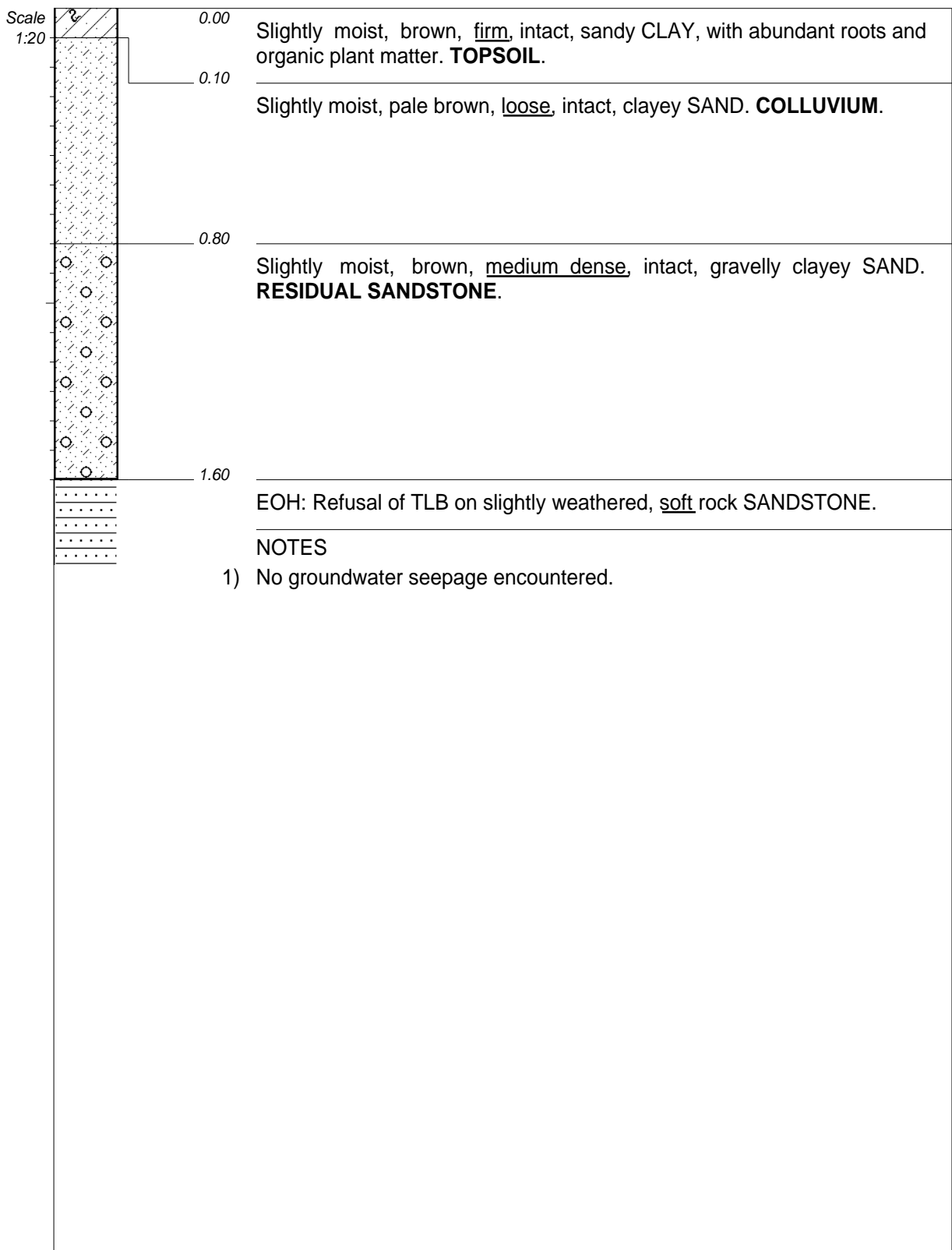
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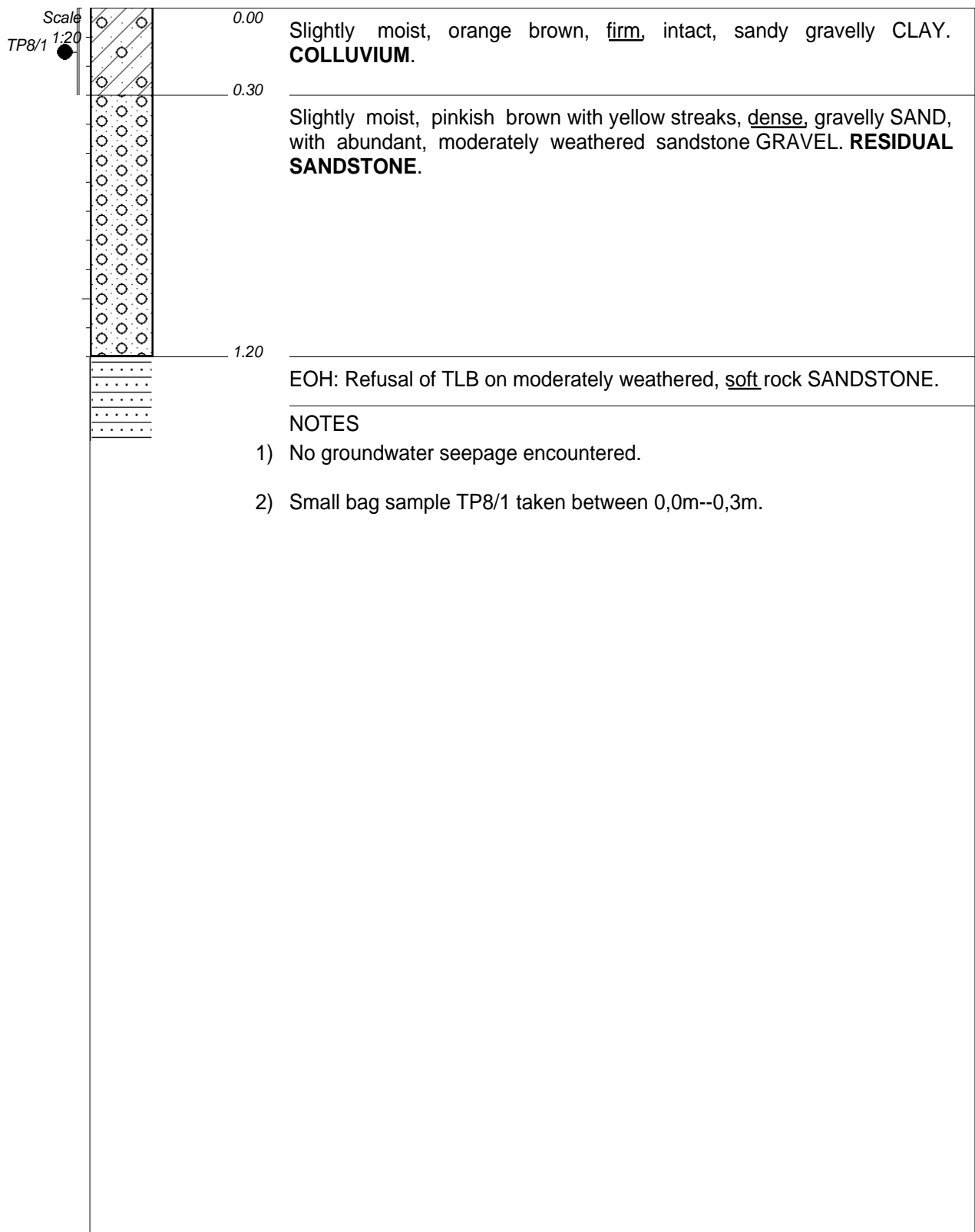
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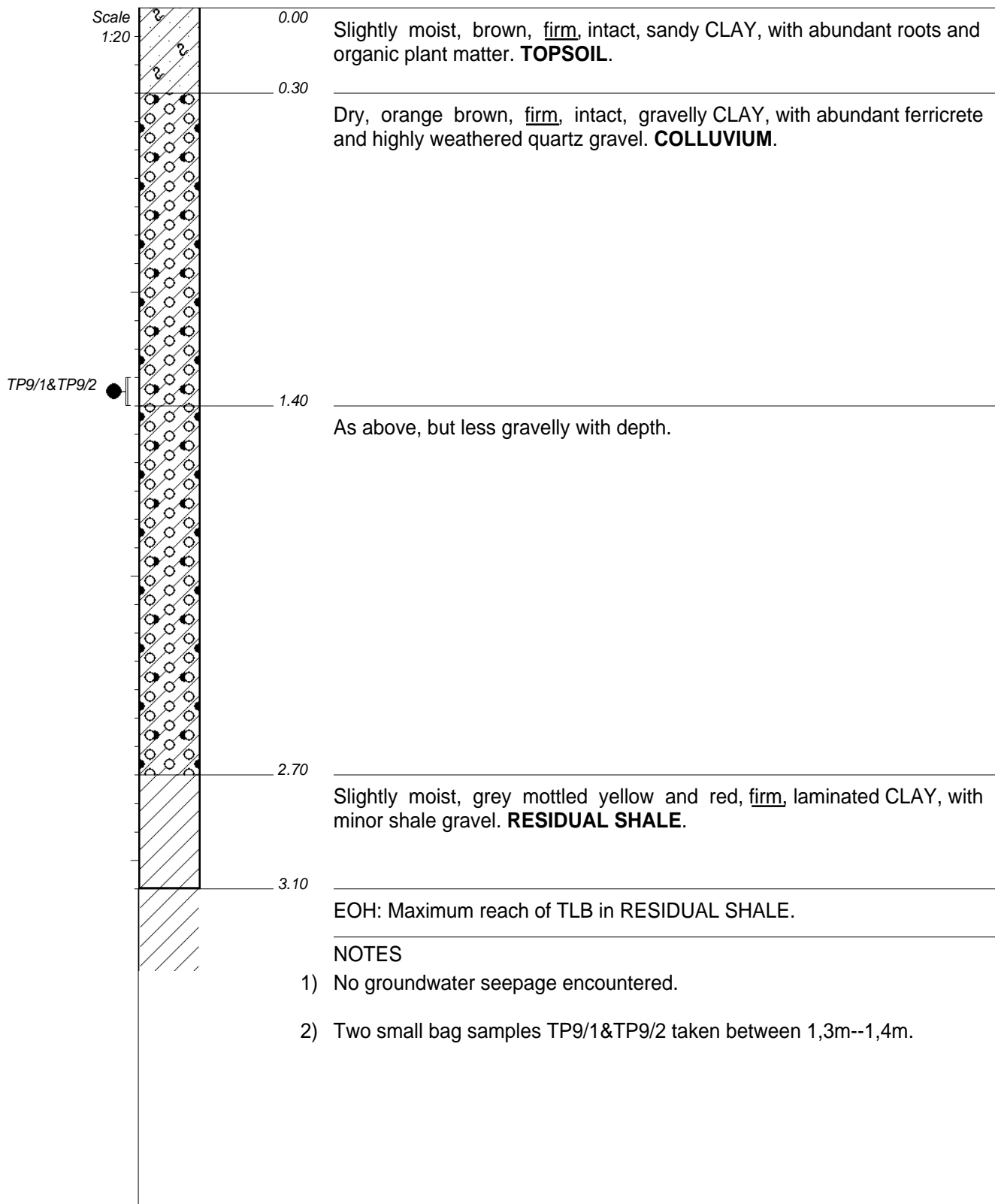
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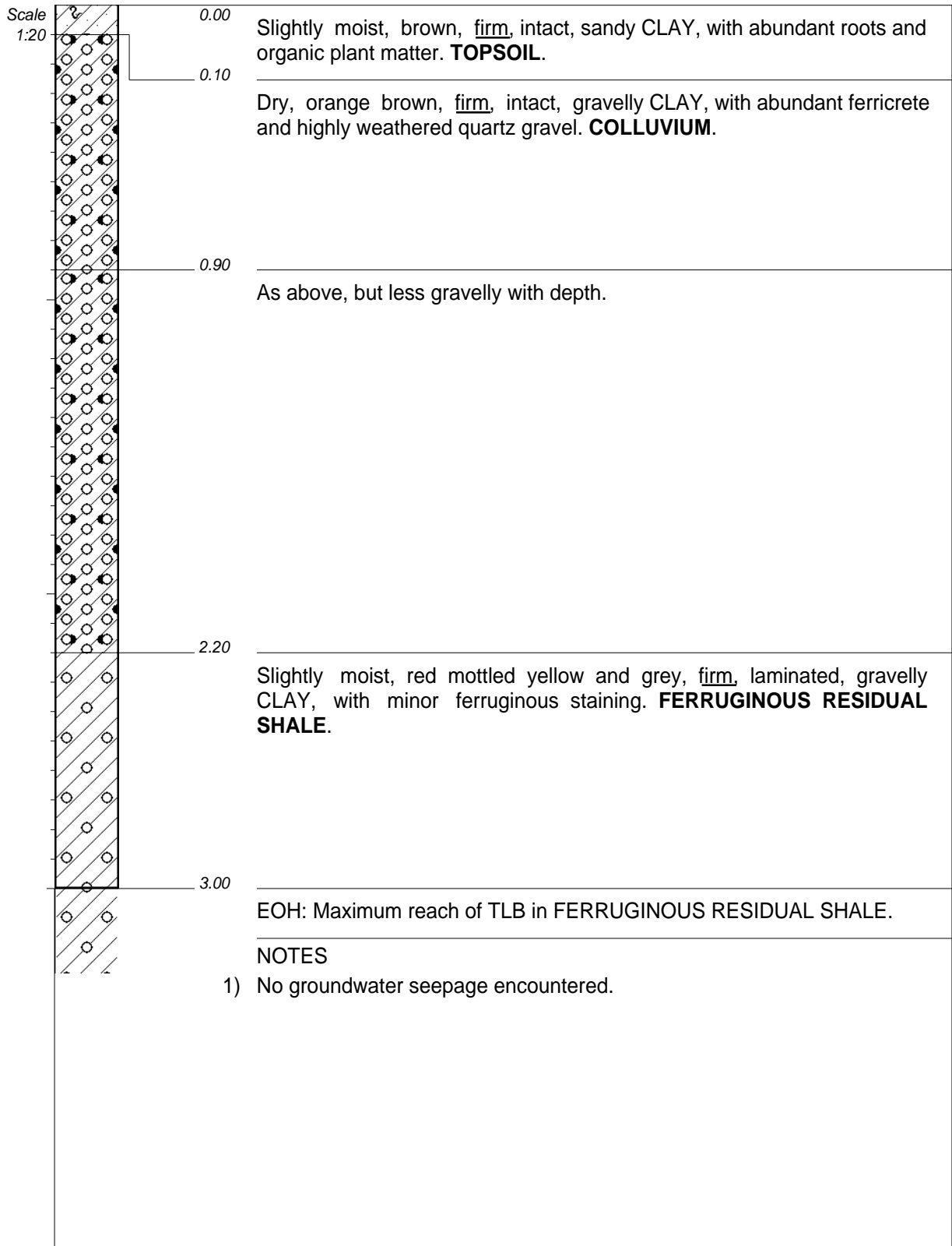


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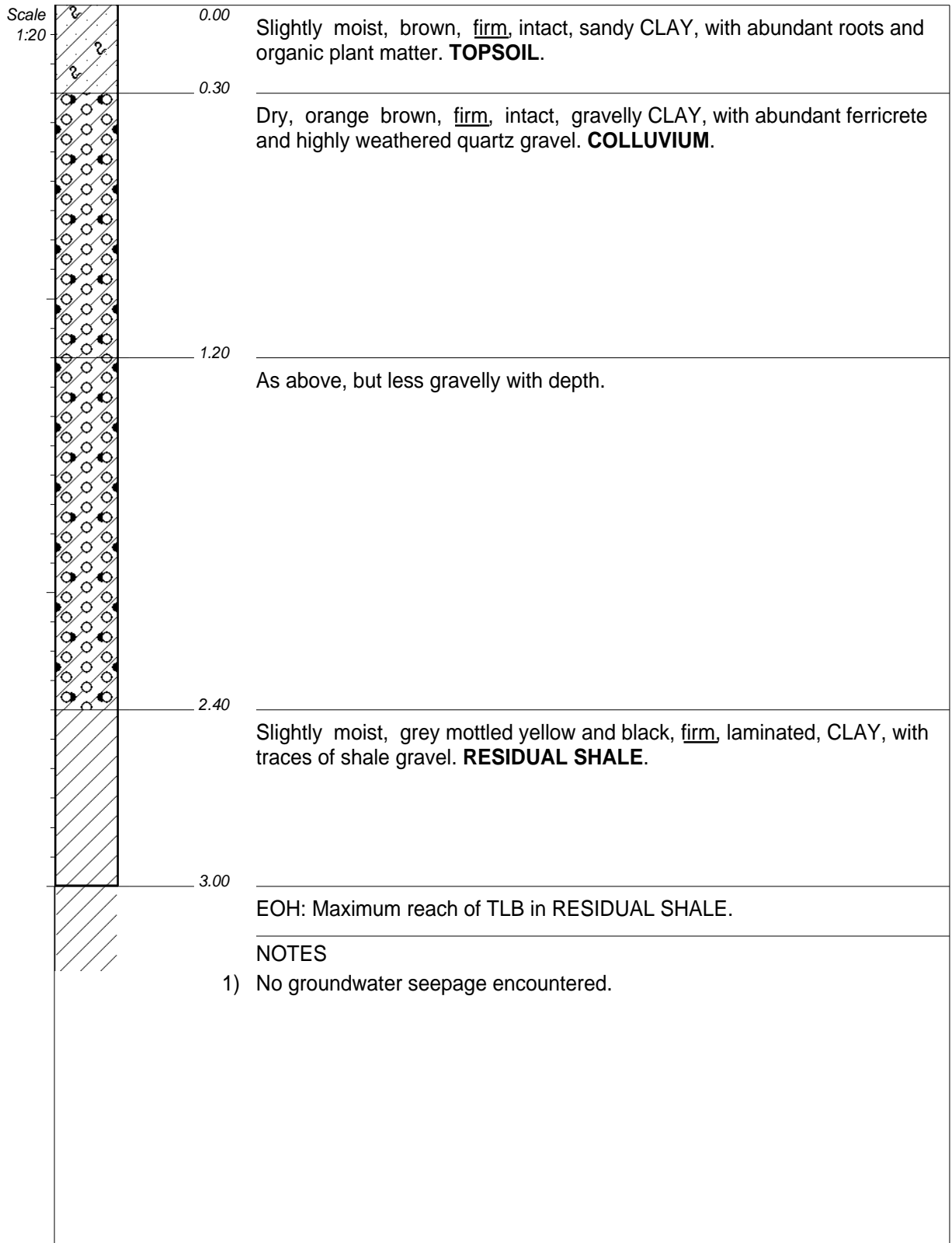
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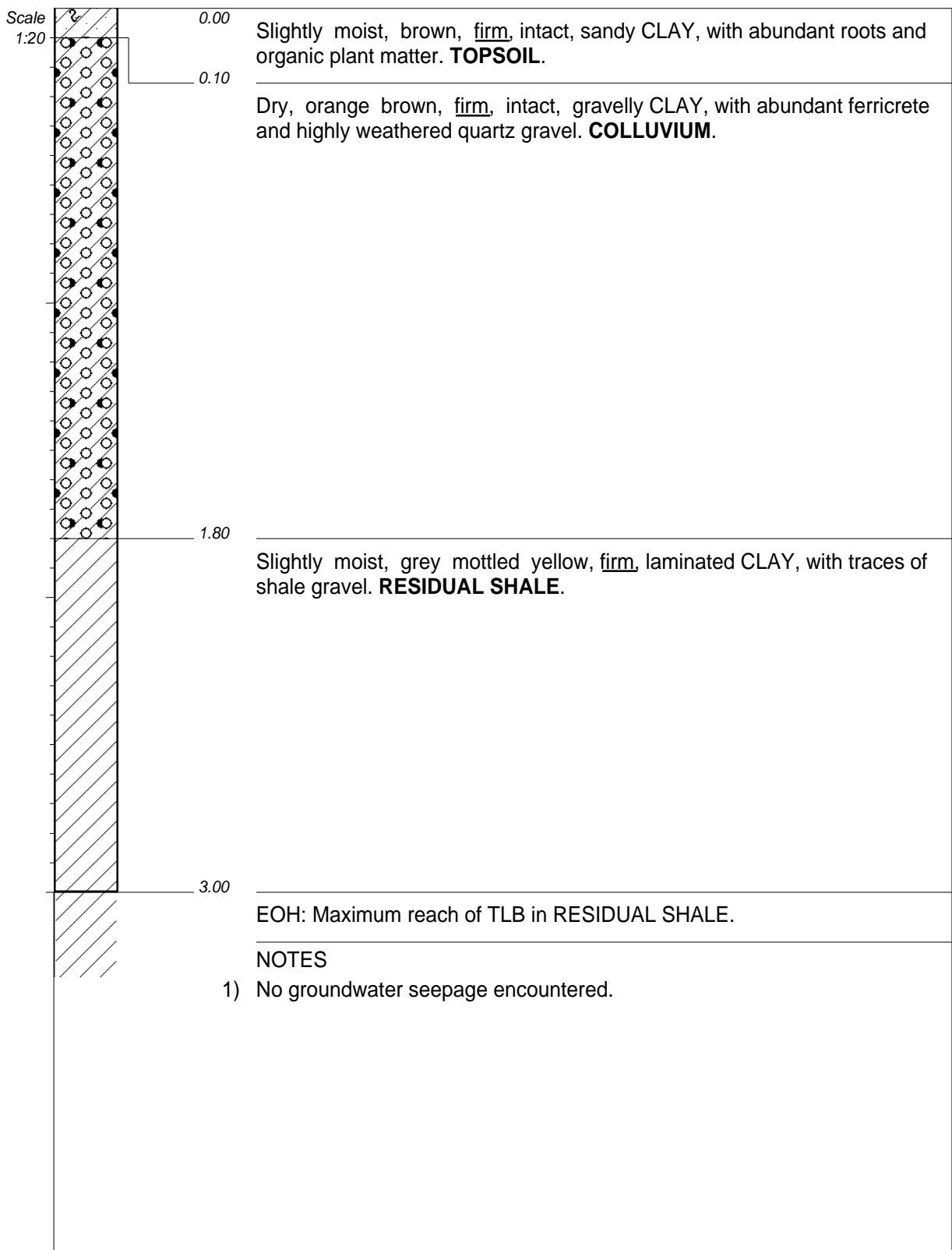
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APPENDIX B

***LABORATORY TEST
RESULTS***

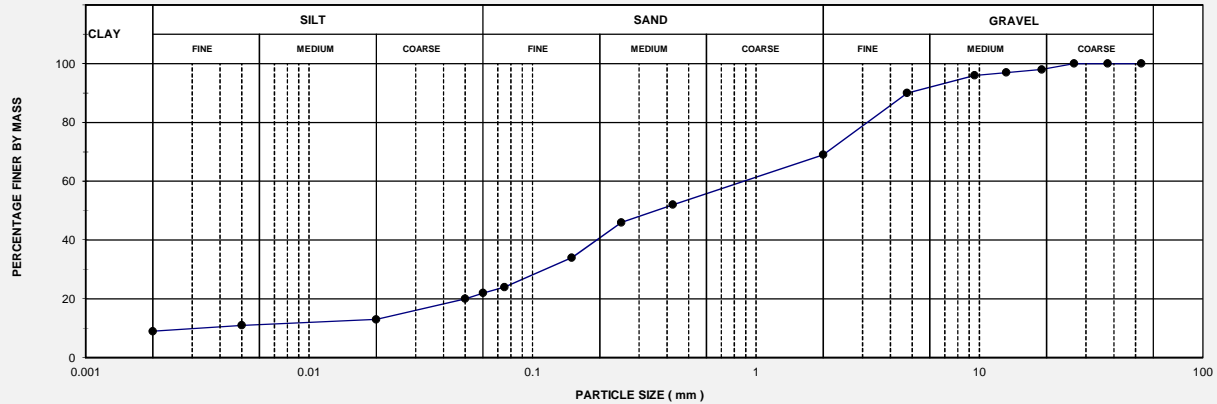


FOUNDATION INDICATOR TEST RESULTS - REP COM 7

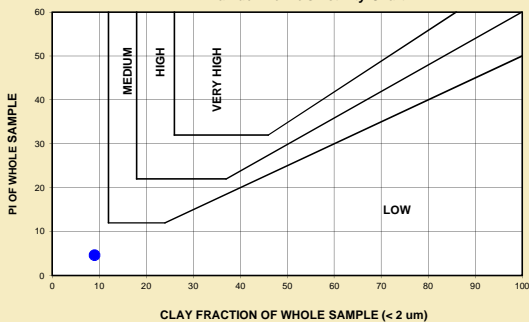
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Project Name: Transalloys Sample List	Layer:	Sample No: 6/10612
Project No:	Lane:	Date: 14/11/2016
Hole/TP No: TP3/1	Stabilizing Agent:	Test Method: TMH1 A1, A5 & ASTM D422
Depth (m): 1.5-1.7	Section:	Client Ref No:
Description: Reddish Brown Colluvium	Chainage:	GPS X:
Additional Info:	Offset:	GPS Y:

SIEVE ANALYSIS				ATTERBERG LIMITS		SOIL CLASSIFICATION	
Sieve (mm)	% Passing	Sieve (mm)	% Passing				
75.0	100	0.425	52	Liquid Limit (%)	22	% Gravel	31
63.0	100	0.250	46	Plastic Limit (%)	13	% Sand	47
53.0	100	0.150	34	Plasticity Index (%)	9	% Silt	13
37.5	100	0.075	24	Weighted PI (%)	4.7	% Clay	9
26.5	100	0.060	22	Linear Shrinkage (%)	4.5	Activity	1.0
19.0	98	0.050	20	Grading Modulus	1.55	% Soil Mortar	69
13.2	97	0.020	13	Uniformity coefficient	333	Coarse Sand Ratio	0.25
9.5	96	0.005	11	Coefficient of curvature	3.6	TRB Classification	A - 2 - 4
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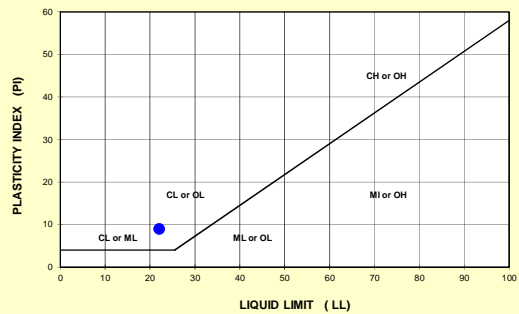
PARTICLE SIZE DISTRIBUTION



POTENTIAL EXPANSIVENESS Van der Merwe's Activity Chart



CASAGRANDE 'A' LINE



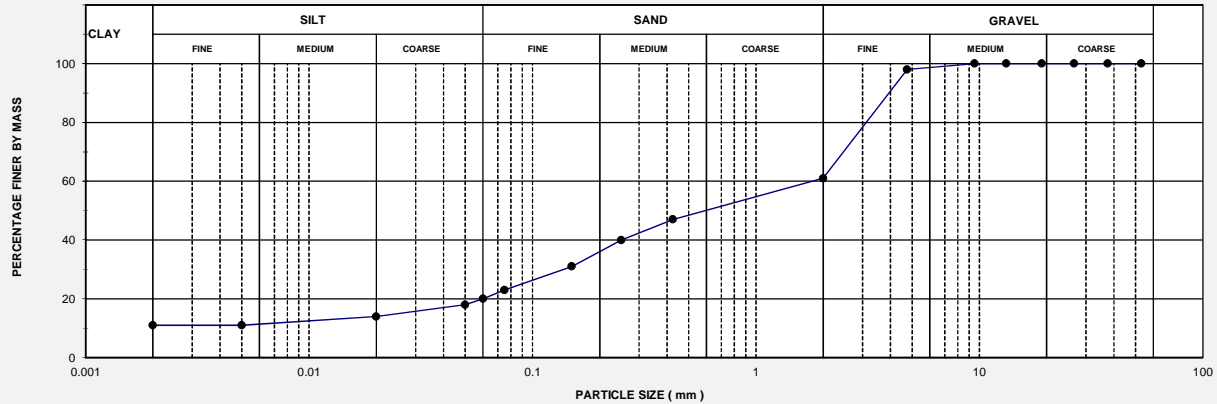


FOUNDATION INDICATOR TEST RESULTS - REP COM 7

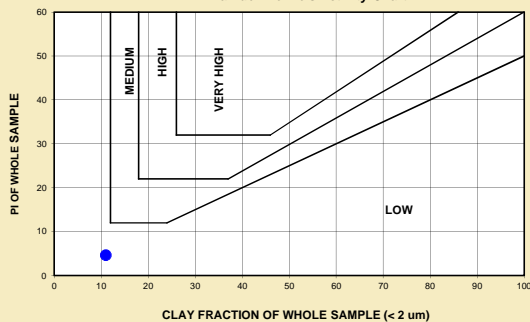
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Project No:	Lane:	Date: 14/11/2016
Hole/TP No: TP4/1	Stabilizing Agent:	Test Method: TMH1 A1, A5 & ASTM D422
Depth (m): 0.4-2.0	Section:	Client Ref No:
Description: Reddish Brown Colluvium	Chainage:	GPS X:
Additional Info:	Offset:	GPS Y:

SIEVE ANALYSIS				ATTERBERG LIMITS		SOIL CLASSIFICATION	
Sieve (mm)	% Passing	Sieve (mm)	% Passing				
75.0	100	0.425	47	Liquid Limit (%)	22	% Gravel	39
63.0	100	0.250	40	Plastic Limit (%)	12	% Sand	41
53.0	100	0.150	31	Plasticity Index (%)	10	% Silt	9
37.5	100	0.075	23	Weighted PI (%)	4.7	% Clay	11
26.5	100	0.060	20	Linear Shrinkage (%)	5.0	Activity	0.9
19.0	100	0.050	18	Grading Modulus	1.69	% Soil Mortar	61
13.2	100	0.020	14	Uniformity coefficient	944	Coarse Sand Ratio	0.23
9.5	100	0.005	11	Coefficient of curvature	5.4	TRB Classification	A - 2 - 4
4.75	98	0.002	11			Unified Classification	SC
2.00	61			Remarks:			

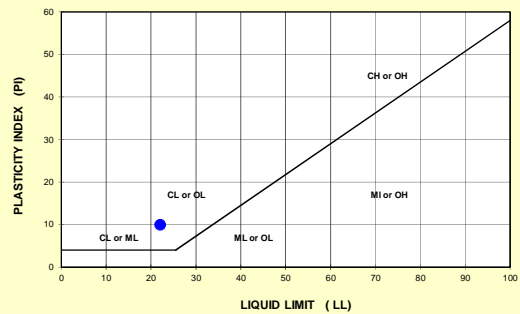
PARTICLE SIZE DISTRIBUTION



POTENTIAL EXPANSIVENESS Van der Merwe's Activity Chart



CASAGRANDE 'A' LINE



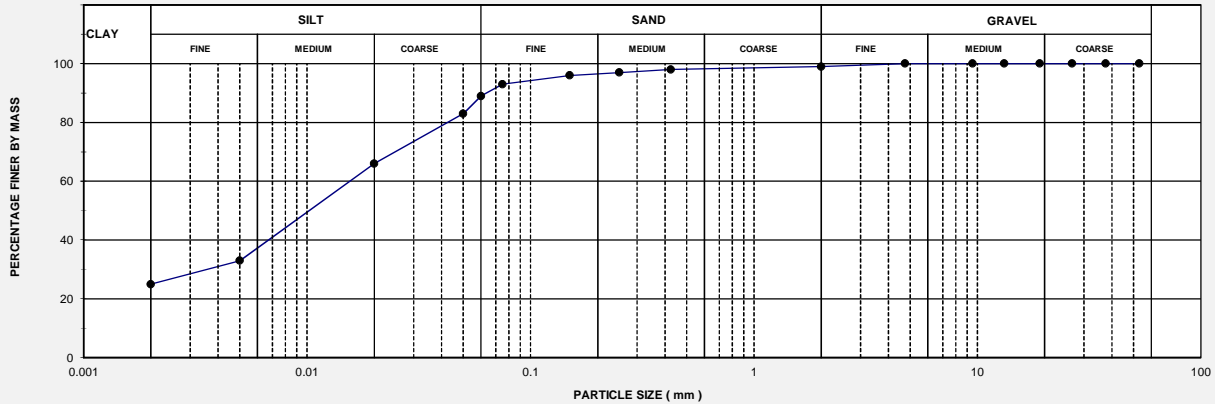


FOUNDATION INDICATOR TEST RESULTS - REP COM 7

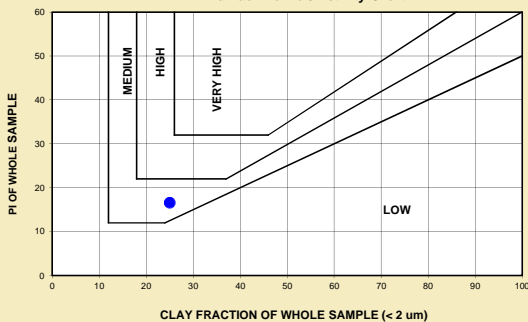
Client: Knight Piesold Consulting	Source/Location:	Job No: 2016-C-1316
Project Name: Transalloys Sample List	Layer:	Sample No: 6/10615
Project No:	Lane:	Date: 14/11/2016
Hole/TP No: TP4/3	Stabilizing Agent:	Test Method: TMH1 A1, A5 & ASTM D422
Depth (m): 2.0-3.0	Section:	Client Ref No:
Description: Grey Mottled Red Residual Shale	Chainage:	GPS X:
Additional Info:	Offset:	GPS Y:

SIEVE ANALYSIS				ATTERBERG LIMITS		SOIL CLASSIFICATION	
Sieve (mm)	% Passing	Sieve (mm)	% Passing				
75.0	100	0.425	98	Liquid Limit (%)	42	% Gravel	1
63.0	100	0.250	97	Plastic Limit (%)	25	% Sand	10
53.0	100	0.150	96	Plasticity Index (%)	17	% Silt	64
37.5	100	0.075	93	Weighted PI (%)	16.7	% Clay	25
26.5	100	0.060	89	Linear Shrinkage (%)	7.5	Activity	0.7
19.0	100	0.050	83	Grading Modulus	0.10	% Soil Mortar	99
13.2	100	0.020	66	Uniformity coefficient	9	Coarse Sand Ratio	0.01
9.5	100	0.005	33	Coefficient of curvature	0.4	TRB Classification	A - 7 - 6
4.75	100	0.002	25			Unified Classification	CL
2.00	99			Remarks:			

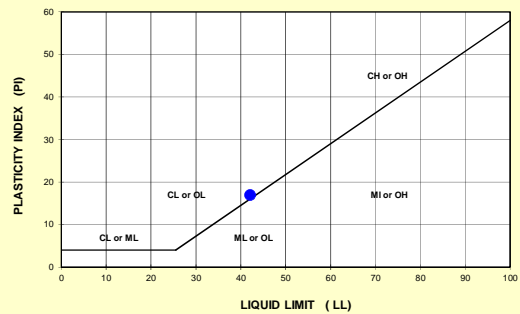
PARTICLE SIZE DISTRIBUTION



POTENTIAL EXPANSIVENESS Van der Merwe's Activity Chart



CASAGRANDE 'A' LINE



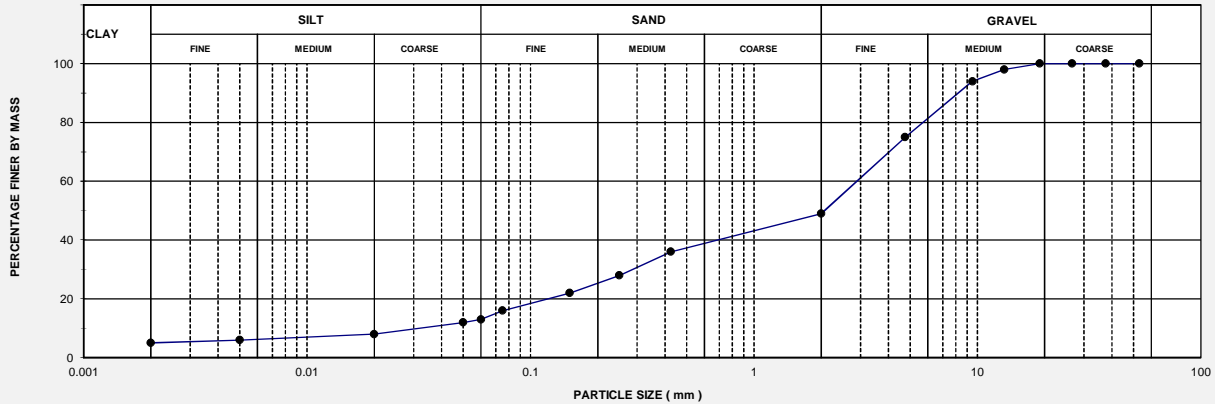


FOUNDATION INDICATOR TEST RESULTS - REP COM 7

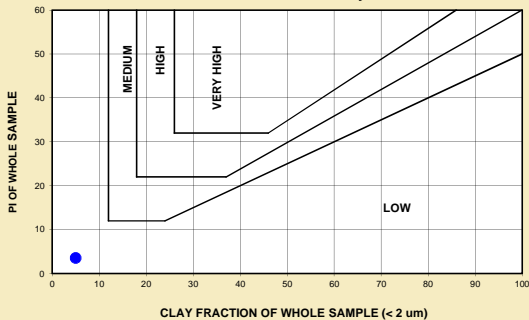
Client: Knight Piesold Consulting	Source/Location:	Job No: 2016-C-1316
Project Name: Transalloys Sample List	Layer:	Sample No: 6/10617
Project No:	Lane:	Date: 14/11/2016
Hole/TP No: TP9/1	Stabilizing Agent:	Test Method: TMH1 A1, A5 & ASTM D422
Depth (m): 0.3-1.4	Section:	Client Ref No:
Description: Orange Brown Colluvium	Chainage:	GPS X:
Additional Info:	Offset:	GPS Y:

SIEVE ANALYSIS				ATTERBERG LIMITS		SOIL CLASSIFICATION	
Sieve (mm)	% Passing	Sieve (mm)	% Passing				
75.0	100	0.425	36	Liquid Limit (%)	21	% Gravel	51
63.0	100	0.250	28	Plastic Limit (%)	11	% Sand	36
53.0	100	0.150	22	Plasticity Index (%)	10	% Silt	8
37.5	100	0.075	16	Weighted PI (%)	3.6	% Clay	5
26.5	100	0.060	13	Linear Shrinkage (%)	5.0	Activity	2.0
19.0	100	0.050	12	Grading Modulus	1.99	% Soil Mortar	49
13.2	98	0.020	8	Uniformity coefficient	85	Coarse Sand Ratio	0.27
9.5	94	0.005	6	Coefficient of curvature	0.7	TRB Classification	A - 2 - 4
4.75	75	0.002	5			Unified Classification	SC
2.00	49			Remarks:			

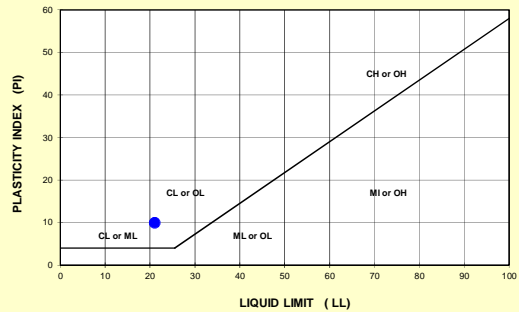
PARTICLE SIZE DISTRIBUTION



POTENTIAL EXPANSIVENESS Van der Merwe's Activity Chart



CASAGRANDE 'A' LINE



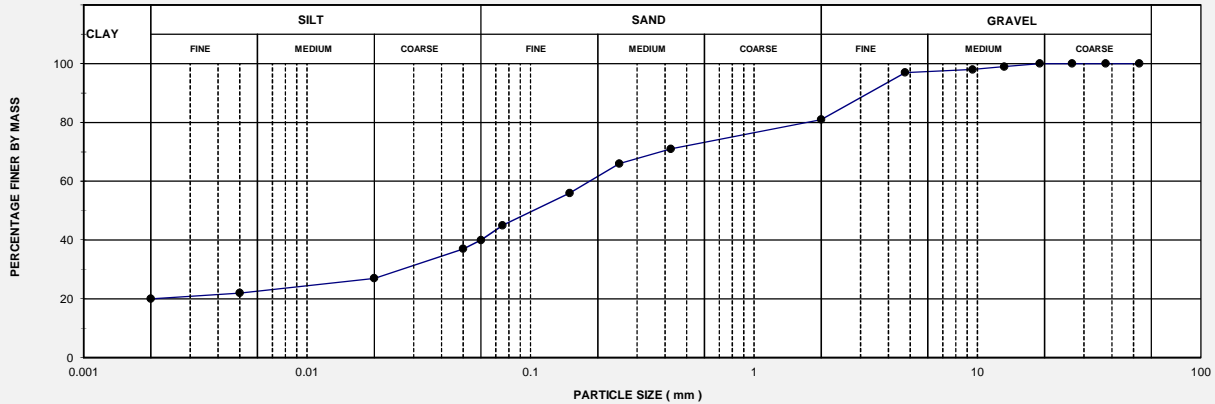


FOUNDATION INDICATOR TEST RESULTS - REP COM 7

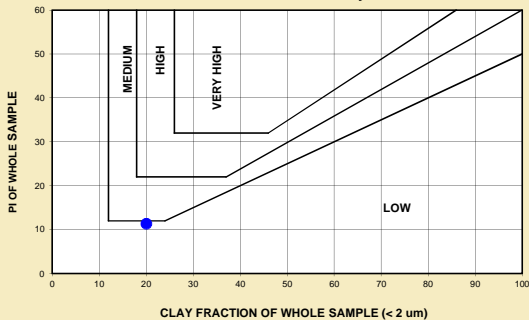
Client: Knight Piesold Consulting	Source/Location:	Job No: 2016-C-1316
Project Name: Transalloys Sample List	Layer:	Sample No: 6/10618
Project No:	Lane:	Date: 14/11/2016
Hole/TP No: TP9/2	Stabilizing Agent:	Test Method: TMH1 A1, A5 & ASTM D422
Depth (m): 1.4-2.7	Section:	Client Ref No:
Description: Reddish Brown Colluvium	Chainage:	GPS X:
Additional Info:	Offset:	GPS Y:

SIEVE ANALYSIS				ATTERBERG LIMITS		SOIL CLASSIFICATION	
Sieve (mm)	% Passing	Sieve (mm)	% Passing				
75.0	100	0.425	71	Liquid Limit (%)	32	% Gravel	19
63.0	100	0.250	66	Plastic Limit (%)	16	% Sand	41
53.0	100	0.150	56	Plasticity Index (%)	16	% Silt	20
37.5	100	0.075	45	Weighted PI (%)	11.4	% Clay	20
26.5	100	0.060	40	Linear Shrinkage (%)	7.0	Activity	0.8
19.0	100	0.050	37	Grading Modulus	1.03	% Soil Mortar	81
13.2	99	0.020	27	Uniformity coefficient	95	Coarse Sand Ratio	0.12
9.5	98	0.005	22	Coefficient of curvature	2.5	TRB Classification	A - 6
4.75	97	0.002	20			Unified Classification	SC
2.00	81			Remarks:			

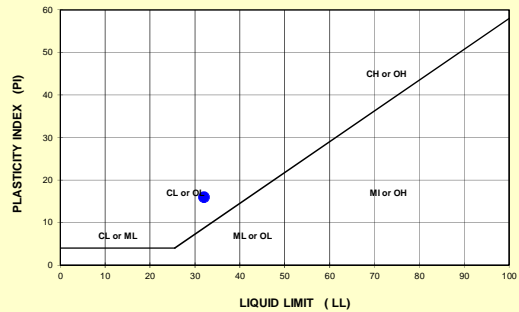
PARTICLE SIZE DISTRIBUTION



POTENTIAL EXPANSIVENESS Van der Merwe's Activity Chart



CASAGRANDE 'A' LINE





BM du Plessis
Civil Engineering

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Project:	2016-C-1316	Test Type:	Permeameter Cell Falling Head Permeability
Sample No:	TP4	Sample Preparation:	Remoulded
Sample Position:	0.4-2.0m	Start Date:	Rev 0 25-Nov-16
Lab No.:	16/628		

Preparation:

Specified Dry Density (kg/m ³):	2025
Optimum Moisture Content (%):	7.6%
Target % of Dry Density (%):	100.0%
Target Dry Density (kg/m ³):	2025
Target Moisture Content (%):	7.6%
Specimen Length L (mm):	68.0
Specimen Diameter (mm):	64.3
Specimen Area A (mm ²):	3250.5
Specimen Vol. (cm ³):	221.0
Sample Mass (g):	322.1
Specimen Moisture Content(%):	7.2%
Specimen Bulk Density (kg/m ³):	1457
Specimen Dry Density (kg/m ³):	1359
Final % of Specified Dry Density (%):	67.1%
Particle Density: <i>Assumed</i>	2.65
Vol. of Soil (V _s) (cm ³):	113.3
Initial Vol. of Voids (V _v) cm ³ :	107.7
Initial Voids Ratio (e) (V _v /V _s):	0.95
Tube Area (a) (mm ²):	168.1
Soaking Tank Water Temperature (°C):	25.0
Temperature Correction Factor:	0.91

Time Readings and Permeability:

	Elapsed Time (min)	Height (h) above outlet (mm)	Height Ratio (h1/h3 or h3/h2)	k _T (m/s)	Averaged k _T :
Run 1	0.0	3540.0	1.10	4.26E-08	
	135.0	3209.2			4.08E-08
	258.0	2956.9	1.09	3.90E-08	
Run 2	0.0	3540.0	1.08	4.01E-08	
	116.0	3269.9			4.46E-08
	241.0	2945.0	1.11	4.91E-08	
Run 3	0.0	3540.0	1.10	4.07E-08	
	135.0	3223.5			4.18E-08
	215.0	3040.2	1.06	4.29E-08	
Run 4	0.0	3540.0	1.09	8.61E-08	
	60.0	3241.3			6.67E-08
	173.0	2959.3	1.10	4.72E-08	

Permeability (K.H. Head Vol 2):

$$k_T = 3.84(aL/At)\log_{10}(h_1/h_2) \times 10^{-9} \text{ m/s}$$

Selected k_T: 4.08E-08

k_{T20} Temperature Correction: 3.71E-08

Note:

Specified density practically not achievable.

Permeability k_{T20} = 3.71E-08 m/s



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Project:	2016-C-1316	Test Type:	Permeameter Cell Falling Head Permeability
Sample No:	TP4	Sample Preparation:	Remoulded
Sample Position:	2.0-3.0m	Start Date:	Rev 0 25-Nov-16
Lab No.:	16/629		

Preparation:

Specified Dry Density (kg/m ³):	1570
Optimum Moisture Content (%):	13.7%
Target % of Dry Density (%):	100.0%
Target Dry Density (kg/m ³):	1570
Target Moisture Content (%):	13.7%
Specimen Length L (mm):	63.0
Specimen Diameter (mm):	63.2
Specimen Area A (mm ²):	3135.8
Specimen Vol. (cm ³):	197.7
Sample Mass (g):	352.3
Specimen Moisture Content(%):	14.4%
Specimen Bulk Density (kg/m ³):	1782
Specimen Dry Density (kg/m ³):	1558
Final % of Specified Dry Density (%):	99.3%
Particle Density: <i>Assumed</i>	2.65
Vol. of Soil (V _s) (cm ³):	116.3
Initial Vol. of Voids (V _v) cm ³ :	81.4
Initial Voids Ratio (e) (V _v /V _s):	0.70
Tube Area (a) (mm ²):	168.1
Soaking Tank Water Temperature (°C):	25.0
Temperature Correction Factor:	0.91

Time Readings and Permeability:

	Elapsed Time (min)	Height (h) above outlet (mm)	Height Ratio (h1/h3 or h3/h2)	kT (m/s)	Averaged k _T :
Run 1	0.0	3540.0	1.06	1.19E-08	
	260.0	3350.8			1.23E-08
	535.0	3150.9	1.06	1.26E-08	
Run 2	0.0	3540.0	1.05	1.20E-08	
	215.0	3381.7			1.20E-08
	560.0	3140.2	1.08	1.21E-08	

Permeability (K.H. Head Vol 2):

$$k_T = 3.84(aL/At)\log_{10}(h_1/h_2) \times 10^{-9} \text{ m/s}$$

Selected k_T: 1.20E-08

k_{T20} Temperature Correction: 1.10E-08

Permeability k_{T20} = 1.10E-08 m/s