VGI CONSULTING

WALTLOO FUEL FARM STRUCTURES
GEOTECHNICAL INVESTIGATION

Report No.: JW053/12/D328 – Rev 1

MARCH 2012

Jones & Wagener
Consulting Civil Engineers
59 Bevan Road PO Box 1434 Rivonia 2128 South Africa
Tel: 00 27 (0)11 519 0200 Fax: 00 27 (0)11 519 0201 email: post@jaws.co.za

DOCUMENT APPROVAL RECORD

Report No.: JW053/12/D328 – Rev 1

ACTION	FUNCTION	NAME	DATE	SIGNATURE
Prepared	Geotechnical Engineer	PJJ Smit	15/03/2012	PS
Reviewed	Director	P van der Berg	15/03/2012	P vd Berg
Approved	Director	P van der Berg	15/03/2012	P vd Berg

RECORD OF REVISIONS AND ISSUES REGISTER

Date	Revision	Description	Issued to	Issue Format	No. Copies
15/03/2012	Rev 0	Geotechnical Report	VGI Consulting	PDF	1
11/04/2012	Rev 1	Additional test results included	VGI Consulting	PDF	1

SYNOPSIS

Jones and Wagener were appointed by VGI Consulting to do geotechnical investigation for proposed new structures at the Waltloo fuel farm. The geotechnical investigation included the profiling of 7 test pits and the testing of samples in the laboratory to determine the ground conditions at the proposed structures.

The proposed structures include new blast proof offices, workshops, ablution facilities, store rooms, control rooms and two tank structures which are mostly sunk into the ground.

Numerous contacts between the Silverton shale and the diabase which intruded the shale rock are present at the site. Four of the seven test pits were stopped in shale rock while three test pits were stopped in residual diabase.

It is expected that most of the hillwash material overlying the site and residual soils will be active. Where roads and terraces that are movement sensitive are to be constructed, it is recommended that the potential expansive material be removed and replaced with either shale rock general fill and / or suitable commercial material. Shale rock is not suitable for the construction of structural fill or layerworks. It is recommended that the most suitable foundation for the proposed buildings are reinforced concrete raft foundations since it addresses both the issue of heave problems, as well as no suitable founding level at shallow depth.

It is expected that excavators will be able to excavate the shale rock where it is highly fractured, but mechanical breakers and blasting may be required as the excavation depth increases. It is recommended that further investigation on the excavatability and the stability of the shale rock at depth is done using rotary core drilling.

Care should be taken when excavations into the shale rock is made for any structures. Sliding failures on bedding planes into excavations along the direction of dip is very common. Although most problems are encountered on the southern excavation face problems due to fractures in the shale rock can be expected on all the excavation faces. Apart from slipping failures, wedge failures and ravelling failures can be expected.

It is therefore recommended that any excavations into the shale include a properly designed support system.

Indications are that no problems due to a shallow ground water table can be expected. The rotary core drilling at the two tank sites will however confirm if this is the case for these excavations as well.

CONTENTS PAGE

APPENDIXES

List of Tables

List of Figures

Jones & Wagener
Consulting Civil Engineers
59 Bevan Road PO Box 1434 Rivonia 2128 South Africa
Tel: 00 27 (0)11 519 0200 Fax: 00 27 (0)11 519 0201 email: post@jaws.co.za

VGI CONSULTING

WALTLOO FUEL FARM STRUCTURES
GEOTECHNICAL INVESTIGATION REPORT NO: JW053/12/D328 – Rev 1

1. INTRODUCTION

1.1 Background

Jones and Wagener were appointed by VGI Consulting to do a geotechnical investigation for proposed new structures at the Waltloo fuel farm. The geotechnical investigation included the profiling of 7 test pits and laboratory testing to determine the ground conditions at the proposed structures. The investigation took place inside the existing fuel farm area.

The proposed structures, site layout and test pit locations can be seen on Figure 1. The proposed structures include new blast proof offices, workshops, ablution facilities, store rooms, control rooms and two tank structures which are mostly sunk into the ground.

Test pits were excavated by hand from the end of January to mid February and was profiled on 1 February and 14 February 2012.

1.2 Definitions and Abbreviations

1.2.1 Commercial

J&W	**J**ones **&** **W**agener (Pty) Ltd - Geotechnical consultant

1.2.2 Technical

Survey & Coordinates:

NGL	**N**atural **G**round **L**evel
WGS84	**W**orld **G**eodetic **S**ystem 19**84**, in latitude and longitude
WG29	**WG**S84 locally projected YXZ co-ordinates around the **29**th longitude

Investigations:

WFFxx	**T**est **P**it position

Soils Classification:

CBR	**C**alifornian **B**earing **R**atio
MDD	**M**aximum **D**ry **D**ensity
Mod AASHTO	**Mod**ified **AASHTO** test for determining MDD and OMC
NDD	**D**ry **d**ensity in the **n**atural or in-situ state
NMC	**N**atural or in-situ **m**oisture **c**ontent
NP	**N**on **P**lastic

SP	**S**lightly **p**lastic
OMC	**O**ptimum **M**oisture **C**ontent
PI	**P**lasticity **I**ndex
SG	**S**pecific **G**ravity
G1 - G10	Standard classification of natural road building materials according to TRH14[1]
C1 - C4	Standard classification of stabilised road building materials according to TRH13[2].

1.3 Reference Documents

The following references were consulted in preparing the scope of the investigation:

(i) 1:50 000 Geological Map, sheet 2528CD - SILVERTON, published by the Drawing Office of the Geological Survey Department, Pretoria, 1973.

(ii) Two drawings showing the proposed structures were provided by VGI Consulting namely Plan nr. 993-100/4 and 993-101/4.

2. TERMS OF REFERENCE

2.1 Proposed Development

The proposed structures include new blast proof offices, workshops, ablution facilities, store rooms, control rooms and two tank structures which are mostly sunk into the ground. The proposed structures superimposed on an aerial photo of the area are shown in green on Figure 1. The aerial photo also shows existing structures that have to be demolished as part of the project.

2.2 Appointments

Jones and Wagener was appointed by VGI Consulting on 22 November 2012 to conduct a geotechnical investigation for the proposed site. A civil contractor was appointed by VGI Consulting / Transnet for the excavation of the test pits.

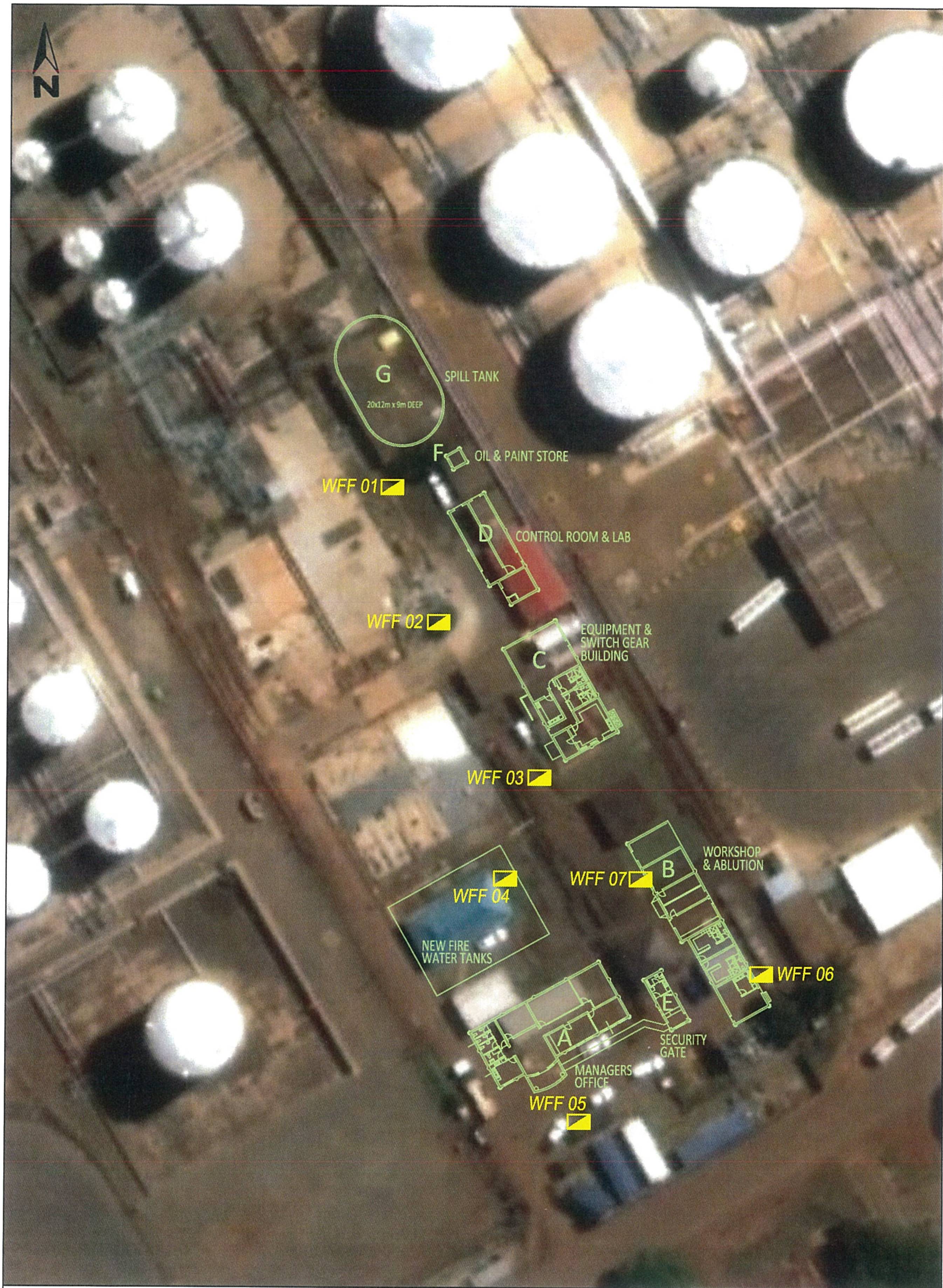
3. SITE DESCRIPTION

3.1 Site Locality

The site is located within the existing Transnet Fuel Farm in Waltloo, Silverton approximately 15km east of the Pretoria CBD.

[1] **TRH14:1985. Guidelines for Road Construction Materials**. Committee for State Road Authorities, Department of Transport, Pretoria.

[2] **TRH13:1986, Cementitious stabilizers in road construction**. Committee for State Road Authorities, Department of Transport, Pretoria.



Jones & Wagener
Consulting Civil Engineers
59 Bevan Road PO Box 1434 Rivonia 2128 South Africa
Tel (011) 519-0200 Fax: (011) 519-0201 Email: post@jaws.co.za

VGI CONSULTING

WALTLOO FUEL FARM GEOTECHNICAL INVESTIGATION

LOCATION OF TESTPITS

Figure 1

Job No D328

Scale 1: 750

3.2 Regional Geology

The regional geology in the area of the site includes shale from the Silverton Formation Pretoria Group which includes numerous Waterberg Group Diabase intrusions in the form of dykes and sills. The Magaliesberg consisting of the Magaliesberg Quartzites is located approximately 4km north of the site. Approximately 2km south of the site is a ridge comprising Daspoort Quartzites.

The site location shown on the geological map of the area is included as Figure 2 below.

3.3 Topography & Drainage

The site is relatively flat and gently falls from south to north.

3.4 Vegetation

Most of the vegetation at the fuel farm has been removed probably during construction to reduce the risk of fires inside the plant and storage areas. Some shrubs and lawns are present around the existing office building and control room. The site is mostly bare.

4. INVESTIGATION

4.1 Overview

The investigation included the excavation of seven test pits by hand to a depth varying between 1,5m and 2,0m. The test pits were excavated near the proposed structures but where access due to existing buildings, structures, cables or pipelines were problematic, the test pits were moved to the nearest accessible position. The test pit excavation started towards the end of January 2012 and was completed on 14 February 2012.

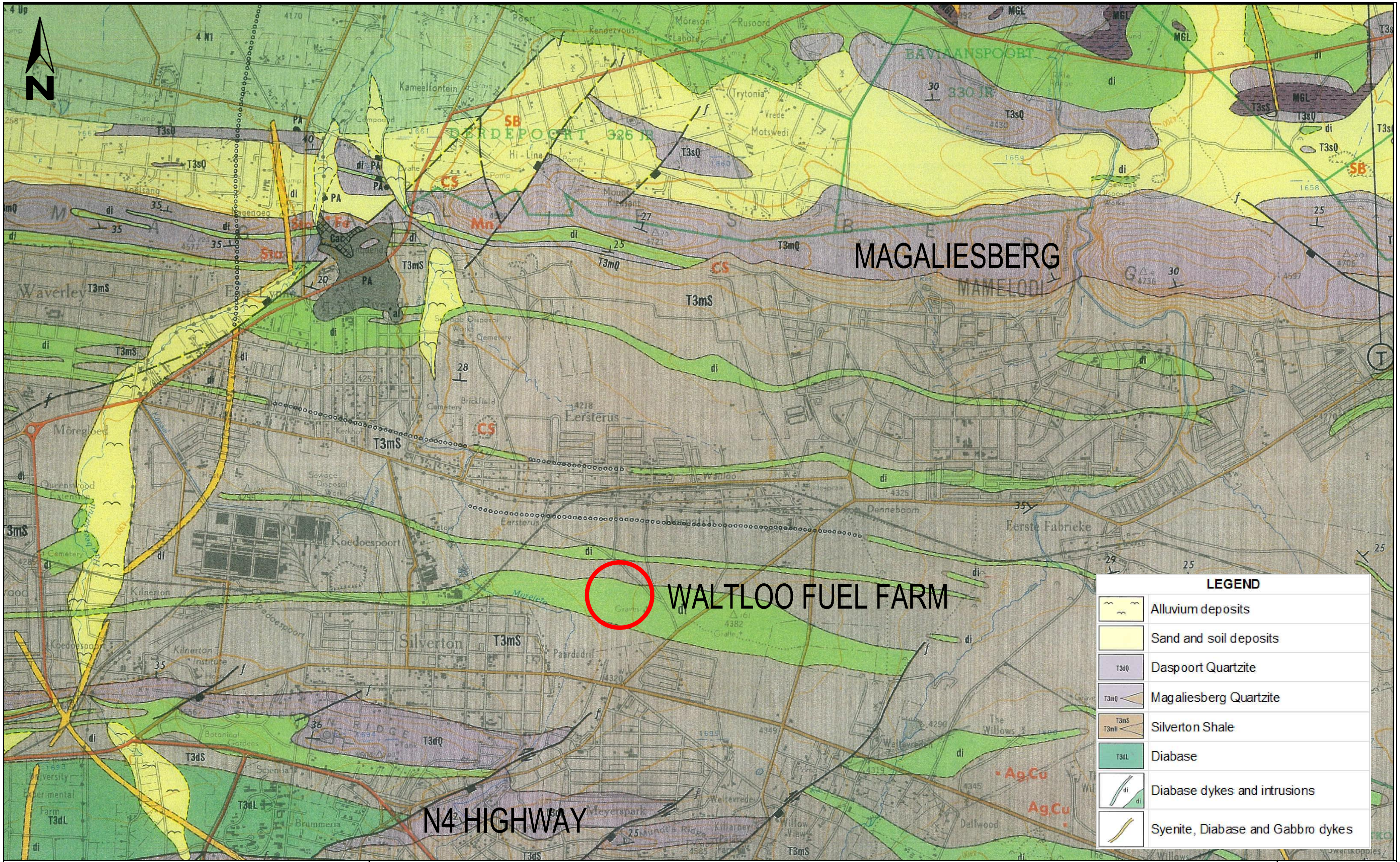
4.2 Survey

The test pit positions were logged with a hand held GPS. Coordinates are referenced to the WGS84 spheroid, projected locally to the South African Grid using WG29 as reference meridian.

5. ROTARY CORE BOREHOLES

During the investigation shallow shale rock (about 1m below NGL) was encountered at the two tank structures. J&W allowed for DPSH testing on site to determine (where possible) the depth of bedrock material in our proposal. Due to the relatively shallow depth of the shale rock the DPSH test would refuse at depths varying from 1m to 1,5m (where shale is encountered) and it was felt that DPSH testing would not provide additional information. For this reason no DPSH testing was done.

Following the initial fieldwork J&W recommended to VGI Consulting to consider drilling at least two rotary core boreholes near the two tank structures where deep excavations are required, typically 6m to 8m deep. J&W obtained quotes from Stefanutti Stocks Geotechnical and Esor Franki for the drilling. J&W further prepared a proposal to assist with setting out the borehole position on site, logging the core and including the profiles in our report. J&W did not receive an instruction to continue with core drilling and no rotary core boreholes were drilled as part of the investigation.



Jones & Wagener

Consulting Civil Engineers

VGI CONSULTING
WALTLOO FUEL FARM
REGIONAL GEOLOGY OF SITE

Figure 2

Job No D328

SCALE 1 : 50 000

5.1 Test Pits

Due to the likeliness of encountering services when excavating test pits, the project manager instructed that all excavation work at the Waltloo fuel farm has to be done by hand. A contractor has appointed to excavate the test pits. In addition the contractor tested for services before the excavation of a test pit commenced. Test pits were then profiled before they were backfilled.

The project manager further instructed that hand excavated test pits deeper than 1,5m have to be battered or shored while workers are inside the excavations. The test pits were stopped at a depth of 1,5m except for the two test pits located near the tank structures which were excavated to 2m after the top approximately 0,7m of the test pits were benched.

The test pits positions are shown on Figure 1.

5.2 Laboratory Testing

Soil samples taken in the test pits during the geotechnical investigation, were tested and the results are included in Appendix B. The following tests were carried out on the samples:

- Grading, indicator and moisture content tests on disturbed samples.
- The tests listed under bullet 1 and the maximum dry density and California Bearing Pressure (CBR) tests on bulk samples.
- Swell pressure test and swelling test on block and reconstituted samples.

5.2.1 Grading, indicator and strength test results

The results of the tests carried out during the geotechnical investigation are summarised in Table 1. A total of 10 samples were tested in the categories of hillwash, residual diabase, residual shale and shale rock.

Table 1 – Summary of test results.

MATERIAL	HILLWASH	RESIDUAL DIABASE	RESIDUAL SHALE	SHALE
ATTERBERGS & GRADING				
No. of Samples	2	4	2	2
% of Clay	14-46 (30.0)	18-45 (30.5)	32-37 (34.5)	5-10 (7.5)
Grading Modulus	0.38-1.37 (0.87)	0.26-0.49 (0.37)	0.43-0.60 (0.515)	1.61-1.91 (1.76)
Specific Gravity kg/m^3	2.71-2.72 (2.715)	2.77-2.85 (2.79)	2.68-2.69 (2.685)	2.72
Liquid Limit %	54.0-74.0 (64.0)	43.7-77.5 (58.5)	66.0-69.0 (67.5)	54.2-59.3 (56.8)
Plasticity Index %	27.3-46.0 (36.5)	14.7-47.2 (31.3)	43.0-46.0 (44.5)	33.5-36.3 (34.9)
PI (whole sample) %	14.5-40.0 (27.3)	14.1-41.1 (28.1)	35.4-36.6 (36.0)	11.4-15.6 (13.5)
Shrinkage Limit %	12.4-16.4 (14.4)	8.8-16.7 (11.8)	14.3-14.4 (14.35)	12.7-13.7 (13.2)
MOISTURE				
No. of samples	2	4	2	2
In situ Moisture Content	14.1-25.6 (19.9)	22.4-26.2 (24.6)	22.1-23.4 (22.7)	
COMPACTION DATA				
No. of samples	-	-	-	2
Max Dry Density kg/m^3	-	-	-	1860-1920 (1890)
Optimum Moisture Content %	-	-	-	13.0-13.7 (13.4)
CBR at 95% Mod AASHTO %	-	-	-	12
TRH14 Classification	-	-	-	G9

Note: Brackets ( ) indicate average values

The results are described in more detail in Section 6.2.2.

5.2.2 Swell testing

Swelling tests were done on three samples to assess the heave potential of the material. Two tests were done on the residual shale which was consolidated to a stress of 50kPa and 100kPa respectively. The third sample consisted of a remoulded residual diabase material which was consolidated to a stress of 50kPa.

Once the samples were consolidated at their natural moisture content the samples were saturated and allowed to swell while the displacements were measured. These measurements were taken until the samples were fully saturated, i.e. the swell displacements stops. On completion of the test the samples were loaded until the samples consolidated to the initial volume. It should be noted that this is not the swell pressure of the sample as determined in the swell pressure test although the swell pressure test is similar.

Table 2 below provides the results obtained from the swell tests.

Table 2 - Summary of swell test results.

	WFF7/03	WFF7/03	WFF2/03
Material type	Residual shale / Hillwash	Residual shale / Hillwash	Residual diabase
Sample preparation	Undisturbed	Undisturbed	Re-moulded
Sample depth	0,9m	0,9m	1,2m
Consolidation pressure	50kPa	100kPa	50kPa
Initial water content	18,9%	21,3%	23,5%
Initial void ratio	0,605	0,634	0,717
Initial Saturation	86,6%	92,3%	90,6%
Final water content	20,8%	23,6%	26,6%
Approximate swell pressure	31kPa	64,5kPa	128kPa

The potential heave can be calculated using the swell from the laboratory testing extrapolated for a 1m thick layer of expansive material. From this calculation the potential heave should the site become saturated varies between 3mm and 5mm. It should be noted that the materials currently is about 90. Should the construction work take place in the winter months the saturation could have reduced significantly and a saturation of 30% to 50% would not be uncommon. The potential heave should the saturation vary from 30% (i.e. a relatively dry site becoming saturated) to fully saturated varies between 20mm and 30mm. It should be noted that this estimation is based on a linear extrapolation, which is not conservative and should be seen as the lower bound of the possible heave.

The heave calculated above can be compared with the guidelines provided by Van der Merwe[3]. Using the Van der Merwe guideline a meter layer of material with a very high swell potential can heave between 75mm and 100mm while the heave for a meter layer with medium swell potential vary between 15mm and 25mm. The samples above tested with a swell potential varying between medium and very high as describe in Section 6.2.2. It can therefore be concluded that from a dry state, heave movements of as much as 100mm would not be unrealistic for these materials.

It can be expected that the in situ moisture content below structures will remain relatively constant while the in situ moisture content outside structure footprints can vary considerably with the seasons. This will result in significant differential movements below the structures and any foundation design should take this into account.

[3] Van der Merwe, D. H., (1964), **The prediction of heave from the plasticity index and percentage clay fraction of soils**. The Civil Engineer in South Africa.

6. DISCUSSION

6.1 Introduction

Four of the seven test pits were stopped in shale bedrock while three test pits were stopped in residual diabase. Numerous contacts between the Silverton Shale and the diabase which intruded the shale rock are present at the site. The southern section of the site around Test Pit WFF05 and a band running through Test Pits WFF02 and WFF03 consist of diabase bedrock. The soil profiles are included as Appendix A to the report.

The typical shale profile can be seen in Photo 1 included in Appendix C.

6.2 Site Stratigraphy

6.2.1 Soil Description

Hillwash

Most of the site is overlain with a layer of red brown, sandy and silty clay, hillwash to a depth of 300mm to 700mm. The moisture content of the hillwash varied from slightly moist to moist and the consistency from soft to stiff, but generally firm. The hillwash layer was further highly fissured and shattered.

Residual diabase

In Test Pits WFF 02, WFF03 and WFF05 residual diabase was encountered to a depth of 1,5m where the test pits were stopped. At the time of the investigation the residual diabase was moist. The material consists of clayey and silty sand varying to a sandy, silty clay. The material consistency of the cohesive soils was generally firm to stiff, while die consistency of the non-cohesive soils was medium dense to dense.

Residual Shale

The upper part of the shale rock has been weathered to a greyish, silty clayey material varying in thickness from 0,4m to 0,9m. The consistency of the shale was generally firm to stiff except for Test Pit WFF06 where the layer was soft. The moisture content at the time of the investigation varied from slightly moist to moist.

Shale rock

The shale rock underlying the residual shale is described in Section 6.2.3 below.

6.2.2 Soil Characteristics

Hillwash

The two hillwash samples tested showed a substantial variance in the clay content of the material, i.e. 14% to 46% as well as the PI which varied from 27% to 46%. The Van der Merwe swell for Sample WFF01/1 is medium and for WFF07/1 (sample with the higher clay content and PI) very high.

<u>Residual Diabase</u>

The residual diabase also showed a substantial variance in clay content and PI, namely 18% to 45% (average 30%) and 14,7% to 47,2% (average 31,3%) respectively. The Van der Merwe swell for the residual diabase varies from medium to very high.

<u>Residual shale and shale rock</u>

The residual shale has a high clay content of 32% to 37% and a high PI of 43% to 46%. The Van der Merwe swell for both the residual shale samples is very high.

Samples tested on the shale rock have a low clay content between 5% and 10%, but the finer portion of the sample has a high PI around 35%. The Van der Merwe swell for the shale rock material was low. The shale rock material is unsuitable for structural layers and both samples tested as a G9 material as per the TRH14[1] classification. The material can therefore only be used as sub grade material, but should be used with caution due to the high PI.

6.2.3 Rock Properties

The diabase bedrock has been weathered to a depth exceeding the test pit depths and it is therefore not possible to comment on the diabase rock properties. Diabase usually forms core stones which become closer packed and larger with depth. Unweathered diabase is generally a very hard rock.

The shale rock is highly fissured and fractured over the top approximately 1m of the layer and is thinly bedded. No refusal was encountered where test pits were excavated into the shale rock up to a depth of 2m. The shale rock is weathered near the top of the rock profile and becomes less weathered with depth. The shale encountered in the test pits can further be classified as a very soft to soft rock becoming medium hard rock with depth.

7. <u>GEOTECHNICAL CONSIDERATIONS</u>

The following geotechnical considerations, based on the guidelines suggested by Partridge et al. 1993[4], should be addressed and considered during the design, as well as in the design of earthworks and foundations:

- Problem Soils
- Groundwater / Seepage
- Excavatability
- Slope Stability
- Corrosivity

7.1 Problem Soils

The hillwash overlaying the site and the residual soils generally consists of clay and is generally highly shattered and fissured with most of the fissures being slick-en-sided. This generally indicates that the soil profile is active. In addition the shales from the Pretoria Group are known to be active and generally weather to an active clay. It is

---

4 Partridge, T.C., Wood, C.K., and Brink, A.B.A. (1993), **Priorities for urban expansion within the PWV metropolitan region: The primacy of geotechnical constraints**, *South African Geographical Journal*, Vol. 75, pp 9-13.

therefore likely that the soils overlying the site and the residual rock is active and could heave when the soil moisture content changes.

7.2 Groundwater and Seepage

No groundwater table or seepage was observed in any of the test pits. It is likely that seepage will occur into deep excavations following high rainfall events. Any seepage into open excavations should be monitored as it could severely influence the stability of excavations.

7.3 Excavatability

No problems were encountered to excavate the transported and residual rock material to a depth varying between 1m and 1,5m. In this area the diabase is generally weathered deeper than the surrounding shale rock.

The three test pits where diabase was encountered could be excavated to a depth of 1,5m without any problems. Bedrock diabase was not encountered in any of the test pits and the depth to diabase bedrock is therefore unknown. It is expected that deep excavations into diabase will be problematic due to the tendency of diabase to form core stones which can have a substantial size making excavation work difficult. In addition un-weathered diabase is generally a very hard rock that will require blasting to excavate.

The shale rock is highly fissured and fractured over the top approximately 1m of the layer and is closely bedded. No refusal was encountered where test pits were excavated into the shale rock up to a depth of 2m. The labourers excavating the test pits did indicate that excavation by hand became very difficult below about 1,5m. It is expected that excavators will excavate the shale rock where it is highly fractured, but mechanical breakers and blasting will be required as the excavation depth increases.

To investigate the excavatability of the shale rock at depth rotary core drilling is necessary.

7.4 Slope Stability

According to A.B.A. Brink (1979) the bedding planes in the Pretoria Group shales are uncommonly smooth and even and have a notorious reputation for sliding on these bedding planes into excavations along the direction of dip. Numerous cases of slope failures have been recorded in the shale rock even at shallow depths.

During the investigation it was noted that the shale bedding planes dip in a northerly direction at an angle of 20° to 30°. This was confirmed by the 1 in 50 000 geological map of the area shown in Figure 2 which give bedding dip angles varying between 25° to 35°.

Although most problems are encountered on the southern excavation face problems due to fractures in the shale rock can be expected on all the excavation faces. Apart from slipping failures, wedge failures and ravelling failures can be expected.

It is therefore recommended that any excavations into the shale include a properly designed support system.

7.5 Corrosivity

The scope of the investigation did not require any test work to assess the corrosivity of the in situ soils and bed rock material.

8. RECOMMENDATIONS

8.1 Terraces and Access roads

Structural terraces and access roads, which are sensitive to movements and heave have to be constructed by first removing the clayey hillwash material to a depth of 0,4m to 0,9m. Where the site is underlain by shale, the residual shale layer will also have to be removed due to the high possibility that this material will heave should the moisture content vary. The terrace and road layer works can then be constructed on the shale rock or compacted residual diabase.

The recommendation above is not applicable to pedestrian walkways and paved areas that will not accommodate heavy vehicles and is therefore not particularly sensitive to movements. In these areas sufficient layers should be constructed to suite the walkway / paving requirements. It should be noted that these areas may require additional maintenance due to uneven surfaces in the future. Special attention should also be given to the design of drainage in order to ensure that the site drains properly and there is no ponding of water. Landscaping and the planting of vegetation that may affect the soil moisture content significantly should also be avoided.

8.2 Foundation structures

Buildings and light structures can be founded on soft rock shale at a depth of about 1,2m below NGL. It will be necessary to remove all the hillwash and residual shale material from the entire structure footprint and to backfill suitable fill below structure floors and surface beds. The foundation excavations should be inspected by a competent person to ensure that all soft and active material has been removed before the foundations are constructed. Alternatively structures can be founded on raft foundations.

Where diabase rock is underlying the structure it will also be necessary to remove the active hillwash material. No competent founding material was observed in test pits excavated into the diabase. In addition the test results indicate that the residual diabase may be active. Structures founded on residual diabase or straddling contacts between the diabase and shale should be founded on raft foundations to prevent damage due to heave.

Structures and services have to be designed to accommodate possible movements in the soil profile.

The founding of heavy structures was not investigated since no heavy structures were indicated on the drawings supplied to J&W. It will be necessary to investigate the foundations of heavy structures (especially on the diabase) further before these foundations are designed.

8.3 Foundation Design Parameters

Foundation bearing pressure on soft shale rock should be limited to 200kPa. Since no competent material was located within the residual diabase horizon it is recommended to found structures on diabase on raft foundations.

8.4 Materials Use

Obtaining construction materials on site did not form part of the investigation. Two samples of shale rock was taken and tested as a G9 material. It is expected that surplus shale rock material will be available from the excavations for the two tank structures. This material is suitable for subgrade material but should be used with caution (i.e. should not be used where movements are undesirable) due to the materials high PI. The excavated shale rock can be seen in Photo 2 included in Appendix C.

The residual diabase is relatively fine grained, has a PI varying between 15% and 47% and was found to be highly variable over the site. It is not recommended to use decomposed diabase as structural fill or layer works.

No structural fill material was encountered in any of the test pits and it will be necessary to import material from commercial or other sources.

8.5 Tank structures

It is expected that excavators will excavate the shale rock where it is highly fractured, but mechanical breakers and blasting will be required as the excavation depth increases. Any excavations into the shale rock have to be properly designed and have to include a proper support system even for shallow excavations.

To investigate the excavatability of the shale rock at depth rotary core drilling is necessary.

The tank structures can be founded on medium to hard rock shale. It is recommended that a competent person inspect the excavations before the tank structures are constructed. Specific note should be taken of any weathered diabase dykes and sills within the shale horizon. It is clear from the investigation that numerous diabase dykes and sills are present in the shale horizon and the tank structures foundations have to take this into account.

9. CONCLUSIONS

Jones and Wagener were appointed by VGI Consulting to do geotechnical investigation for proposed new structures at the Waltloo fuel farm. The geotechnical investigation included the profiling of 7 test pits and the testing of samples in the laboratory to determine the ground conditions at the proposed structures. The test pits were profile on 1 and 14 February 2012.

The proposed structures include new blast proof offices, workshops, ablution facilities, store rooms, control rooms and two tank structures which are mostly sunk into the ground.

Numerous contacts between the Silverton shale and the diabase which intruded the shale rock are present at the site. Four of the seven test pits were stopped in shale rock while three test pits were stopped in residual diabase.

It is expected that most of the hillwash material overlying the site and residual soils will be active. Where roads and terraces that are movement sensitive are to be constructed, it is recommended that the potential expansive material be removed and replaced with either shale rock general fill and / or suitable commercial material. Shale rock is not suitable for the construction of structural fill or layerworks. It is recommended that the most suitable foundation for the proposed buildings are reinforced concrete raft foundations since it addresses both the issue of heave problems, as well as no suitable founding level at shallow depth.

It is expected that excavators will be able to excavate the shale rock where it is highly fractured, but mechanical breakers and blasting may be required as the excavation depth increases. It is recommended that further investigation on the excavatability and the stability of the shale rock at depth is done using rotary core drilling.

Care should be taken when excavations into the shale rock is made for any structures. Sliding failures on bedding planes into excavations along the direction of dip is very common. Although most problems are encountered on the southern excavation face problems due to fractures in the shale rock can be expected on all the excavation faces. Apart from slipping failures, wedge failures and ravelling failures can be expected.

It is therefore recommended that any excavations into the shale include a properly designed support system.

Indications are that no problems due to a shallow ground water table can be expected. The rotary core drilling at the two tank sites will however confirm if this is the case for these excavations as well.

PJJ Smit
for Jones & Wagener

Dr JP van der Berg Pr Eng

6 March 2012

Document source: C:\Alljobs\D328_Waltloo-tank-farm\Reports\D328-00_REP-001_r0_ps-Geotech.docx
Document template: repGeo_r12a.dotx

APPENDIX A

TESTPIT PROFILES

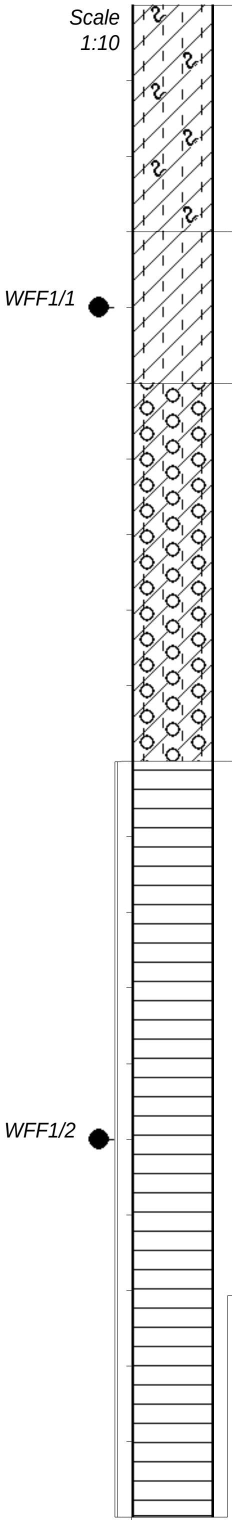
Jones & Wagener
Consulting Civil Engineers
59 Bevan Road PO Box 1434 Rivonia 2128 South Africa
Tel: 011-519-0200 or 011-803-1455 Fax: 011-803-1456 post@jaws.co.za

VGI CONSULTING
WALTLOO FUEL FARM

HOLE No: WFF 01
Sheet 1 of 1

JOB NUMBER: D328

Scale 1:10



0.00

Moist, red brown, <u>firm</u>, fissured and shattered, silty CLAY. **HILLWASH** with roots.

0.30

Moist, grey brown, <u>firm</u>, fissured, silty CLAY. Residual **SHALE / HILLWASH**.

0.50

Closely packed angular shale gravels to 50mm in a matrix of moist, grey blotched orange and olive, silty CLAY. Reworked residual **SHALE**. Overall consistency <u>dense</u>.

1.00

Red, brown, black and orange, highly weathered becoming moderately weathered with depth, <u>very soft rock becoming medium hard rock</u> below 1.2m, closely jointed and bedded; **SHALE**.

<u>Note</u>:
1. Bedding planes dip in a NE direction.

2.00

NOTES

1) TP stopped at required depth, no refusal.

2) No seepage or water table.

3) TP excavated by hand.

4) Indicator sample WFF1/1 taken at 0.4m and bulk sample WFF1/2 taken from 1.0m--2.0m.

CONTRACTOR : GQ CONSTRUCTION
MACHINE :
DRILLED BY : EXCAVATED BY HAND
PROFILED BY : PS

INCLINATION : VERTICAL
DIAM : 1m x 1m
DATE : 14/02/2012
DATE : 14/02/2012

ELEVATION :
X-COORD : 2 846 637
Y-COORD : 68 712

HOLE No: WFF 01

TYPE SET BY : DIANNE
SETUP FILE : STANDARD.SET
DATE : 15/03/12 12:00
TEXT : ..\D328\D328PS~1.DOC

Jones & Wagener
Consulting Civil Engineers
59 Bevan Road PO Box 1434 Rivonia 2128 South Africa
Tel: 011-519-0200 or 011-803-1455 Fax: 011-803-1456 post@jaws.co.za

VGI CONSULTING
WALTLOO FUEL FARM

HOLE No: WFF 02
Sheet 1 of 1

JOB NUMBER: D328

Scale 1:10

0.00 – 0.70		Moist, reddish brown, firm, fissured and shattered, silty CLAY with scattered angular shale gravel. **HILLWASH**.
0.70 – 1.10	WFF2/1	Moist, red blotched olive, firm to stiff, fissured, sandy clayey SILT from reworked residual **DIABASE**.
1.10 – 1.50	WFF2/2, WFF2/3	Moist, orange streaked red brown and olive, firm to stiff, relic jointed, slightly clayey sandy SILT. Reworked residual **DIABASE**.

NOTES

1) TP stopped at required depth.

2) No seepage or water table.

3) TP excavated by hand.

4) Indicator samples WFF2/1 taken at 0.8m; WFF2/2 taken at 1.2m.

5) Block sample WFF2/3 taken at 1.24m.

CONTRACTOR : GQ CONSTRUCTION
MACHINE :
DRILLED BY : EXCAVATED BY HAND
PROFILED BY : PS

INCLINATION : VERTICAL
DIAM : 1m x 1m
DATE : 14/02/2012
DATE : 14/02/2012

ELEVATION :
X-COORD : 2 846 657
Y-COORD : 68 705

HOLE No: WFF 02

TYPE SET BY : DIANNE
SETUP FILE : STANDARD.SET

DATE : 15/03/12 12:00
TEXT : ..\D328\D328PS~1.DOC

Jones & Wagener
Consulting Civil Engineers
59 Bevan Road PO Box 1434 Rivonia 2128 South Africa
Tel: 011-519-0200 or 011-803-1455 Fax: 011-803-1456 post@jaws.co.za

VGI CONSULTING
WALTLOO FUEL FARM

HOLE No: WFF 03
Sheet 1 of 1

JOB NUMBER: D328

Scale 1:10

0.00 – 0.20	Closely packed angular and sub-rounded quartz and shale gravels to 50mm in a matrix of slightly moist, off-white and light red, silty fine and medium SAND. **FILL**. Overall consistency medium dense.
0.20 – 1.20	Moist, brown mottled olive, stiff becoming firm below 0.6m, fissured and shattered over top 0.6m, silty CLAY with relatively closely packed rounded diabase gravels and boulders to 0.7m and angular shale gravels to 40mm. **FILL**.
1.20 – 1.50	Moist, red with olive patches, firm to stiff, fissured and shattered, silty SAND. Residual **DIABASE / FILL**?

NOTES

1) TP stopped at required depth, no refusal.

2) No seepage or water table.

3) TP excavated close to concrete reservoir.

4) No samples taken.

CONTRACTOR : GQ CONSTRUCTION
MACHINE :
DRILLED BY : EXCAVATED BY HAND
PROFILED BY : PS

INCLINATION : VERTICAL
DIAM : 1m x 1m
DATE : 14/02/2012
DATE : 14/02/2012

ELEVATION :
X-COORD : 2 846 680
Y-COORD : 68 690

HOLE No: WFF 03

TYPE SET BY : DIANNE
SETUP FILE : STANDARD.SET

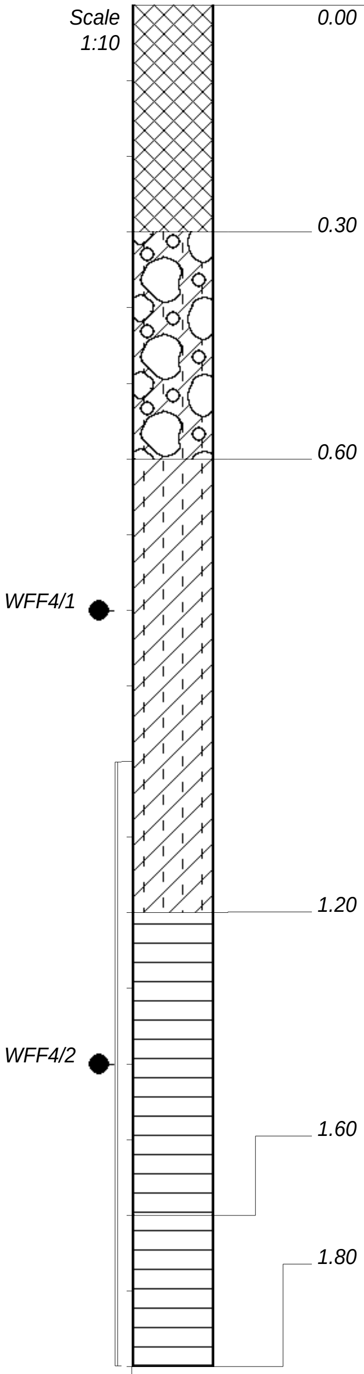
DATE : 15/03/12 12:00
TEXT : ..\D328\D328PS~1.DOC

Jones & Wagener
Consulting Civil Engineers
59 Bevan Road PO Box 1434 Rivonia 2128 South Africa
Tel: 011-519-0200 or 011-803-1455 Fax: 011-803-1456 post@jaws.co.za

VGI CONSULTING
WALTLOO FUEL FARM

HOLE No: WFF 04
Sheet 1 of 1

JOB NUMBER: D328



0.00 – 0.30	Slightly moist, brown layered red-brown, stiff, fissured, silty CLAY with fine roots and scattered sub-rounded diabase gravels to 200mm. **FILL**.
0.30 – 0.60	Slightly moist to moist, dark reddish brown, firm to stiff, fissured and shattered, silty CLAY with relatively closely packed gravels and boulders to 300mm. Residual **SHALE**.
0.60 – 1.20	Moist, grey mottled olive brown, firm to stiff, shattered and slickensided, silty CLAY from slightly reworked residual **SHALE**.
1.20 – 1.60	Dark grey with orange and red staining on joints, highly weathered, closely fissured and bedded with clayey gouge layer in joints, very soft rock; **SHALE**. Note: 1.Bedding plane dips at 20° to 30° towards north.
1.60 – 1.80	Red, brown, black and grey, highly weathered, closely jointed and bedded, very soft rock becoming soft rock below 1.6m; **SHALE** breaking out in angular gravel to 80mm.

NOTES

1) Testpit stopped at specified depth.

2) Testpit excavated by hand.

3) No seepage or water table.

4) Sample WFF4/1 taken at 0.8m depth.

5) Bulk sample WFF4/2 taken from 1.0m--1.8m.

CONTRACTOR : GQ CONSTRUCTION
MACHINE :
DRILLED BY : EXCAVATED BY HAND
PROFILED BY : PS

INCLINATION : VERTICAL
DIAM : 1m x 1m
DATE : 14/02/2012
DATE : 14/02/2012

ELEVATION :
X-COORD : 2 846 695
Y-COORD : 68 695

HOLE No: WFF 04

TYPE SET BY : DIANNE
SETUP FILE : STANDARD.SET

DATE : 15/03/12 12:00
TEXT : ..\D328\D328PS~1.DOC

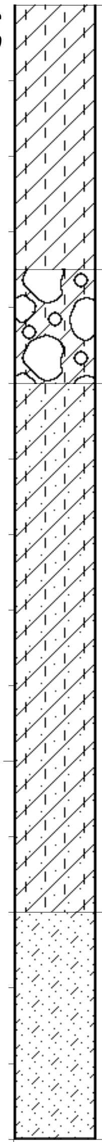
Jones & Wagener
Consulting Civil Engineers
59 Bevan Road PO Box 1434 Rivonia 2128 South Africa
Tel: 011-519-0200 or 011-803-1455 Fax: 011-803-1456 post@jaws.co.za

VGI CONSULTING
WALTLOO FUEL FARM

HOLE No: WFF 05
Sheet 1 of 1

JOB NUMBER: D328

Scale 1:10



0.00		Moist, reddish-brown, firm, fissured and shattered, silty CLAY. **HILLWASH**.
0.35		Closely packed rounded and sub-rounded angular gravels and boulders to 300mm in a matrix of moist, red-brown speckled light grey and black, silty CLAY. Overall consistency medium dense. **PEBBLE MARKER**.
0.50	*WFF5/1*	Moist, red-brown blotched olive and orange, stiff, fissured, sandy silty CLAY from reworked residual **DIABASE**.
1.20	*WFF5/2*	Moist, olive blotched red-brown streaked black, medium dense to dense, clayey fine SAND with relic joints. Residual **DIABASE**. Note 1. Profile becomes less weathered with depth.
1.50		

NOTES

1) TP stopped at required depth, no refusal.

2) No seepage or water table.

3) Indicator sample WFF5/1 taken at 0.6m and WFF5/2 taken at 1.3m.

4) Testpit excavated by hand.

CONTRACTOR : GQ CONSTRUCTION
MACHINE :
DRILLED BY : EXCAVATED BY HAND
PROFILED BY : PS

INCLINATION : VERTICAL
DIAM : 1m x 1m
DATE : 01/02/2012
DATE : 01/02/2012

ELEVATION :
X-COORD : 2 846 731
Y-COORD : 68 684

HOLE No: WFF 05

TYPE SET BY : DIANNE
SETUP FILE : STANDARD.SET

DATE : 15/03/12 12:00
TEXT : ..\D328\D328PS~1.DOC

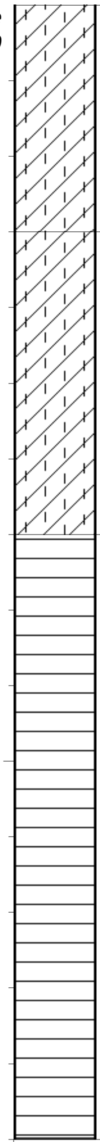
Jones & Wagener
Consulting Civil Engineers
59 Bevan Road PO Box 1434 Rivonia 2128 South Africa
Tel: 011-519-0200 or 011-803-1455 Fax: 011-803-1456 post@jaws.co.za

VGI CONSULTING
WALTLOO FUEL FARM

HOLE No: WFF 06
Sheet 1 of 1

JOB NUMBER: D328

Scale 1:10



0.00

Moist, brown speckled reddish brown, soft to firm, shattered, fissured and slickensided, slightly sandy silty CLAY. **HILLWASH**.

Note:
1. Layer contains sub-angular shale gravels to 70mm.

0.30

Moist, olive brown mottled grey brown, soft with firm patches, shattered and slickensided, silty CLAY breaking out in very soft angular gravels. Residual **SHALE**.

Note:
1. Relic jointed.

0.70

Dark grey with olive staining on joints, very soft rock becoming soft rock with depth, highly weathered, closely jointed and bedded; **SHALE**.

1.50

NOTES

1) Testpit stopped at specified depth.

2) Testpit excavated by hand.

3) No seepage or water table.

4) Bedding plane dipping from 20° to 30° towards north.

CONTRACTOR : GQ CONSTRUCTION
MACHINE :
DRILLED BY : EXCAVATED BY HAND
PROFILED BY : PS

INCLINATION : VERTICAL
DIAM : 1m x 1m
DATE : 01/02/2012
DATE : 01/02/2012

ELEVATION :
X-COORD : 2 846 709
Y-COORD : 68 657

HOLE No: WFF 06

TYPE SET BY : DIANNE
SETUP FILE : STANDARD.SET
DATE : 15/03/12 12:00
TEXT : ..\D328\D328PS~1.DOC

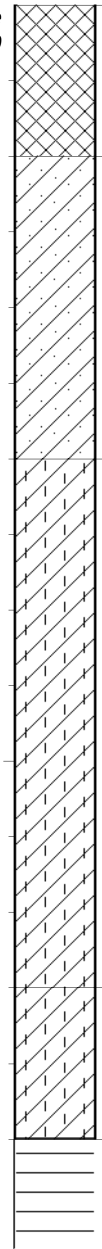
Jones & Wagener
Consulting Civil Engineers
59 Bevan Road PO Box 1434 Rivonia 2128 South Africa
Tel: 011-519-0200 or 011-803-1455 Fax: 011-803-1456 post@jaws.co.za

VGI CONSULTING
WALTLOO FUEL FARM

HOLE No: WFF 07
Sheet 1 of 1

JOB NUMBER: D328

Scale 1:10



0.00

Slightly moist, light orange brown, medium dense, slightly silty fine SILT, relatively closely packed angular quartzite gravels to 50mm. **FILL**.

Note:
1. Layer dipping at 30° towards west.

0.20

Moist, dark reddish brown, stiff, sandy CLAY with scattered gravels and boulders to 30mm. **HILLWASH**.

Note:
1. Bottom of layer represents pebble marker.

WFF7/1

0.60

Moist, olive brown mottled grey, firm, silty CLAY, shattered, fissured and slickensided. Residual **SHALE**.

WFF7/2
WFF7/3

1.30

Moist, grey mottled olive, stiff, silty CLAY, relic jointed and fissured breaking out in fine soft gravels to 10mm. **SHALE**.

1.50

End of hole. Dark grey black, highly weathered, closely fissured, very soft rock breaking out in angular gravels to 50mm. Residual **SHALE**.

NOTES

1) Testpit stopped at specified depth.

2) No seepage or water table.

3) Indicator samples WFF7/1 taken at 0.6m and WFF7/2 taken at 1.0m.

4) Block sample WFF7/3 taken at 1.04m.

CONTRACTOR :	GQ CONSTRUCTION	*INCLINATION :*	VERTICAL	*ELEVATION :*	
MACHINE :		*DIAM :*	1m x 1m	*X-COORD :*	2 846 695
DRILLED BY :	EXCAVATED BY HAND	*DATE :*	01/02/2012	*Y-COORD :*	68 675
PROFILED BY :	PS	*DATE :*	01/02/2012		
TYPE SET BY :	*DIANNE*	*DATE :*	*15/03/12 12:00*	*HOLE No:*	WFF 07
SETUP FILE :	*STANDARD.SET*	*TEXT :*	*..\D328\D328PS~1.DOC*		

APPENDIX B

LABORATORY TEST RESULTS

Jones & Wagener
Consulting Civil Engineers
59 Bevan Road PO Box 1434 Rivonia 2128 South Africa
Tel: (011) 519-0200 Fax: (011) 803-1456 email: post@jaws.co.za

Client:	VGI CONSULTING	Our Ref:	D328
Job:	WALTLOO FUEL FARM	Set no.:	1
Lab:	GEOTECHNICAL INVESTIGATION	Made by:	PS
Tests:	FOR PROPOSED STRUCTURES	Date:	08 March 2012

Classification Data

			1	2	3	4	5	6	7	8	9	10
Hole no.			WFF1	WFF1	WFF2	WFF2	WFF4	WFF4	WFF5	WFF5	WFF7	WFF7
Sample Name			WFF1/1	WFF1/2	WFF2/1	WFF2/2	WFF4/1	WFF4/2	WFF5/1	WFF5/2	WFF7/1	WFF7/2
Depth		m	0.4	1.0-2.0	0.8	1.2	0.8	1.0-1.8	0.6	1.3	0.6	1.0
Description			Res Shale / Hillwash	Shale rock (Bulk)	Res Diabase	Res Diabase	Res Shale	Shale rock (Bulk)	Res Diabase	Res Diabase	Hillwash	Res Shale
Specific Gravity:	G_s		2.710	-	2.770	2.770	2.680	2.720	2.770	2.850	2.720	2.690
Grading:												
		75.0	100	100	100	100	100	100	100	100	100	100
		63.0	100	100	100	100	100	100	100	100	100	100
		53.0	100	100	100	100	100	100	100	100	100	100
		37.5	100	100	100	100	100	100	100	100	100	100
		26.5	100	100	100	100	100	100	100	100	100	100
		19.0	91	100	100	100	100	100	100	100	100	100
		13.2	84	100	100	100	100	100	100	100	100	100
		9.5	81	95	100	100	100	97	100	100	100	100
		6.7	80	90	100	100	100	86	100	100	100	100
	No 4	4.75	77	85	100	100	100	76	96	100	100	100
	No 8	2.36	70	68	98	99	97	56	92	99	96	97
	No 10	2.00	67	63	97	98	94	52	91	99	94	95
	No 16	1.18	60	53	94	96	87	42	88	98	90	90
	No 30	0.600	55	46	93	90	80	36	87	97	88	86
	No 40	0.425	53	43	92	87	77	34	87	96	87	85
	No 50	0.300	51	41	91	83	76	31	86	94	86	84
	No 70	0.212	49	38	90	78	75	29	85	90	85	83
	No 100	0.150	47	36	89	74	73	27	85	83	84	82
	No 200	0.075	43	33	85	66	69	23	83	71	81	77
	No 230	0.060	34	28	69	50	53	20	69	54	63	60
	Hydrometer	0.050	34	27	67	48	53	19	68	52	63	60
	Hydrometer	0.020	29	23	60	37	50	16	63	41	61	57
	Hydrometer	0.005	20	15	48	24	40	11	52	25	52	46
	Hydrometer	0.002	14	10	40	18	32	5	45	19	46	37
Grading Properties												
D_{10}		mm		0.002				0.004				
D_{30}		mm	0.025	0.066		0.009		0.252		0.008		
D_{60}		mm	1.180	1.707	0.020	0.069	0.060	2.714	0.014	0.065	0.017	0.060
Coefficient of Uniformity	CU			853.6				632.4				
Coefficient of Curvature	CC			1.3				5.5				
Grading Modulus	**GM**		**1.37**	**1.61**	**0.26**	**0.49**	**0.60**	**1.91**	**0.39**	**0.34**	**0.38**	**0.43**
Gravel	G	%	33	37	3	2	6	48	9	1	6	5
Sand	S	%	33	35	28	48	41	32	22	45	31	35
Silt	M	%	20	18	29	32	21	15	24	35	17	23
Clay	C	%	14	10	40	18	32	5	45	19	46	37
Fines	M+C	%	34	28	69	50	53	20	69	54	63	60
Atterberg Limits												
Liquid Limit	LL	%	54	59	67	46	69	54	78	44	74	66
Plasticity Index	PI	%	27	36	42	22	46	34	47	15	46	43
Linear Shrinkage	LS	%										
Natural Moisture Content	w	%	14.1	9.3	22.4	25.8	23.4	7.7	26.2	24.0	25.6	22.1
Dry Density	ρ_d	kg/m^3										
Plastic Limit	PL	%	27	23	25	25	23	21	30	29	28	23
PI Whole Sample		%	14	16	38	19	35	11	41	14	40	37
Saturation	S	%										
Liquidity Index	LI		-0.5	-0.4	-0.1	0.1	0.0	-0.4	-0.1	-0.3	-0.1	0.0
			Brittle	Brittle	Brittle	Plastic	Plastic	Brittle	Brittle	Brittle	Brittle	Brittle
Clay Activity	A		1.95	3.63	1.04	1.21	1.44	6.70	1.05	0.77	1.00	1.16
			Active	Active	Normal	Normal	Active	Active	Normal	Normal	Normal	Normal
Vd Merwe Swell			Medium	Low	V/High	Medium	V/High	Low	V/High	Medium	V/High	V/High
Pidgeon Free Swell		%	1.3	6.5	11.1		8.1	4.9	9.6		9.4	10.1
Weston Swell @ p(kPa)	50	%	0.2	0.4	1.8	0.2	0.9	0.1	1.9	0.3	1.7	1.3
Brackley Swell @ p(kPa)	50	%										
Classification												
Matrix Description			**Silty SAND**	**Silty SAND**	**Sandy CLAY**	**Silty SAND**	**Sandy CLAY**	**Silty SAND**	**Sandy CLAY**	**Silty SAND**	**Sandy CLAY**	**Sandy CLAY**
British			**CHS**	**GCH**	**CH**	**CI**	**CH**	**GCH**	**CV**	**MI**	**CV**	**CH**
AASHTO			**A-7-6[7]**	**A-2-7[4]**	**A-7-6[20]**	**A-7-6[12]**	**A-7-6[18]**	**A-2-7[2]**	**A-7-5[20]**	**A-7-6[1]**	**A-7-6[20]**	**A-7-6[20]**
Unified			**SC**	**SC**	**CH**	**CL**	**CH**	**SC**	**CH**	**ML/OL**	**CH**	**CH**

Jones & Wagener Consulting Civil Engineers 59 Bevan Road PO Box 1434 Rivonia 2128 South Africa Tel: (011) 519-0200 Fax: (011) 803-1456 email: post@jaws.co.za		
Client:	VGI CONSULTING	Our Ref: D328
Job:	WALTLOO FUEL FARM	Set no.: 1
Lab:	GEOTECHNICAL INVESTIGATION	Made by: PS
Tests:	FOR PROPOSED STRUCTURES	Date: 08 March 2012

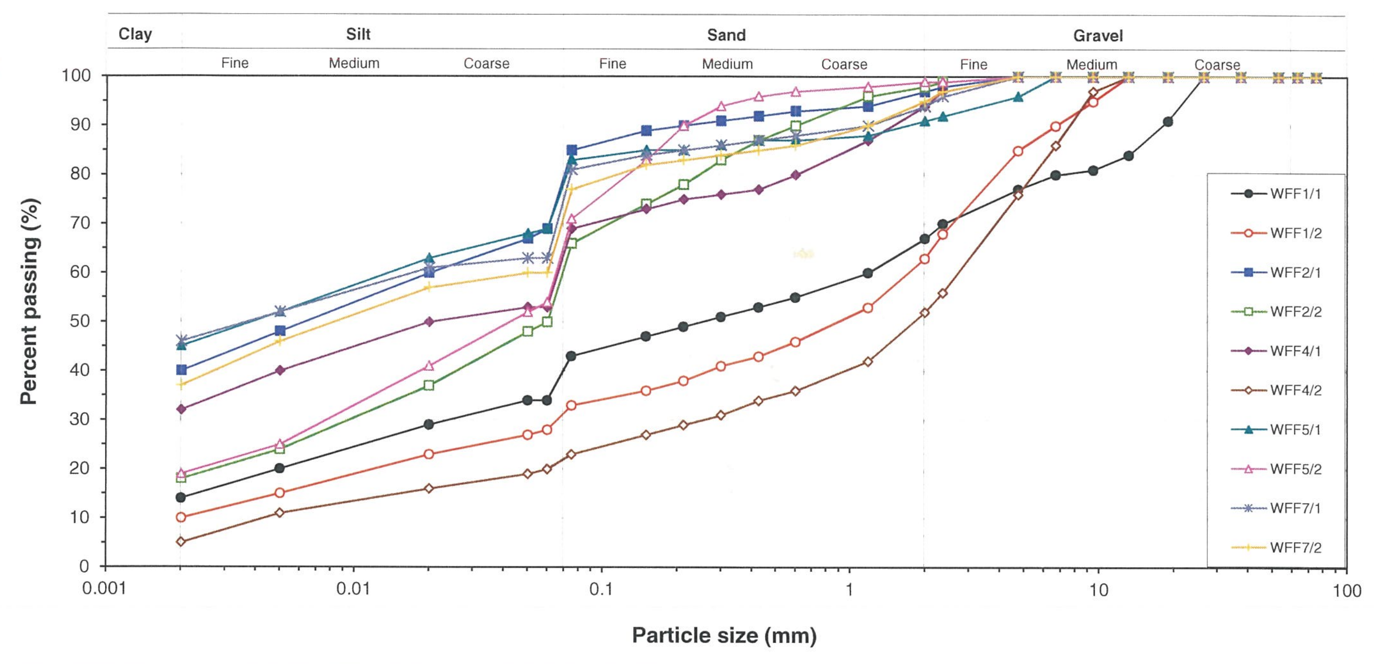
Compaction Data

			1	2	3	4	5	6	7	8	9	10
Hole no.			WFF1	WFF1	WFF2	WFF2	WFF4	WFF4	WFF5	WFF5	WFF7	WFF7
Sample Name			WFF1/1	WFF1/2	WFF2/1	WFF2/2	WFF4/1	WFF4/2	WFF5/1	WFF5/2	WFF7/1	WFF7/2
Depth		m	0.4	1.0-2.0	0.8	1.2	0.8	1.0-1.8	0.6	1.3	0.6	1
Description			Res Shale / Hillwash	Shale rock (Bulk)	Res Diabase	Res Diabase	Res Shale	Shale rock (Bulk)	Res Diabase	Res Diabase	Hillwash	Res Shale
Compaction Energy				Mod				Mod				
Moisture Content	1	%										
	2											
	3											
	4											
	5											
	6											
Dry Density	1	kg/m^3										
	2											
	3											
	4											
	5											
	6											
Maximum Dry Density	**MDD**	kg/m^3		**1860**				**1920**				
Optimum Moisture	**OMC**	**%**		**13.7**				**13.0**				
California Bearing Ratio												
Moisture Content		%		Mod				Mod				
Dry Density	100	kg/m^3		1860				1920				
	97			1825				1880				
	95			1765				1825				
	93			1730				1785				
	90			1675				1730				
Swell	100	%		1.00				0.80				
	95			1.10				0.80				
	90			1.20				0.90				
CBR @ 2.54mm	100	%		17				17				
	97			15				15				
	95			12				12				
	93			10				10				
	90			8				8				
Classification												
Natural - TRH14				**G9**				**G9**				
				Soil				**Soil**				
				SL/SG				**SL/SG**				

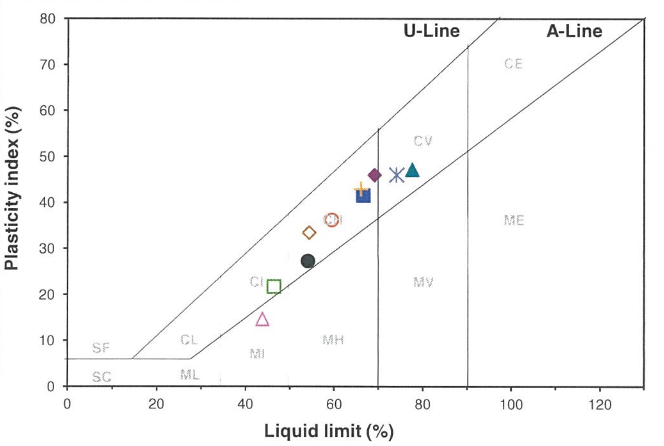
Jones & Wagener
Consulting Civil Engineers
59 Bevan Road PO Box 1434 Rivonia 2128 South Africa
Tel: (011) 519-0200 Fax: (011) 803-1456 email: post@jaws.co.za

Client:	VGI CONSULTING	Our Ref:	D328
Job:	WALTLOO FUEL FARM	Set no.:	1
Lab:	GEOTECHNICAL INVESTIGATION	Made by:	PS
Tests:	FOR PROPOSED STRUCTURES	Date:	08 March 2012

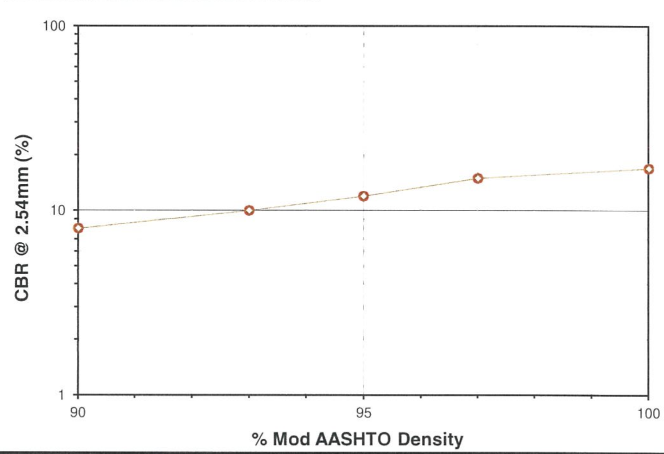
PARTICLE SIZE DISTRIBUTION



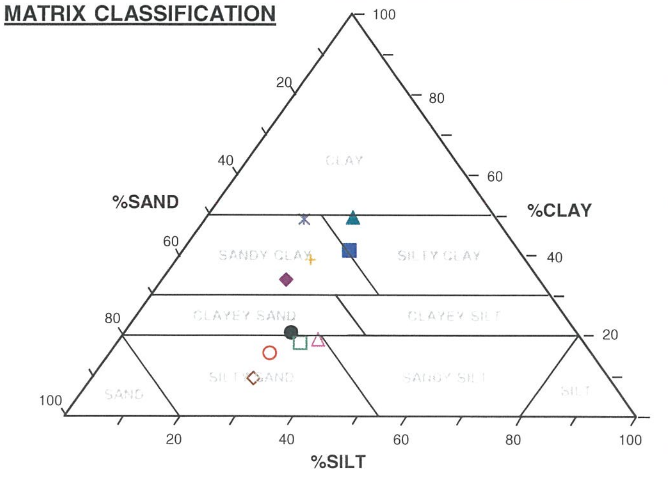
CASAGRANDE CHART



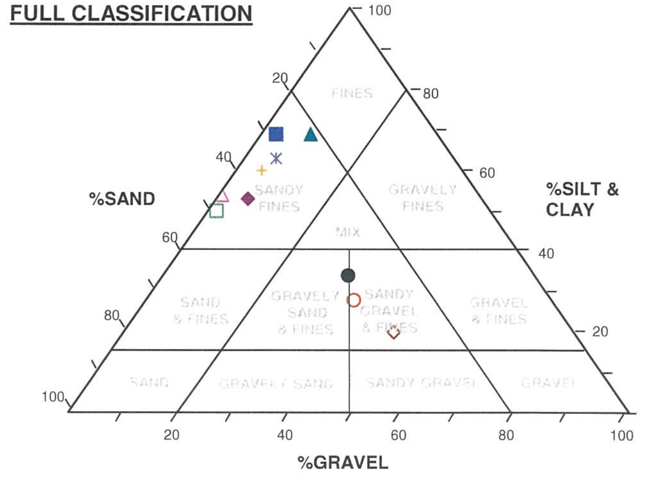
CALIFORNIA BEARING RATIO



MATRIX CLASSIFICATION



FULL CLASSIFICATION



APPENDIX C

PHOTOS

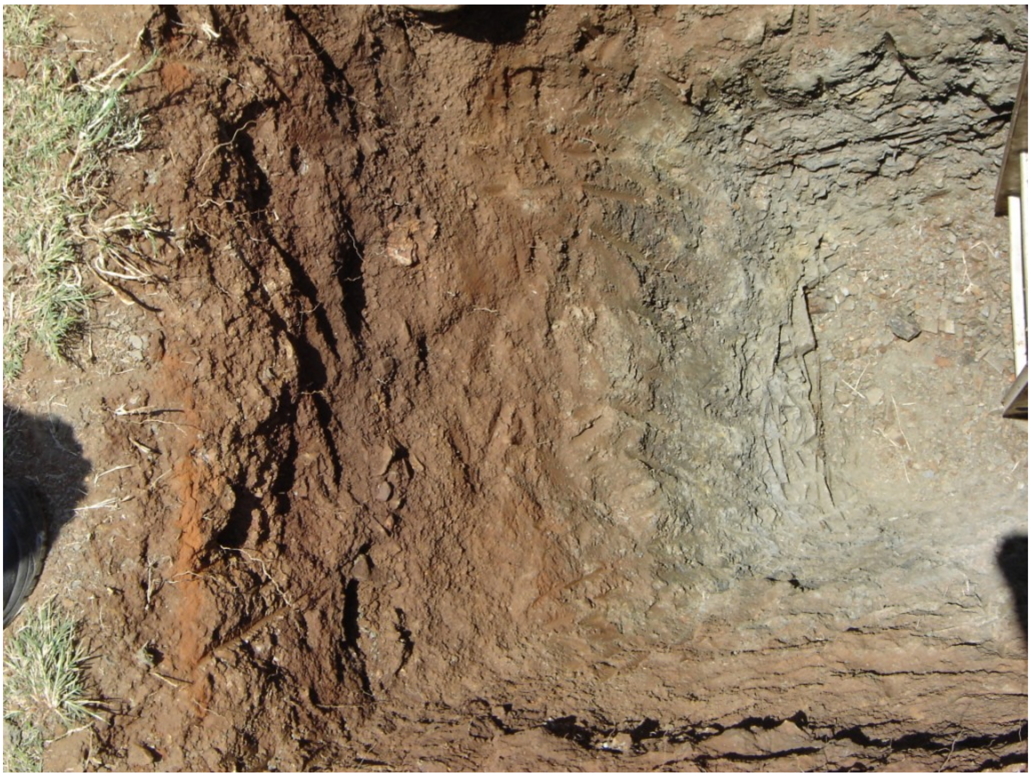


Photo 1 – Reddish hillwash, residual shale and shale rock.

. **Photo 2 - Shale rock excavated as gravel from testpit**