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# TCTA

# MOKOLO AND CROCODILE WATER AUGMENTATION PROJECT (MCWAP)

**CONTRACT № TCTA 07-041**

**CONSULTING SERVICES FOR MCWAP**

## PHASE 2: GEOTECHNICAL INVESTIGATIONS
## Stage 1: Tarantaalpan – Operational Reservoir

## VOLUME 1: GEOTECHNICAL DATA REPORT

**JULY 2012**

**MOKOLO CROCODILE CONSULTANTS**

**Report No: 2A-R-111E-43 (Rev A)**

# MOKOLO AND CROCODILE WATER AUGMENTATION PROJECT

## CONTRACT № TCTA 07-041

## DOCUMENT CONTROL SHEET

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Title : **Phase 2: Geotechnical Investigations**
**Stage 1: Tarantaalpan – Operational Reservoir**
**Volume 1: Geotechnical Data Report**

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[1] Finalisation pending outstanding Phase 2 Geotechnical Results

# MOKOLO AND CROCODILE WATER AUGMENTATION PROJECT

# CONTRACT № TCTA 07-041

# PHASE 2: GEOTECHNICAL INVESTIGATIONS
# Stage 1: Tarantaalpan – Operational Reservoir

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# MOKOLO AND CROCODILE WATER AUGMENTATION PROJECT

# CONTRACT № TCTA 07-041

# PHASE 2: GEOTECHNICAL INVESTIGATIONS Stage 1: Tarantaalpan – Operational Reservoir

# VOLUME 1: GEOTECHNICAL DATA REPORT

# EXECUTIVE SUMMARY

## Introduction

Mokolo Crocodile Consultants (MCC) has been appointed by the Trans-Caledon Tunnel Authority (TCTA), the implementing agency, to undertake the detailed design of the Mokolo and Crocodile Water Augmentation Project (MCWAP).

The MCWAP is implemented using a phased approach. Phase 2 has, for practical reasons, been split into 4 Stages. This Report deals with Phase 2: Stage 1 of the Project, extending from Tarantaalpan in the south, parallel to the railway line to the Operational Reservoir in the north, a distance of approximately 55,5 km. Similar and separate reports have been generated for the other 3 Stages.

In partial fulfilment of Sub-Task 1.1.1E – Field Investigation Report of Appendix A of the Scope of Services for the MCWAP, further geotechnical investigations were undertaken. Following an evaluation of available geotechnical information obtained from feasibility stage investigations, this task comprised the planning and execution of geotechnical field investigations. The feasibility investigation work comprised a few (at 5 km spacing) test pits along the centreline.

Report “Phase 2 Stage 1: Geotechnical Investigations” comprises three volumes, of which this is Volume 1:

- Volume 1: Geotechnical Data Report (**This Volume**);
- Volume 2: Annexures supporting Volume 1; and
- Volume 3: Geotechnical Interpretive Report.

This Volume contains the narrative, factual data, whilst Volume 2 contains the Annexures supporting the Report. Volume 3 interprets the data contained in Volumes 1 and 2 and should be read in conjunction with them.

## Background

The Department of Water Affairs (DWA) commissioned the Mokolo and Crocodile River (West) Water Augmentation Project (MCWAP) Feasibility Study to analyse the options for transferring water from the Mokolo Dam and Crocodile River (West). In April 2008 the Technical Module of this study was awarded to Africon (now incorporated in Aurecon) in association with Kwezi V3 (now incorporated in Worley Parsons), VelaVKE and specialists. The focus of the Technical Module was to investigate the feasibility of options to:

- Augment the supply from Mokolo Dam to supply the growing water requirement for the interim period until a transfer pipeline from the Crocodile River (West) can be implemented (Phase 1); and
- Transfer water from the Crocodile River (West) to the Lephalale area (Phase 2).

The Technical Module had been programmed to be executed at a Pre-feasibility level of investigation to identify different options and recommend the preferred schemes. This was followed by a feasibility level investigation of the preferred water schemes. Recommendations on the preferred options for Phase 1 and Phase 2 were presented to DWA during October 2008 and draft reports were submitted during December 2008. The Feasibility Stage of the project commenced in January 2009 and considered numerous water requirement scenarios, project phasing and optimisation of pipeline routes. The study team submitted draft Feasibility Reports during October 2009 to the MCWAP Main Report in November 2009.

As part of the Tender Design stage, detailed geotechnical investigations have been performed for Phase 2 Stage 1 of the MCWAP. Components investigated include the pipeline route, the Operational Reservoir, road and river crossings and borrow pits.

This Report outlines and summarises the results and findings of the geotechnical investigations.

## Pipeline Route Investigations

The pipeline route investigation comprised test pitting at a nominal spacing of 200 m (using a TLB[1]) along the centreline of the pipeline route. The pits were dug to a depth of 4 m (or to refusal of the TLB) and were profiled in accordance with standard procedures and profiles of each test pit have been compiled. The soils encountered were sampled and tested to assess their suitability for use as bedding and selected backfill to the pipe. Laboratory tests (Indicator and compactability tests) were carried out on representative samples. Occasional pH, conductivity tests and chemical (SRB) tests were carried out on different soil types in order to assess the aggressiveness of the soils towards the steel pipeline.

Geotechnical tests (triaxial, shearbox and Constrained Soil Modulus) were carried out in order to quantify the characteristics of the soils when used as bedding or selected backfill to the pipeline.

The topsoil and subsoil (at borrow pit sites and along the centreline) were tested to establish their fertility and to provide baseline data when rehabilitating borrow pits and over the backfilled pipeline.

[1]Minimum characteristics: a) Backhoe depth not less than 4 m; gross power not less than 70 kW; and bucket breakout force not less than 60 kN.

Dynamic Probes – Light (commonly referred to as DCPs) were conducted in and adjacent to selected test pits in order to provide a quantitative assessment of the consistency of the soils encountered. These soundings were reduced to equivalent Standard Penetration Tests (SPT) N-values (blows per 300 mm penetrated) and are presented graphically (as SPT N-values versus depth) on the soil profiles.

**Borrow Pits**

Six borrow pits were located, providing suitable bedding and selected backfill material, generally at an economic spacing for haulage purposes during construction. In places the targeted spacing of 5 km has not been achieved. For approximately 15 km south of the Matlabas River a gap exists as permission to prospect was not granted by the affected landowners. Additionally the borrow source (BP38) located immediately south of this area, proved, upon laboratory testing, to be unsuitable. A further gap is present south of BP33 as the borrow source investigated in this area (BP28) also proved to be too clayey. Further investigation is necessary to resolve these shortcomings. The results of the borrow pit investigation are presented in Annexure B, and include locality plans, test pit profiles and results of laboratory testing. The main characteristics are summarised hereunder in Table 16.

**Table 16: Borrow pit summary**

| BP no. | Location (WGS84 Lo27) | | Chainage (m) | Offset to pipeline (m) | Est. volume bedding & soft backfill ($m^3$) | Compactability Factor (range) |
|---|---|---|---|---|---|---|
| | Y | X | | | | |
| 28 | -045 267 | 2 697 434 | 8,600 | 200L | Unsuitable, too clayey | |
| 33 | -045 410 | 2 687 900 | 17,900 | 100L | 200,000 | 0.29 – 0.40 |
| 41 | 044 850 | 2 682 930 | 23,100 | 600L | >100,000 | 0.32 – 0.47 |
| 38 | -044 400 | 2 675 400 | 31,200 | 800L | Unsuitable, too clayey | |
| 39 | -042 250 | 2 663 800 | 42,900 | 70R | 100,000 | 0.30 – 0.38 |
| 42 | -041 400 | 2 658 300 | 46,900 | 70R | >100,000 | 0.35 – 0.40 |
| 44 | -039 920 | 2 651 500 | 54,800 | 100L | >100,000 | 0.34 – 0.47 |
| 43 | -040 400 | 2 645 700 | 63,000 | 100L | 100,000 | 0.32 – 0.39 |

L = Left / West of pipeline R = Right / East of pipeline

The granular materials from BP 33 shows elevated sulphide levels.

### Road and River Crossings

At the R510 Road Crossing (farm Ruigtevley 97KQ), the rockhead was intersected between 3.70 m and 4.20 m and medium hard rock Waterberg sandstone was encountered at a depth of 4.90 m and 5.25 m respectively.

At the Railway Overpass Road Crossing (farm Groenrivier 95KQ, Ptn 37), the rockhead was intersected between 1.70 m and 3.75 m and medium hard to hard rock Waterberg sandstone was encountered at a depth of 2.20 m and 4.50 m, respectively.

At the Road D2701 Crossing (farm Haarlem Oost 51KQ), the rockhead was intersected between 1.35 m and 1.75 m and hard Lebowa Granite was encountered at a depth of between 2.57 m and 6.75 m.

At the Matlabas River Crossing (approximately Chainage 41,820 to 49,000 m), the rockhead was intersected between 2.50 m and 5.48 m. Medium hard rock Waterberg siltstone was encountered from 7.90 m on the left bank, while very soft to hard rock post-Waterberg diabase (dolerite) was encountered from 7.50 m on the right bank.

At the Operational Reservoir (Chainage 63,200 m; farm Rooipan 357LQ Ptn 4), the rockhead was intersected between 2.20 m and 4.37 m and localized soft to medium hard rock sandstone was encountered below 5.40 m. Nodular and honeycomb to hardpan ferrricrete occurred between 1.40 m and 3.41 m.

### Findings

The geology of the area comprises Waterberg sandstone over most of the route, with limited exposures of granite in the south. Diabase is intruded into the Waterberg and granite over the southern half (essentially south of the Matlabas River). North of the Matlabas River, extensive occurrences of Quaternary sand occur, blanketing the sandstone. Calcrete and ferricrete (with occasional silcrete) occur at the base of the sand.

The investigation was carried out in March and April, after the rainy season. Despite this, in only a single test pit (CC/202) was groundwater encountered and this was recorded as “slight seepage”. The loose sand above the seepage (at 2.1 m depth) caved in.

In addition to the bedding material from the borrow pits, gravel (present below the sand) was identified and sampled for use in gravelling haul roads and regravelling of existing roads that may be damaged during hauling operations.

The nearest known commercial sources of crushed stone and crusher dust are located about 90 km south of the southern end of the stage. Alternatively these materials can be sourced from Lephalale (about 65 km from the Operational Reservoir).

## Laboratory Test Results

At time of writing, not all laboratory test results have necessarily been supplied by the testing laboratory and the following cut-off dates apply:

- Received by 31 July 2011; bound into Annexures (Volume 2) and have been interpreted in Volume 3; and
- Received after 1 August 2011, are not bound into Volume 2, not interpreted in Volume 3 and are stored electronically in the Project Files.

On the first page to each Annexure in Volume 2 a summary is included detailing the status of any outstanding test results.

# MOKOLO AND CROCODILE WATER AUGMENTATION PROJECT

# CONTRACT № TCTA 07-041

# PHASE 2: GEOTECHNICAL INVESTIGATIONS
# Stage 1: Tarantaalpan – Operational Reservoir

# VOLUME 1: GEOTECHNICALDATA REPORT

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# MOKOLO AND CROCODILE WATER AUGMENTATION PROJECT

# CONTRACT № TCTA 07-041

# PHASE 2: GEOTECHNICAL INVESTIGATIONS Stage 1: Tarantaalpan – Operational Reservoir

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# MOKOLO AND CROCODILE WATER AUGMENTATION PROJECT

# CONTRACT № TCTA 07-041

# PHASE 2: GEOTECHNICAL INVESTIGATIONS STAGE 1: Tarantaalpan – Operational Reservoir

# VOLUME 1: GEOTECHNICAL DATA REPORT

# GLOSSARY

| | |
|---|---|
| ARC | Agricultural Research Council of South Africa |
| BH | Borehole |
| BP | Borrow pit |
| CBR | California Bearing Ratio |
| DCP | Dynamic Cone Penetrometer |
| DPL | Dynamic Probe – Light |
| DWA | Department of Water Affairs |
| MCC | Mokolo Crocodile Consultants |
| MCWAP | Mokolo and Crocodile Water Augmentation Project |
| PI | Plasticity Index |
| PPI | Probable Performance Index |
| Ptn | Portion |
| SANAS | South African National Accreditation System |
| SPT | Standard Penetration Test |
| SRB | Sulphate Reducing Bacteria |
| TCTA | Trans-Caledon Tunnel Authority |
| TLB | Tractor-loader-backhoe |
| WGS84 | World Geodetic System (dated 1984) |

# 1 INTRODUCTION

Mokolo Crocodile Consultants (MCC) has been appointed by the Trans-Caledon Tunnel Authority (TCTA), the implementing agency, to undertake the detailed design of the Mokolo and Crocodile Water Augmentation Project (MCWAP).

The MCWAP is implemented using a phased approach. In partial fulfilment of Sub-Task 1.1.1E – Field Investigation Report of Appendix A of the Scope of Services for the MCWAP, further geotechnical investigations were undertaken. Following an evaluation of existing available geotechnical information obtained from Feasibility Stage investigations, this task comprised the planning and execution of further geotechnical field investigations which had been identified as being necessary. The Feasibility Stage work comprised investigation of the sub-surface materials along the pipeline route.

The results of the geotechnical investigations conducted during the Feasibility Stage, and forming part of Sub-Task 1.1.1E, are presented and interpreted by MCC as baseline information on the engineering properties, the corrosion properties and the agricultural properties during the design, tender and construction stages.

For practical purposes Phase 2 is reported on in 4 separate Stages as follows:

- Stage 1: Tarantaalpan to Operational Reservoir (along Transnet rail line) (55.5 km);
- Stage 2: Crocodile River to Transnet rail line (42.0 km);
- Stage 3: Operational Reservoir to Steenbokpan (approximately 27.8 km); and
- Stage 4: Steenbokpan to Matimba (approximately 37.9 km).

This Report deals only with Phase 2 Stage 1 of the Project. Similar reports will be compiled for the other three Stages making up Phase 2. The location of the different Stages is shown on the Locality Plan (Figure 1).

The diameter of the pipeline has not yet been established. Interpretations given in the report assumes a diameter of 2,000 mm and will have to be amended once the actual pipe diameter is known.

## 1.1 Background

### 1.1.1 Feasibility Investigations

The Department of Water Affairs (DWA) commissioned the Mokolo and Crocodile River (West) Water Augmentation Project (MCWAP) Feasibility Study to analyse the options for transferring water from the Mokolo Dam and Crocodile River (West). In April 2008 the Technical Module of this study was awarded to Africon (now incorporated in Aurecon) in association with Kwezi V3 (now incorporated in Worley Parsons), VelaVKE and specialists. The focus of the Technical Module was to investigate the feasibility of options to:

- Augment the supply from Mokolo Dam to supply the growing water requirement for the interim period until a transfer pipeline from the Crocodile River (West) could be implemented (Phase 1); and
- Transfer water from the Crocodile River (West) to the Lephalale area (Phase 2).

The Technical Module had been programmed to be executed at a Pre-Feasibility level of investigation to identify different options and recommend the preferred schemes. This was followed by a Feasibility level investigation of the preferred water schemes. Recommendations on the preferred options for Phase 1 and Phase 2 were presented to DWA during October 2008 and draft and final reports were submitted during December 2008. The Feasibility Stage of the project commenced in January 2009 and considered numerous water requirement scenarios, project phasing and optimisation of pipeline routes. The study team submitted draft Feasibility Reports during October 2009 to the MCWAP Main Report in November 2009.

As part of the Feasibility investigations, geotechnical investigations were performed for Phase 2 of the MCWAP. These included the following:

**a) Pipeline Route Investigations**

The pipeline route investigation carried out during the Feasibility Stage comprised test pitting (using a TLB2) along the centreline of the pipeline route at a nominal spacing of 5 km. The pits were dug to a depth of 4 m (or to refusal of the TLB), were profiled in accordance with standard procedures and logs of each test pit compiled. The soils encountered were visually evaluated to provide a preliminary assessment of their suitability for use as bedding and selected backfill to the pipe. No borrow sources were identified, nor was any laboratory testing carried out on any samples.

Dynamic Probes – Light (DPL, commonly referred to as DCPs) were conducted adjacent to and in selected test pits in order to provide a quantitative assessment of the consistency of the soils encountered. These soundings were reduced to equivalent Standard Penetration Tests (SPT) N-values (blows per 300 mm penetrated) and are presented graphically (as SPT N-values versus depth) on the soil profiles.

Applicable data from these investigations has been extracted from the reports on this work and is integrated into the current report.

The fieldwork was carried out under competitive tender by the soils testing laboratory, Civilab.

**b) Potential Borrow Pits**

No borrow pit investigation was carried out.

[2] Minimum characteristics: a) Backhoe depth not less than 4 m; gross power not less than 70 kW; and bucket breakout force not less than 60 kN

**c) Feasibility Study Report**

Supporting Report 8b – Detailed Geotechnical Investigations (Report Number P RSA A000/00/8409) prepared by the lead Consultant, Africon, in association with other consultants, covers the results obtained from these investigations undertaken during Feasibility Stage.

### 1.1.2 Current Investigations

Following selection of the final alignment, a detailed geotechnical investigation was carried out to characterise the material conditions along the pipeline and to define borrow sources along the route. The investigation comprised the following aspects:

a) Excavation of test pits at nominal 200 m centres along the pipeline;
b) The proving of sources of borrow material for bedding and backfill material at a nominal spacing of 5 km. Test pits were dug at a nominal spacing of 30 m to prove a nominal 100,000 $m^3$ of suitable material at each borrow site;
c) Laboratory testing (Indicators, pH, conductivity, compactability, triaxial, shearbox, Constrained Soil Modulus) was carried out to characterise the materials encountered;
d) Additionally, SRB and Fertility tests were carried out to define the corrosion potential of the soils encountered and to provide baseline data for rehabilitation along the pipeline and at borrow pits;
e) Core drilling was carried out at the crossing of various surfaced roads, the Matlabas River and the Operational Reservoir to provide foundation and subsurface data at these positions; and
f) A desk-top seismic hazard assessment.

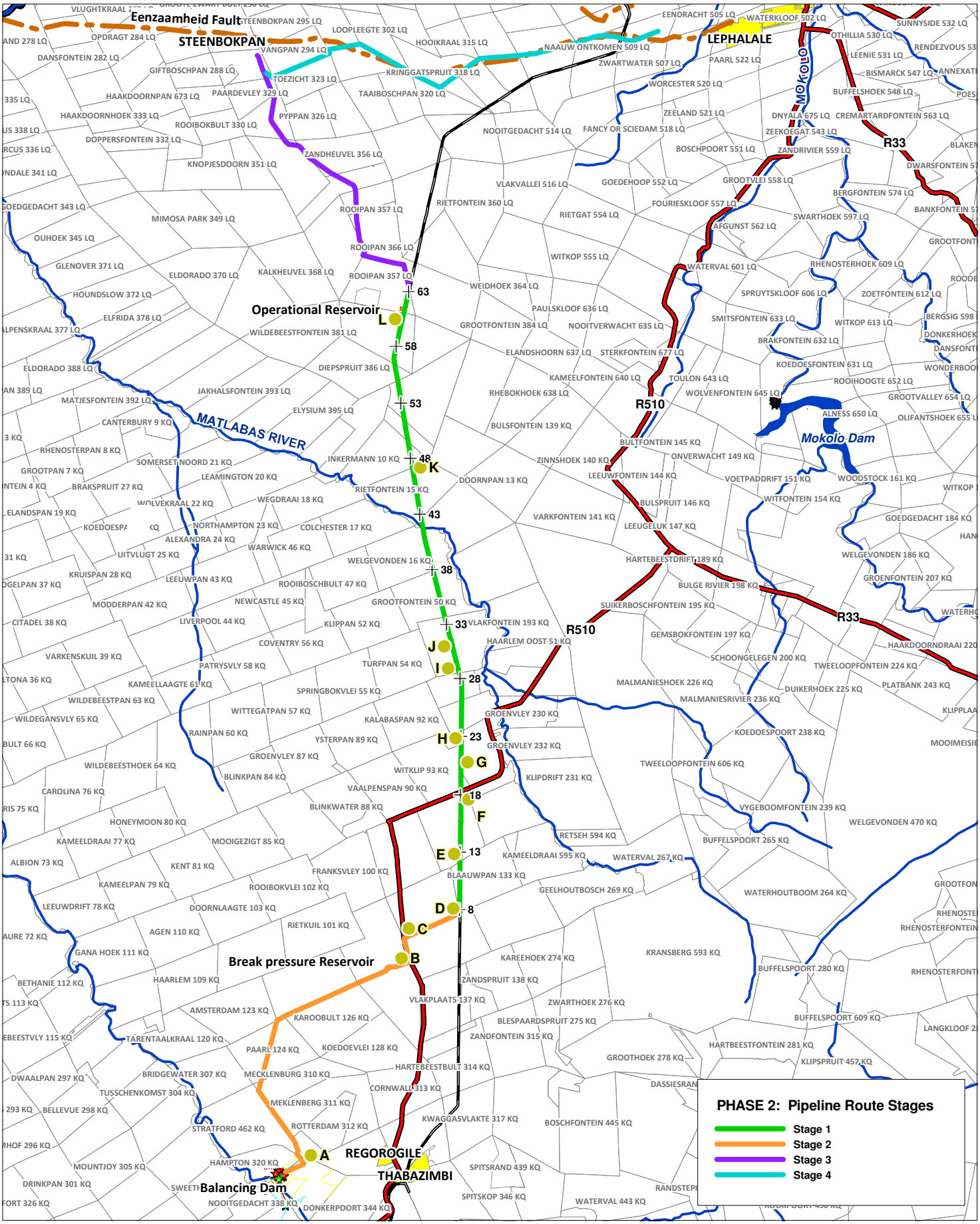
The fieldwork and laboratory testing was carried out by Geostrada, under competitive tender. Core drilling was carried out by Geomech Africa, also under competitive tender.

## 2 SCOPE OF REPORT

### 2.1 Scope of Geotechnical Investigations

This Report covers and summarises the results of the detailed geotechnical investigations conducted during the Tender Design Stage along the pipeline route from Tarantaalpan (Chainage 7,700 m) to the Operational Reservoir (Chainage 63,200 m), a distance of 55.5 km. The pipeline over this part of the route is located on the western side of and parallel to the Thabazimbi – Lephalale railway line.

A Locality Map for Phase 2 is included as Figure 1 (Drawing No. 2A-G3-020).




**Legend**

- Spoil Sites
- km
- Main Roads
- Railway Line
- Rivers
- Farm Boundaries
- Towns

Scale: 1:440,000

5 0 5 10
Kilometers

N

**Project:** Mokolo and Crocodile (West) Water Augmentation Project

**Drawing Title:** Phase 2 Locality Plan

**Drawing Number:** 2A-G3-020

**Rev:** FIG 1



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# 3 AVAILABLE GEOTECHNICAL INFORMATION

## 3.1 Desk Study

The investigations commenced with a desk study of available information, the findings of which are summarised hereunder:

- Consultation with Transnet personnel – no records could be traced of previous geotechnical investigations for the existing Thabazimbi – Lephalale railway line. This was unfortunate, as the pipeline parallels the railway line for the full 55.5 km; and
- Researching documented geology on published geological maps.

## 3.2 Published Information

Available geological information included the published 1:250 000 scale geological maps (Council for Geoscience). The sheets relevant to this report are:

- Sheet 2326 Ellisras; and
- Sheet 2426 Thabazimbi.

## 3.3 Feasibility Study Investigations

During the Feasibility Study for the MCWAP, test pitting was carried out along the centreline of the pipeline route, at a nominal spacing of 5 km. Test pits were profiled, but no laboratory testing was carried out. The investigation was reported to the (then) Department of Water Affairs and Forestry as the report “Mokolo and Crocodile River (West) Water Augmentation Project (MCWAP) Feasibility Study: Technical Module: Supporting Report No. 8b: Detail Geotechnical Investigations: Phase 2”.

The data from the earlier report has been extracted and is incorporated into this Report.

# 4 INVESTIGATION METHODOLOGY

This section describes the investigation methodology followed during the Tender Design investigations.

## 4.1 Outline

A broad outline of the geotechnical investigations comprised the following:

- Assessment of climate and weathering;
- Desk study of available information;
- Field verification of the geology;
- Rotary core drilling;
- Test pitting along the pipeline;
- Test pitting in potential borrow pits;
- Dynamic Penetrometer Light (DPL) tests (commonly referred to as DCP tests);
- Laboratory testing of material samples taken in the field; and
- Desk-top seismic hazard assessment.

As the pipeline diameter had not been fixed at the time of the investigations, these were based on an assumed diameter of 2,000 mm.

## 4.2 Desk Study

Available geological and geotechnical data was assessed in order to obtain background information relating to the expected geotechnical conditions on the site. On a broad level, the published geological maps (Council for Geoscience) were studied and images from Google Earth®. The available sources of information are listed in Section 3.2 above.

## 4.3 Field Verification of the Geology

During the field investigations a visual inspection of rock outcrops was carried out (and areas of outcrop were marked up on aerial photographs) in order to confirm the geology of the site.

The co-ordinates of test pits excavated along the pipeline were recorded using a hand-held GPS instrument. Coordinates comply with the WGS84 co-ordinate system, utilising the Hartbeeshoek94 Datum (South African Grid, Lo 27). The boreholes drilled at road and river crossings and at the Operational Reservoir were accurately surveyed after completion.

## 4.4 Rotary Core Drilling (see Annexure C)

Rotary core boreholes were drilled at a limited number of locations along the pipeline route where it crosses existing roads and rail infrastructure and at pipeline structures. Boreholes were drilled at the following sites:

- R510 road crossing (farm Ruigtevley 97 KQ Remainder);
- Railway overpass road crossing (farm Groenrivier 95KQ, Ptn. 37);
- Road D2701 road crossing (farm Haarlem Oost 51KQ Ptn. 5);
- Matlabas River crossing; and
- at the Operational Reservoir.

This drilling was carried out in order to provide information regarding the in-situ conditions at these sites.

Borehole cores were logged by an engineering geologist in accordance with accepted South African practice (SANS 633: 2009 DRAFT) and the cores photographed. Borehole logs were prepared using DotPlot® software and are included in Annexure C1. Photographs of the core boxes are included in Annexure C2.

Borehole location and details are listed below in Table 1.

The borehole cores are available for inspection at the Department of Water Affairs' premises in Brits.

**Table 1: Summary of borehole details**

| Borehole no. | Coordinates (WGS84, Lo27) | | BH collar elevation | BH depth (m) |
|---|---|---|---|---|
| | Y | X | | |
| 49 | -45 628.99 | 2 687 642.82 | 1014.04 | 10.35 |
| 50 | -45 629.76 | 2 687 583.33 | 1014.66 | 10.15 |
| 51 | -45 674.16 | 2 682 745.84 | 1021.42 | 9.85 |
| 52 | -45 674.64 | 2 682 712.94 | 1021.23 | 9.99 |
| 53 | -45 034.77 | 2 675 409.25 | 986.10 | 10.19 |
| 54 | -45 026.23 | 2 675 344.67 | 982.22 | 10.00 |
| 55 | -42 294.61 | 2 664 487.92 | 937.92 | 10.17 |
| 56 | -42 290.64 | 2 664 468.35 | 935.31 | 10.18 |
| 57 | -42 282.77 | 2 664 418.42 | 938.87 | 10.00 |
| 58 | -40 928.81 | 2 643 289.72 | 1015.30 | 10.00 |
| 59 | -40 776.60 | 2 643 586.67 | 1030.09 | 10.03 |
| 60 | -41 045.10 | 2 643 573.76 | 1032.43 | 10.14 |

## 4.5 Centreline Test Pitting (see Annexure A)

Test pits were dug along the pipeline route in order to assess the thicknesses and quality of the in-situ material. The test pits were dug using a New Holland B90B tractor-loader-backhoe (TLB). Excavation with a TLB gives a direct assessment of the excavatability of the materials present and allows their inspection in an undisturbed state.

The characteristics of the TLB are:

**Table 2: Characteristics of TLB**

| Specification | New Holland B90B |
|---|---|
| Overall power (kW) | 72 |
| Maximum Torque (Nm/rpm) | 400/1400 |
| Bucket width (mm) | 610 |
| Maximum reach (mm) | 4270 |

Holes were generally dug to refusal of the TLB, or to a maximum depth of 4 m (based on an assumed 2,000 mm diameter pipeline).

A summary of all the test pits dug is given in Annexure A1.

The profiles encountered were logged by a geospecialist and samples were taken of representative horizons. Test pit profiles appear in Annexure A2. Profiles were logged in accordance with Brink and Bruin, 2002.

After logging and sampling the holes were backfilled using the TLB. Where the nature of the in-situ materials permitted it, DPL tests were carried out in order to obtain a quantitative assessment of the consistency of the soils encountered. The DPL soundings are reduced to equivalent SPT N-values (blows per 300 mm penetrated) and presented graphically as N-value versus depth on the test pit profiles.

Slight seepage was encountered in a single test pit (CC/202) at a depth of 2.1 m.

At the time of profiling, a visual assessment of the conditions encountered in the hole was made in order to allow interpolation of laboratory test results between the sites, and comments were recorded relating to:

- depth of refusal and nature of material on which refusal took place;
- stability of trench sides;
- likely longer term (safe) side slopes during construction;
- the presence of groundwater/seepage, level of occurrence, initial inflow and rest level after 24 hours;
- the anticipated utilisation (as bedding or soft backfill) of the soils encountered; and
- any other observations relevant to construction of the pipeline.

It must be accepted that these comments were made without the benefit of laboratory test results or detailed analysis, are indicative only of the observations made on site, must NOT be relied on and do not form part of interpretation of the data.

### 4.6 Borrow Sources (see Annexures B and D)

Sources of material suitable for use as bedding or soft backfill to the pipe were sought at a nominal spacing of 5 km along the pipeline and volumes were proven by digging test pits on a grid of 30 m. Assuming a pipe diameter of 2 m and corresponding trench dimensions, the target volume of material was 100,000 $m^3$ per borrow pit, which approximates to 200% of the volume of material required as bedding/backfill for 5 km of pipeline. The estimated requirement of 100,000 $m^3$/5 km ignores the fact that suitable bedding and backfill material may be sourced from the pipe trench.

With reference to borrow sources of potential bedding and selected backfill material, the investigation was aimed at locating material with the following minimum quality characteristics:

a) Maximum particle size 19 mm;
b) Not more than 5% passing the 13.2 mm sieve;
c) Not more than 20% passing the 0.425 mm sieve; and
d) PI less than 12.

While these do not necessarily meet the specification for bedding and selected backfill, they were target values for identifying borrow sources.

The compactability requirements for the selected granular material are ideally as follows:

**Table 3: Suitability of granular backfill material**

| Compactability Factor[3] | Suitability |
|---|---|
| ≤0.1 | Material suitable |
| > 0.1 ≤0.4 | Material suitable (except for flexible pipes that may be subject to waterlogged conditions) but require extra care in compaction |
| > 0.4 | Material unsuitable |

Where gravel is present below the bedding material, this was sampled and tested to define its use in gravelling haul and access roads.

The results of the laboratory testing are given in Annexure B and plans of individual borrow pits are given in Annexure D.

## 4.7 Laboratory Testing (see Annexure B)

Laboratory testing was carried out in order to quantify the characteristics of the materials encountered along the pipeline route.

All laboratory testing was carried out by SANAS-accredited testing laboratories (Geostrada, ARC and Waterlab). The standard test methods employed are shown on the test results. The following tests were carried out:

- Road Indicator tests (sieve grading and Atterberg Limit determinations);
- Foundation Indicator testw (as above but with hydrometer gradings to quantify the silt and clay fractions);
- Compactability tests and moisture content;
- pH and conductivity;
- CBR tests on potential gravel materials;
- Shearbox tests;
- Triaxial tests;
- $M_s$ (constrained soil modulus) tests;
- Soil fertility tests (carried out by ARC); and
- SRB potential tests (carried out by Waterlab).

The results of the laboratory testing are given in the Annexures as follows:

- Annexure A – Centreline Data; and
- Annexure B – Borrow Pit Data.

[3] *per SABS 1200 LB and SABS 0120: Part 3 LB*

### 4.8 Soil Fertility Testing

Samples of fertile soil were taken from the topsoil (0 to 300 mm) and subsoil (300 mm to 600 mm) with a minimum of two soil test pits per property in order to establish baseline parameters of the agricultural properties of the fertile segment. Samples were also taken from borrow pits. The samples, of approximately 2 kg, were placed in clean plastic bags for laboratory testing.

The following soil analyses were determined on each fertile soil sample:

- Plant available nutrients – P, K, Mg, Ca;
- pH (TMH1 A20);
- %C;
- Soil particle size;
- %N;
- Cation Exchange Capacity (CEC); and
- Electric conductivity (TMH1 A21T).

Testing was carried out in accordance with the standards given in the Soil Science Society of SA handbook. The test results are given in Annexure A3.4 (for the centreline) and Annexure B2.4 (for borrow pits).

## 5 GENERAL GEOLOGICAL SETTING

### 5.1 Regional Geology

Virtually the entire site, except for limited exposures of granite in the south, is underlain by sandstones of the Waterberg Group, which are considered to be between 1,700 and 2,000 million years in age (Johnson et. al., 2006). The Lebowa Granite Suite (3G1) ranges between 2,050 and 2,060 million years in age.

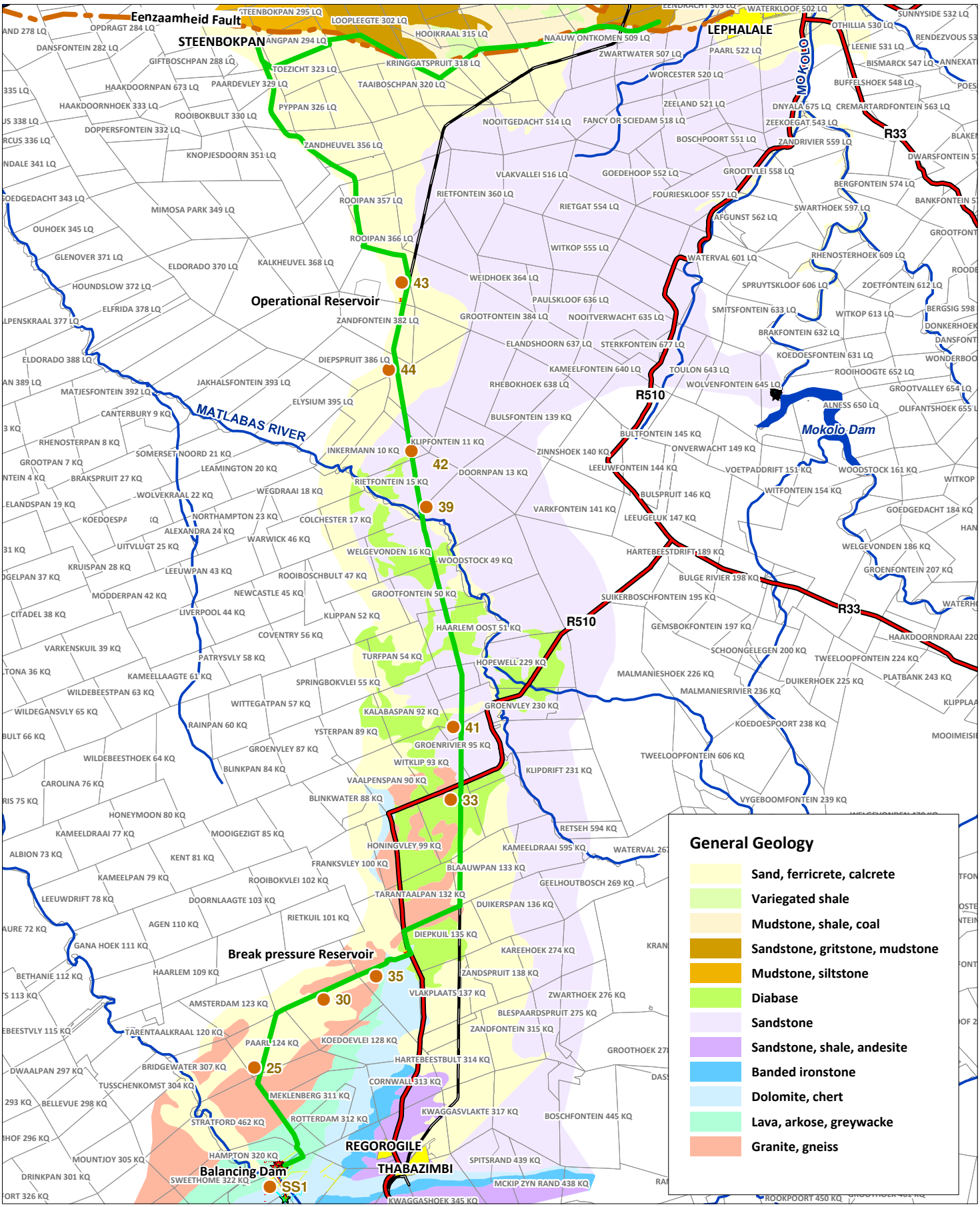
Diabase (dolerite) has intruded the sandstones of the Waterberg Group and the Lebowa Granite and appears to be in the form of sills.

Extensive areas, particularly in the north, are covered by Quaternary Age sands which are younger than 1.8 million years. These sands obscure much of the underlying bedrock.

The regional geology is shown on Figure 2 (Drawing Number 2A-G3-021).

### 5.2 Structural Geology

The sandstones of the Waterberg Group are near-horizontally bedded with a very shallow dip towards the north. Prominent NE- and NW-striking lineaments are recognised. The Lebowa Granite forms the Basement Complex in the area. Diabase is intruded in irregular bodies (generally sills or inclined sheets) into both the granite and Waterberg.

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MOKOLO CROCODILE Consultants



## Legend

**PIPELINE ROUTES**

- Phase 2
- Main Roads
- Borrow Pits
- Railway Line
- Rivers
- Farm Boundaries
- Towns

Scale: 1:440,000

5 0 5 10
Kilometers

N

**Project:** Mokolo and Crocodile (West) Water Augmentation Project

**Drawing Title:** Regional Geology

**Drawing Number:** 2A-G3-021

**Rev:** FIG 2

K:\Projects\Mokolo\WORKSPACES\March_11\MCWAP_Regional Geology_a4.WOR

### 5.3 Economic Geology

No deposits of economic value are known to be present along the route.

### 5.4 Climate and Weathering

The study area lies to the west of the climatic N = 5 line (Weinert, 1980), which indicates that mechanical disintegration is the dominant mode of weathering; but both chemical and mechanical modes of weathering are likely to have an influence.

### 5.5 Seismic Hazard

According to Kijko, *et. al*. 2003 the area of interest is associated with Peak Ground Acceleration values between 0,08 and 0,10 g, with a 10% probability of being exceeded in a 50 year period.

## 6 INVESTIGATION FINDINGS

### 6.1 General Geology

Virtually the whole length of the pipeline route is underlain by Waterberg sandstones. These outcrop south of the Matlabas River, but are blanketed by Quaternary Age deposits (sand, calcrete, ferricrete) north of this. In the south, limited occurrences of granite are present.

Diabase (apparently in the form of extensive sills), has intruded the Waterberg Group and Lebowa Granite.

The geology of the area may be summarised as shown on the Table below.

**Table 4: Geology**

| Rock Type | Formation | Group | Remarks |
|---|---|---|---|
| Sand, ferricrete, calcrete, silcrete | | | Quaternary |
| Diabase | | | Post-Waterberg intrusive |
| Sandstone, conglomerate | Mogalakwena | Waterberg | |
| Granite, gneiss | | | Lebowa Granite Suite |

## 6.2 Core Drilling Investigations

### 6.2.1 R510 Road Crossing (farm Ruigtevley 97KQ)

The R510 road (Thabazimbi – Lephalale) crosses over the railway line at about Chainage 18,300 m. The pipeline parallels the railway line and will pass under the western approach embankment of the road/rail bridge.

Two rotary core boreholes, BH49 and BH50, were drilled on either side of the R510 road, within the railway reserve on the farm Ruigtevley 97KQ Remainder. The borehole positions are indicated on Figure 3: R510 Road Crossing – Farm Ruigtevley 97KQ: Borehole Layout (Drawing No. 2E-G3-202).

Borehole logs and borehole core photographs are in Annexure C.

#### a) Drilling results

Drilling results indicate the rockhead within the two boreholes varies between 3.70 m and 4.20 m.

The succession in BH49 comprises 2.00 m of silty sand to clayey, silty sand hillwash; overlying clayey, silty sand with nodular ferricrete to 3.42 m. From 3.42 m a thin residual sandstone layer of clayey, silty, fine sand was encountered to 3.70 m. From 3.70 m highly to completely weathered, soft to very soft rock sandstone was intersected, extending to 4.90 m below which is moderately weathered, soft to medium hard rock sandstone of the Waterberg Group to a minimum depth of 10.35 m.

The succession in BH50 comprises 1.50 m clayey sand hillwash underlain by slightly ferruginised, clayey silty, fine sand and gravels to 4.20 m. Below 4.20 m highly to completely weathered, soft to very soft rock sandstone was encountered, extending to 5.25 m. Below 5.25 m moderately weathered, medium hard rock sandstone of the Waterberg Group occurs to a minimum depth of 10.15 m.

A summary of the findings of the drilling is given in Table 5: R510 Road Crossing (farm Ruigtevley 97KQ) – Summarised drilling results.

**Table 5: R510 Road Crossing (farm Ruigtevley 97KQ) – Summarised drilling results**

| BH no. | Clayey to silty sand (Hillwash) | Clayey silty sand with ferricrete nodules (Pedogenic horizon) | Clayey silty fine sand (Residual sandstone) | Highly to completely weathered, soft to very soft rock sandstone | Moderately weathered soft to medium hard rock sandstone |
|---|---|---|---|---|---|
| BH49 | 0-2.00 | 2.00-3.42 | 3.42-3.70 | 3.70-4.90 | 4.90-10.35+ |
| BH50 | 0-1.50 | 1.50-4.20 | - | 4.20-5.25 | 5.25-10.15+ |

Note: All depths in metres


| BOREHOLE CO-ORDINATES LIST Lo 27 (HARTEBEESHOEK 94) | | |
|---|---|---|
| NAME | Y CO-ORDINATE | X CO-ORDINATE |
| BH49 | – 45628.987 | + 2687642.823 |
| BH50 | – 45629.755 | + 2687583.329 |

## NOTES:

1. ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE SHOWN.
2. ALL ELEVATIONS IN METRES ABOVE SEA LEVEL UNLESS OTHERWISE SHOWN.
3. FOR DETAILED BOREHOLE LOGS REFER TO GEOTECHNICAL REPORT ANNEXURE F.

## LEGEND:

600 — REFERENCE LINE FOR GEOLOGICAL PROFILE

BH20 — BOREHOLE POSITION

| REFERENCE DRAWINGS | | REVISIONS | | | |
|---|---|---|---|---|---|
| DRG. No. | TITLE | REV No. | DATE | DESCRIPTION | APPR. |
| | | A | 02/02/11 | FOR INFORMATION | PLR |

| | | | |
|---|---|---|---|
| DESIGNED: | G DAVIS | PROJECT ENGINEER: | P LE ROUX |
| DRAWN: | D VAN COLLER | TCTA: | |
| CHECKED: | G DAVIS | | |
| CHIEF DESIGNER: | G DAVIS | SCALE: | 1:500 |

SCALE 1 : 500 0 2.5 5 10 15 20 25

Mokolo Crocodile Consultants

TCTA A new word for water

# MOKOLO CROCODILE WATER AUGMENTATION PROJECT ( MCWAP )

## GEOTECHNICAL

ROAD CROSSING – FARM RUIGTEVLEY 97 KQ (BH49 & BH50)

BOREHOLE LAYOUT

| A3 | DWAF DRG. No. | DRAWING NUMBER | 2E – G3 – 202 | REV No. A |
|---|---|---|---|---|

**b) Groundwater**

A water level was measured in one of the boreholes (BH49) a day after the drilling started and is listed in Table 6 below.

**Table 6: R510 Crossing (Farm Ruigtevley 97KQ) - Water Levels**

| Borehole no. | Coordinates (WGS84 Lo27) | | BH depth (m) | Water level (m) | Date taken |
|---|---|---|---|---|---|
| | Y | X | | | |
| BH49 | -045 628.99 | 2 687 642.82 | 10.35 | 2.35 | 03-06-2010 |
| BH50 | -045 629.76 | 2 687 583.33 | 10.15 | - | - |

It must be borne in mind that water is used during the drilling process and this may influence the measured water levels in the short term. The water level was taken the day after drilling started, which gave the water in the borehole time to settle overnight. No measurement was carried out in BH50.

### 6.2.2 Railway Overpass Road Crossing (farm Groenrivier 95KQ, Ptn 37)

A local farm access road crosses over the railway line at about Chainage 23,200 m. The pipeline parallels the railway line and will pass under the western approach embankment of the road/rail bridge.

Two boreholes, BH51 and BH52, were drilled either side of the road next to the railway line in the railway reserve at farm Groenrivier 95KQ Ptn. 37. The borehole positions are indicated on Figure 4: Railway Overpass Road Crossing – Farm Groenrivier 95KQ: Borehole Layout (Drawing No. 2E-G3-203).

Borehole logs and borehole core photographs are presented in Annexure C.

**a) Drilling Results**

The rockhead within the two boreholes varies between 1.70 and 3.75 m.

The succession in BH51 comprises 2.70 m of transported, silty sand becoming clayey sand, underlain by clayey gravel to honeycomb ferricrete to 3.80 m. These materials are underlain by highly to completely weathered, soft to very soft rock sandstone to a depth of 4.50 m. From 4.50 m slightly to unweathered, medium hard to hard rock sandstone of the Waterberg Group was encountered to a minimum depth of 9.85 m.

The succession in BH52 comprises 1.50 m silty sand to clayey, silty sand hillwash overlying a thin sandy gravel (nodular ferricrete) to hardpan ferricrete to 1.80 m. From 1.80 m moderately weathered, medium hard to hard rock sandstone was encountered to 2.20 m; underlain by slightly to unweathered, hard rock sandstone of the Waterberg Group to a minimum depth of 9.99 m.

A summary of the findings of the drilling is given in Table 7.

**Table 7: Railway Overpass Road Crossing (farm Groenrivier 95KQ Ptn 37) – Summarised drilling results**

| BH No. | Silty sand to clayey silty sand (Transported) | Sandy and clayey nodular to honeycomb ferricrete (pedogenic horizon) | Highly to completely weathered, soft to very soft rock sandstone | Moderately weathered, medium hard to hard rock sandstone | Slightly to unweathered, medium hard to hard rock sandstone |
|---|---|---|---|---|---|
| BH51 | 0 - 2.70 | 2.70 - 3.80 | 3.80 - 4.50 | | 4.50 - 9.85 |
| BH52 | 0 - 1.50 | 1.50 - 1.80 | - | 1.80 - 2.20 | 2.20 - 9.99 |

Note: All depths in metres

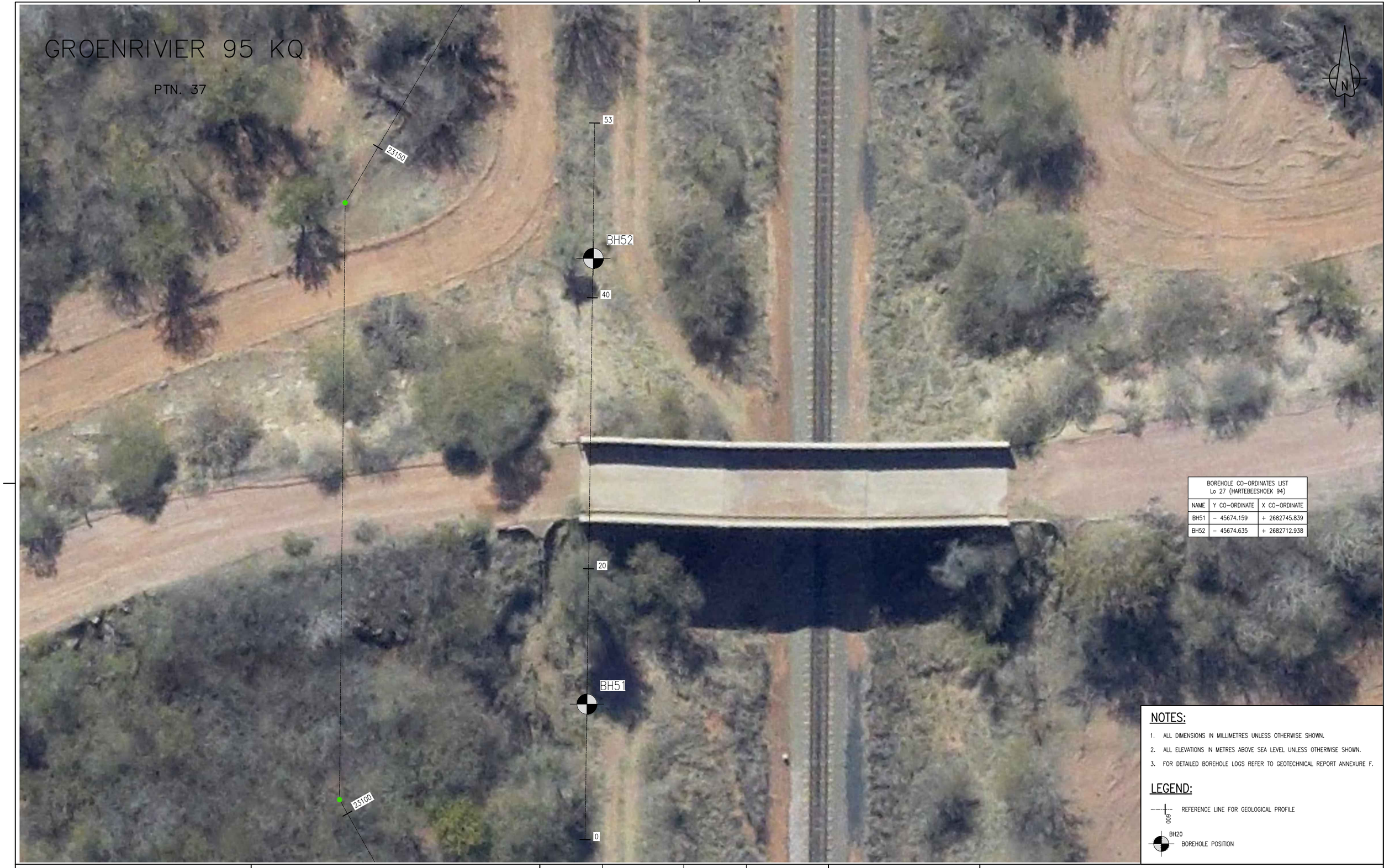
**b) Groundwater**

The water level was only measured in one of the boreholes (BH52) the day after the drilling started and is listed in Table 8 below.

**Table 8: Railway Overpass Road Crossing (farm Groenrivier 95KQ Ptn 37): Water Levels**

| Borehole no. | Coordinates (WGS84 Lo27) | | BH depth (m) | Water level (m) | Date taken |
|---|---|---|---|---|---|
| | Y | X | | | |
| BH51 | -04 5674.16 | 2 682 745.84 | 9.85 | - | - |
| BH52 | -04 5674.64 | 2 682 712.94 | 9.99 | 1.5 | 01-06-2010 |

It must be borne in mind that water is used during the drilling process and this may influence the measured water levels in the short term. The water level was taken the day after drilling started, which gave the water in the borehole time to settle overnight. No water measurement was done in BH51.




| BOREHOLE CO-ORDINATES LIST Lo 27 (HARTEBEESHOEK 94) | | |
|---|---|---|
| NAME | Y CO-ORDINATE | X CO-ORDINATE |
| BH51 | – 45674.159 | + 2682745.839 |
| BH52 | – 45674.635 | + 2682712.938 |

## NOTES:

1. ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE SHOWN.
2. ALL ELEVATIONS IN METRES ABOVE SEA LEVEL UNLESS OTHERWISE SHOWN.
3. FOR DETAILED BOREHOLE LOGS REFER TO GEOTECHNICAL REPORT ANNEXURE F.

## LEGEND:

600 — REFERENCE LINE FOR GEOLOGICAL PROFILE

BH20 — BOREHOLE POSITION

| REFERENCE DRAWINGS | | REVISIONS | | | |
|---|---|---|---|---|---|
| DRG. No. | TITLE | REV No. | DATE | DESCRIPTION | APPR. |
| | | A | 02/02/11 | FOR INFORMATION | PLR |

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|---|---|---|---|
| DESIGNED: | G DAVIS | PROJECT ENGINEER: | P LE ROUX |
| DRAWN: | D VAN COLLER | TCTA: | |
| CHECKED: | G DAVIS | | |
| CHIEF DESIGNER: | G DAVIS | SCALE: | 1:250 |

SCALE: 1:250 — 0 2,5 5 7,5 10 12,5

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# MOKOLO CROCODILE WATER AUGMENTATION PROJECT ( MCWAP )

## GEOTECHNICAL

ROAD CROSSING – FARM GROENRIVIER 95 KQ (BH51 & BH52)

BOREHOLE LAYOUT

| A3 | DWAF DRG. No. | DRAWING NUMBER | 2E – G3 – 203 | REV No. A |
|---|---|---|---|---|

### 6.2.3 Road D2701 Crossing (farm Haarlem Oost 51KQ Ptn 5)

The road crosses over the railway line at about Chainage 30,600 m. The pipeline parallels the railway line and will pass under the western approach embankment of the road/rail bridge.

Two boreholes, BH53 and BH54, were drilled on either side of the D2701 road in the railway reserve on farm Haarlem Oost 51KQ Ptn.5. The boreholes were drilled on the western side of the railway line. The borehole positions are indicated on Figure 5: D2701 Road Crossing - Farm Haarlem Oost 51KQ: Borehole Layout (Drawing No. 2E-G3-204).

Borehole logs and borehole core photographs are in Annexure C.

#### a) Drilling Results

The boreholes indicate the rockhead within the two boreholes varies between 1.35 and 1.75 m.

The succession in BH53 comprises 1.35 m of transported, silty, clayey sand becoming clayey sand with gradually increasing proportion of ferricrete nodules. From 1.35 to 2.57 m moderately weathered, medium hard rock granite occurs. Slightly weathered, hard rock granite was encountered from 2.57 to 6.10 m, underlain by slightly to unweathered, very hard rock Lebowa Granite to a minimum depth of 10.19 m.

The succession in BH54 comprises 0.90 m clayey sand fill and hillwash with gravels, overlying clayey sand and nodular ferricrete to 1.72 m. From 1.72 to 6.75 m highly to completely weathered, soft and very soft rock granite occurs. This is underlain by slightly to moderately weathered, hard rock granite to 8.30 m overlying highly to completely weathered, soft and very soft rock Lebowa Granite to a minimum depth of 10.00 m.

A summary of the findings of the drilling is given in Table 9.

**Table 9: Road D2701 Crossing (farm Haarlem Oost 51KQ) – Summarised drilling results**

| BH no. | Silty sand, silty clayey sand (Trans-ported) | Clayey sand, ferricrete nodules (Slightly pedogenic horizon) | Highly to completely weathered, soft to very soft rock granite | Moderately weathered, medium hard rock granite | Slightly to moderately weathered, hard rock granite | Slightly weathered to unweathered, very hard rock granite |
|---|---|---|---|---|---|---|
| BH53 | 0-0.40 | 0.40 - 1.35 | | 1.35 - 2.57 | 2.57 - 6.10 | 6.10 - 10.19 |
| BH54 | 0-0.90 | 0.90 - 1.72 | 1.72 - 6.75<br>8.30 - 10.0 | - | 6.75 - 8.30 | - |

Note: All depths in metres


| BOREHOLE CO-ORDINATES LIST Lo 27 (HARTEBEESHOEK 94) | | |
|---|---|---|
| NAME | Y CO-ORDINATE | X CO-ORDINATE |
| BH53 | – 45034.767 | + 2675409.245 |
| BH54 | – 45026.225 | + 2675344.672 |

## NOTES:

1. ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE SHOWN.
2. ALL ELEVATIONS IN METRES ABOVE SEA LEVEL UNLESS OTHERWISE SHOWN.
3. FOR DETAILED BOREHOLE LOGS REFER TO GEOTECHNICAL REPORT ANNEXURE F.

## LEGEND:

600 — REFERENCE LINE FOR GEOLOGICAL PROFILE

BH20 — BOREHOLE POSITION

| REFERENCE DRAWINGS | | REVISIONS | | | |
|---|---|---|---|---|---|
| DRG. No. | TITLE | REV No. | DATE | DESCRIPTION | APPR. |
| | | A | 02/02/11 | FOR INFORMATION | PLR |

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|---|---|---|---|
| DESIGNED: | G DAVIS | PROJECT ENGINEER: | P LE ROUX |
| DRAWN: | D VAN COLLER | TCTA: | |
| CHECKED: | G DAVIS | | |
| CHIEF DESIGNER: | G DAVIS | SCALE: | 1:500 |

SCALE 1 : 500 (0, 2.5, 5, 10, 15, 20, 25)

MOKOLO CROCODILE Consultants

TCTA A new word for water

# MOKOLO CROCODILE WATER AUGMENTATION PROJECT ( MCWAP )

## GEOTECHNICAL

ROAD CROSSING – FARM HAARLEM OOST 51 KQ (BH53 & BH54)

BOREHOLE LAYOUT

| A3 | DWAF DRG. No. | DRAWING NUMBER | 2E – G3 – 204 | REV No. A |
|---|---|---|---|---|

**a) Groundwater**

A water level was measured in one of the boreholes the day after the drilling started and is listed in Table 10 below.

**Table 10: Road D2710 Crossing (farm Haarlem Oost 51KQ): Water Levels**

| Borehole no. | Coordinates (WGS84 Lo27) | | BH depth (m) | Water level (m) | Date taken |
|---|---|---|---|---|---|
| | Y | X | | | |
| BH53 | -045 034.77 | 2 675 409.25 | 10.19 | 1.00 | 31-05-2010 |
| BH54 | -045 026.23 | 2 675 344.67 | 10.00 | - | - |

It must be borne in mind that water is used during the drilling process and this may influence the measured water levels in the short term. The water level was recorded the day after drilling started, which allowed time to settle overnight. No water measurement was done on BH54.

### 6.2.4 Matlabas River Crossing (approximate Chainage 41,820 to 41,900 m)

The railway line crosses the Matlabas River between approximately Chainage 41,820 m and 41,900 m. The pipeline parallels the railway line and will cross the river just west of the rail bridge.

Three boreholes, BH55, BH56 and BH57, were drilled at the river crossing; BH57 on the right bank (northern), BH55 on the far left bank (southern) and BH56 on the left (southern) bank of the river next to the water. The borehole positions are indicated on Figure 6: Matlabas River Crossing: Borehole Layout (Drawing No. 2E-G3-205).

Borehole logs and borehole core photographs are in Annexure C.

**a) Drilling Results**

The boreholes reveal the rockhead depths vary between 2.50 m and 5.48 m.

The succession in BH55 comprises 5.48 m of alluvial sand underlain by moderately weathered, soft to medium hard rock siltstone to 7.90 m. From 7.90 m to 10.17 m slightly weathered medium hard rock siltstone of the Waterberg Group was encountered.

The succession in BH56 comprises 4.00 m of coarse, alluvial sand overlying highly to moderately weathered, soft rock siltstone to 4.81 m. From 4.81 m to 7.90 m moderately weathered, soft to medium hard rock siltstone was encountered. This is underlain by slightly to unweathered, medium hard rock siltstone of the Waterberg Group, to a depth of at least 10.18 m.


| BOREHOLE CO-ORDINATES LIST Lo 27 (HARTEBEESHOEK 94) | | |
|---|---|---|
| NAME | Y CO-ORDINATE | X CO-ORDINATE |
| BH55 | – 42294.605 | + 2664487.916 |
| BH56 | – 42290.642 | + 2664468.347 |
| BH57 | – 42282.765 | + 2664418.417 |

## NOTES:

1. ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE SHOWN.
2. ALL ELEVATIONS IN METRES ABOVE SEA LEVEL UNLESS OTHERWISE SHOWN.
3. FOR DETAILED BOREHOLE LOGS REFER TO GEOTECHNICAL REPORT ANNEXURE F.

## LEGEND:

600 — REFERENCE LINE FOR GEOLOGICAL PROFILE

BH20 — BOREHOLE POSITION

| REFERENCE DRAWINGS | | REVISIONS | | | |
|---|---|---|---|---|---|
| DRG. No. | TITLE | REV No. | DATE | DESCRIPTION | APPR. |
| | | A | 02/02/11 | FOR INFORMATION | PLR |

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|---|---|---|---|
| DESIGNED: | G DAVIS | PROJECT ENGINEER: | P LE ROUX |
| DRAWN: | D VAN COLLER | TCTA: | |
| CHECKED: | G DAVIS | | |
| CHIEF DESIGNER: | G DAVIS | SCALE: | 1:500 |

SCALE 1 : 500 0 2,5 5 10 15 20 25

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# MOKOLO CROCODILE WATER AUGMENTATION PROJECT ( MCWAP )

## GEOTECHNICAL

MATLABAS RIVER CROSSING (BH55, BH56 & BH57)

BOREHOLE LAYOUT

| A3 | DWAF DRG. No. | DRAWING NUMBER | 2E – G3 – 205 | REV No. A |
|---|---|---|---|---|

The succession in BH57 comprises fill material of silty to clayey sand and gravels to 2.50 m, overlying highly to completely weathered, soft to very soft rock siltstone of the Waterberg Group to 7.50 m. From 7.50 m to 8.00 m slightly to moderately weathered, hard rock diabase (dolerite) is intersected, overlying highly to completely weathered, very soft to medium hard rock diabase to a minimum depth of 10.00 m. The diabase is a post-Waterberg intrusion.

A summary of the findings of the drilling is given in Table 11.

**Table 11: Matlabas River Crossing (Chainage 41,820 to 49,000 m) – Summarised drilling results**

| BH no. | Sand (Alluvium) | Silty to clayey sand (Made ground) | Highly to moderately weathered siltstone | Moderately weathered, soft to medium hard rock siltstone | Slightly weathered, medium hard rock siltstone | Slightly weathered to unweathered, medium hard rock siltstone |
|---|---|---|---|---|---|---|
| BH55 | 0 - 5.48 | - | - | 5.48 - 7.90 | 7.90 - 10.17 | |
| BH56 | 0 - 4.00 | - | 4.00 - 4.81 | 4.81 - 7.90 | - | 7.90 - 10.18 |
| BH57 | - | 0 - 2.50 | 2.50 - 7.50 | 8.00 – 10.00# | | 7.50 - 8.00# |

Notes: All depths in metres # = diabase/dolerite

**b) Groundwater**

A water level was measured in one of the boreholes (BH55) the day after the drilling started and is listed in Table 12 below.

**Table 12: Matlabas River Crossing (Chainage 41,820 to 41,900 m): Water Levels**

| Borehole no. | Coordinates (WGS84 Lo27) | | BH depth (m) | Water level (m) | Date taken |
|---|---|---|---|---|---|
| | Y | X | | | |
| BH55 | -042 294.61 | 2 664 487.92 | 10.17 | 1.15 | 28-05-2010 |
| BH56 | -042 290.64 | 2 664 468.35 | 10.18 | - | - |
| BH57 | -042 282.77 | 2 664 418.42 | 10.00 | - | - |

It must be borne in mind that water is used during the drilling process and this may influence the measured water levels in the short term. The water level was measured the day after drilling started, which allowed the water time to settle overnight. No water measurement was done in boreholes BH56 and BH57.

### 6.2.5 Operational Reservoir (Chainage 63,200 m; Farm Rooipan 357LQ Ptn 4)

Three boreholes, BH58, BH59 and BH60, were drilled on the footprint of the reservoir to a maximum depth of 10 m. The borehole positions are indicated on Figure 7: Operational Reservoir: Borehole Layout (Drawing No. 2D-G3-001).

It had been intended also to carry out test pitting, but the landowner withdrew permission for access. This investigation will have to be carried out in the future, once the matter of access has been resolved.

Borehole logs and borehole core photographs are in Annexure C.

#### a) Drilling results

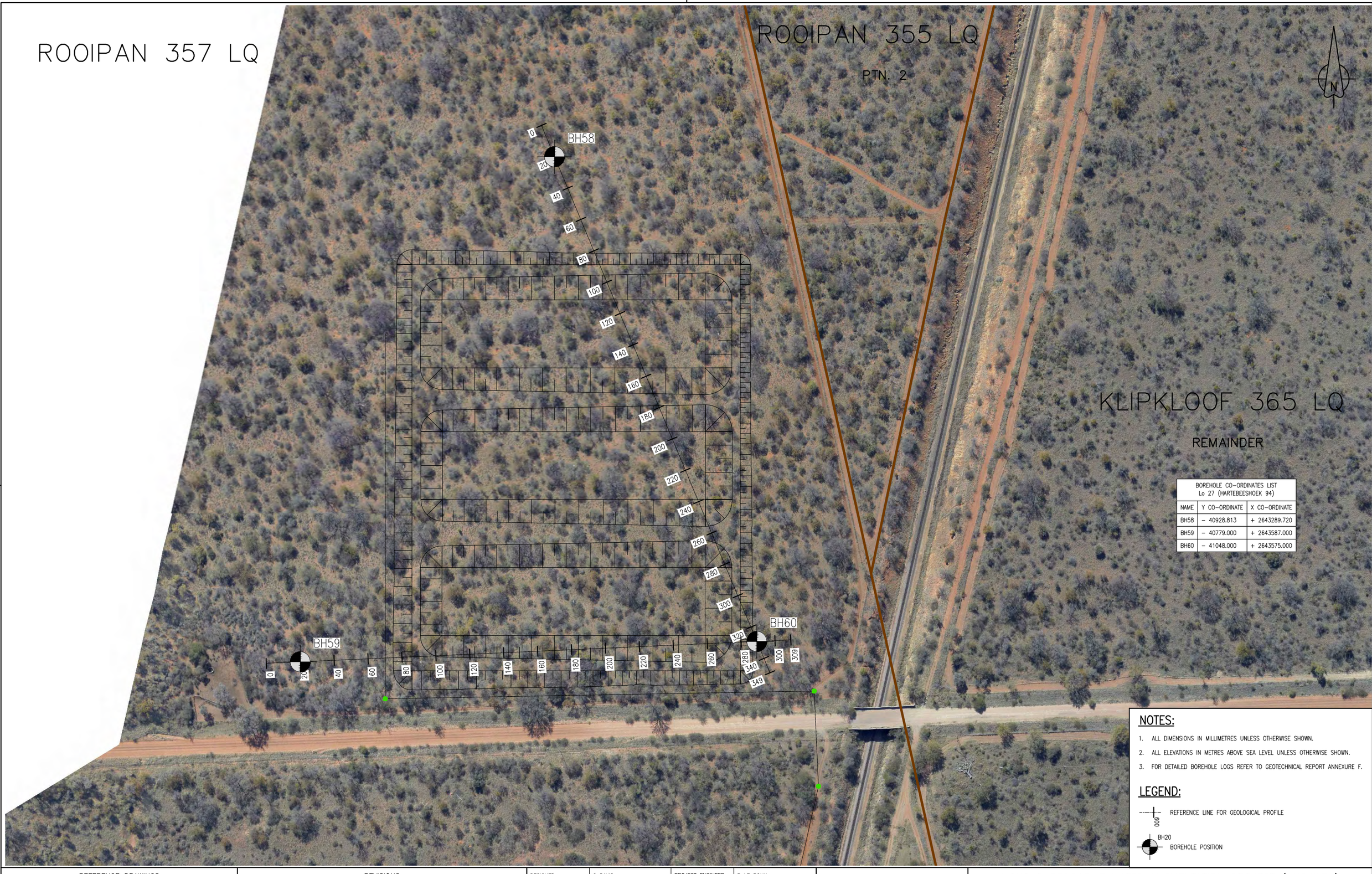
The rockhead in the three boreholes varies in depth between 2.20 m and 4.37 m.

The succession in BH58 comprises transported silty sand to a depth of 1.40 m, overlying silty, sandy gravel (residual sandstone with ferricrete nodules) to 2.65 m. This is underlain by highly to moderately weathered, soft rock sandstone to a depth of 7.50 m. From 7.50 m to 10.00 m highly weathered, very soft rock sandstone of the Waterberg Group was encountered.

The succession in BH59 comprises 2.20 m of transported silty sand overlying a thin hardpan ferricrete to 2.70 m. From 2.70 m to 3.25 m highly to completely weathered, very soft rock sandstone occurs, underlain by highly weathered, medium hard rock sandstone to a depth of 3.90 m. Moderately weathered, soft to medium hard rock sandstone was encountered from 3.90 m to 9.50 m, underlain by highly weathered, soft rock sandstone from the Waterberg Group to a minimum depth of 10.03 m.

The succession in BH60 comprises 2.00 m of transported silty sand overlying honeycomb to hardpan ferricrete to 3.41 m. From 3.41 m to 4.37 m residual sand derived from sandstone occurs, overlying highly weathered, soft rock sandstone to a depth of 5.44 m. Moderately weathered, medium hard rock sandstone of the Waterberg Group was encountered from 5.44 m to a minimum depth of 10.14 m.

A summary of the findings of the drilling is given in Table 13.




| BOREHOLE CO-ORDINATES LIST Lo 27 (HARTEBEESHOEK 94) | | |
|---|---|---|
| NAME | Y CO-ORDINATE | X CO-ORDINATE |
| BH58 | – 40928.813 | + 2643289.720 |
| BH59 | – 40779.000 | + 2643587.000 |
| BH60 | – 41048.000 | + 2643575.000 |

## NOTES:

1. ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE SHOWN.
2. ALL ELEVATIONS IN METRES ABOVE SEA LEVEL UNLESS OTHERWISE SHOWN.
3. FOR DETAILED BOREHOLE LOGS REFER TO GEOTECHNICAL REPORT ANNEXURE F.

## LEGEND:

600 — REFERENCE LINE FOR GEOLOGICAL PROFILE

BH20 — BOREHOLE POSITION

| REFERENCE DRAWINGS | | REVISIONS | | | |
|---|---|---|---|---|---|
| DRG. No. | TITLE | REV No. | DATE | DESCRIPTION | APPR. |
| | | A | 02/02/11 | FOR INFORMATION | PLR |

| | | | |
|---|---|---|---|
| DESIGNED: | G DAVIS | PROJECT ENGINEER: | P LE ROUX |
| DRAWN: | D VAN COLLER | TCTA: | |
| CHECKED: | G DAVIS | | |
| CHIEF DESIGNER: | G DAVIS | SCALE: | 1:2000 |

SCALE 1 : 2000 0 25 50 75 100

MOKOLO CROCODILE Consultants

TCTA A new word for water

# MOKOLO CROCODILE WATER AUGMENTATION PROJECT ( MCWAP )

## GEOTECHNICAL

OPERATIONAL RESERVOIR (BH58, BH59 & BH60)

BOREHOLE LAYOUT

| A3 | DWAF DRG. No. | DRAWING NUMBER | 2D – G3 – 001 | REV No. A |
|---|---|---|---|---|

**Table 13: Operational Reservoir (Chainage 63,200 m; Farm Rooipan 357LQ Ptn 4) - Summarised drilling results**

| BH no. | Silty sand (Transported) | Silty sand with ferricrete nodules or honeycomb to hardpan ferricrete (pedogenic horizon) | Sand (residual sandstone) | Highly to completely weathered, soft to very soft rock sandstone | Moderately weathered, soft rock to medium hard rock sandstone |
|---|---|---|---|---|---|
| BH58 | 0 - 1.40 | 1.40 - 2.65 | - | 2.65 - 3.00<br>7.50 - 10.00 | 3.00 - 7.50 |
| BH59 | 0 - 2.20 | 2.20 - 2.70 | - | 2.70 - 3.90<br>9.50 - 10.03 | 3.90 - 9.50 |
| BH60 | 0 - 2.00 | 2.00 - 3.41 | 3.41 - 4.37 | 4.37 - 5.44 | 5.44 - 10.14 |

Note: All depths in metres

**b) Groundwater**

A water level was measured in one of the boreholes (BH60) the day after the drilling started and is listed in Table 14 below.

**Table 14: Operational Reservoir (Chainage 63,200 m; Farm Rooipan 357LQ Ptn 4): Water levels**

| Borehole no. | Coordinates (WGS84 Lo27) | | BH depth (m) | Water level (m) | Date taken |
|---|---|---|---|---|---|
| | Y | X | | | |
| BH58 | -040 928.81 | 2 643 289.72 | 10.00 | - | - |
| BH59 | -040 776.60 | 2 643 586.67 | 10.03 | - | - |
| BH60 | -041 045.10 | 2 643 573.76 | 10.14 | 3.75 | 25-05-2010 |

It must be borne in mind that water is used during the drilling process and this may influence the measured water levels in the short term. Measurement of the water level the day after drilling started allowed the water in the borehole time to settle overnight. No water measurements were conducted in BH58 and BH59.

## 6.3 Centreline Investigation (see Annexure A)

Test pits were excavated at a nominal spacing of 200 m along the pipeline. Locations where excavation was not possible, due to rock outcrop or other inaccessible areas, were recorded and are shown on Drawings 2E-G7-006 to -034, included in Annexure E in Volume 2.3. The test pit profiles are given in Annexure A2 and photographs of the test pits in Annexure A5.

Pits were excavated using a TLB (New Holland B90B) and profiled by a geospecialist in accordance with the standards given in the Geoterminology Workshop 1990 (Brink and Bruin, 2002). For ease of access, test pits were dug within the Transnet rail reserve and are thus offset by approximately 30 – 100 m from the pipeline. The terms used are defined in Annexure A6. Dynamic Penetrometer Light (DPL or DCP) soundings were undertaken adjacent to and within the test pits in order to provide a quantitative assessment of the consistency of the in-situ materials. These soundings are shown graphically on the relevant soil profiles as equivalent SPT N-values (blows per 300 mm penetrated).

A summary of the ground conditions at each test pit position along the pipeline route is given on spreadsheets in Annexure A1. Graphical representations of the excavation depth for each test pit are included as Figure 8 and Figure 9.

In only a single test pit (CC/202) was any instability of the sides of the test pits found. This is based on an assessment of test pits of limited length and which stood open for about 20 minutes before being backfilled. Test pit CC/202 encountered “slight” seepage at 2.1 m depth and the sand above this caved in.

The DPL soundings are shown as equivalent SPT N-values (blows per 300 mm) and are shown graphically as N-value versus depth on the soil profiles. The majority of the pits terminated on sandstone, ferricrete or calcrete. The TLB used was able to excavate into the weathered zone of the sandstone but refused when unweathered rock was encountered. An inspection of cuttings on the adjacent railway line reveals that the sandstone generally broke out in blocks and there is ample evidence that it had to be blasted.

Shearbox tests were conducted on sandy materials in order to provide a quantitative assessment of the stability of the test pit sides and allow prediction of their stand-up time. The results of these tests are given in Table 15.

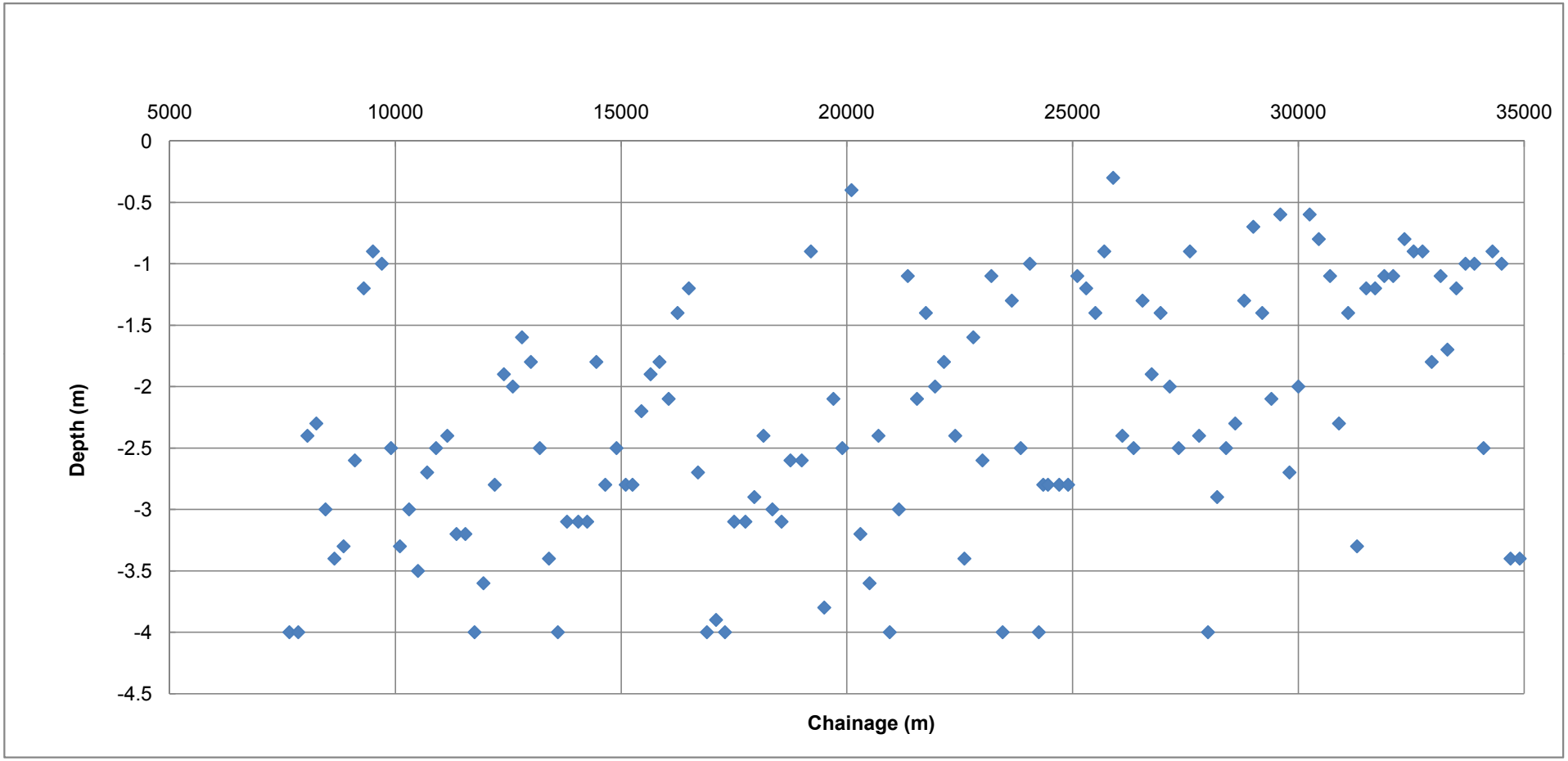



**FIGURE 8: PIPELINE: DEPTH TO REFUSAL**
**Tarantaalpan - Operational Reservoir: Chainage 7,700 - 35,000 m**

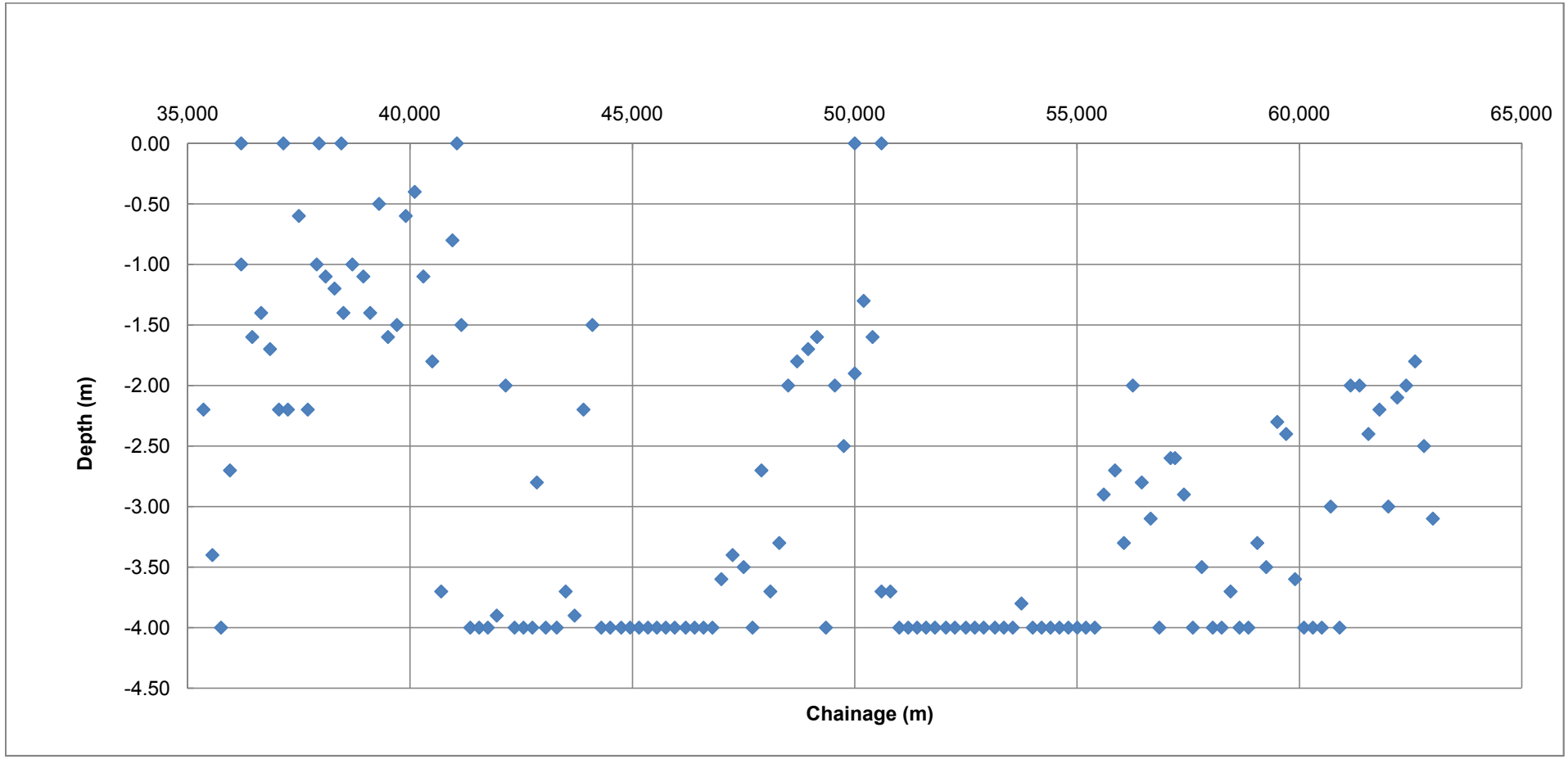



**FIGURE 9: PIPELINE: DEPTH TO REFUSAL**
**Tarantaalpan - Operational Reservoir: Chainage 35,000 - 63,200 m**

**Table 15: Summary of shearbox test results**

| Test pit no. | Depth (m) | Angle of internal friction Ø (˚) | Cohesion c (kPa) | Classification (AASHTO/USC) | Comment |
|---|---|---|---|---|---|
| CC/44 | 0.3 - 2.3 | 39 | 0 | A6 / SC | Clayey SAND |
| CC/69 | 0.2 - 2.5 | 41 | 0 | A2-4 / SM | Silty SAND |
| CC/158 | 0 - 4.0 | 26 | 11 | A2-4 / SM | Silty SAND |
| CC/159 | 3.0 - 3.3 | 31 | 16 | A7-5 / CL | Sandy CLAY |
| CC/211 | 0.3 - 2.2 | 41 | 0 | A2-4 / SM | Silty SAND |

### 6.3.1 pH and Conductivity

The pH and conductivity of the soils present was measured in laboratory tests and these indicate that the pH ranges from 4.05 to 9.8, and the conductivity from less than 0.001 to 0.510 S/m. The results of laboratory tests are shown in Annexure A3.

### 6.3.2 Corrosivity

SRB testing was carried out by Waterlab and the results are given in Annexure A3.3. In only a single sample of those tested (at CC/25) was an elevated level of sulphide found.

### 6.3.3 SRB Testing

The data was analysed in terms of the Probable Performance Index (PPI). The soil resistivity (inverse of conductivity) indicates that most of the soil is generally non corrosive, with the exception of test pit CC/15.

## 6.4 Borrow Materials (see Annexure B)

### 6.4.1 Granular Backfill Material

In order to locate suitable bedding and soft backfill material, an investigation of potential borrow sources was undertaken. It was intended to locate borrow pits (BP) at a nominal spacing of 5 km, each capable of providing at least 100,000 $m^3$ of material. The results of this investigation are presented in Annexure B, and include test pit profiles and results of laboratory testing, and are summarised hereunder in Table 16. Borrow pit plans are presented in Annexure D in Volume 2.3.

The material from BP 38 is outside the target specification (too clayey), resulting in a gap of approximately 19,8 km between BP 41 and BP 39. Another gap of about 10 km occurs south of BP33, because BP28 proved to be unsuitable (too clayey). The nearest BP (on Stage 2) to the southern end of Stage 1 is about 10 km beyond the southern end of Stage 1.

Test pits were dug at a nominal 30 m spacing at the borrow pits in order to prove volume.

**Table 16: Borrow pit summary**

| No | Location (WGS84 Lo27) | | Chainage (m) | Offset to pipeline (m) | Est. volume bedding &soft backfill ($m^3$) | Compactability Factor (range) |
|---|---|---|---|---|---|---|
| | Y | X | | | | |
| 28 | -045 267 | 2 697 434 | 8,600 | 200 L | Unsuitable, too clayey | |
| 33 | -045 410 | 2 687 900 | 17,900 | 100 L | 200,000 | 0.29 – 0.40 |
| 41 | 044 850 | 2 682 930 | 23,100 | 600 L | >100,000 | 0.32 – 0.47 |
| 38 | -044 400 | 2 675 400 | 31,200 | 800 L | Unsuitable, too clayey | |
| 39 | -042 250 | 2 663 800 | 42,900 | 70 R | 100,000 | 0.30 - 0.38 |
| 42 | -041 400 | 2 658 300 | 46,900 | 70 R | >100,000 | 0.35 – 0.40 |
| 44 | -039 920 | 2 651 500 | 54,800 | 100 L | >100,000 | 0.34 – 0.47 |
| 43 | -040 400 | 2 645 700 | 63,000 | 200 L | 100,000 | 0.32 – 0.39 |

L = Left/West of pipeline R= Right/East of pipeline

In addition to oversize material that is present in some of the borrow materials; roots occur frequently, often for the full depth of the test pits. The roots are shown on the photographs bound into Annexure B. It must be noted that the test pits were generally positioned to avoid large trees.

The results of the compactability tests undertaken on samples recovered at certain borrow pits are given in Annexure B2.1. The criteria used for this classification are given in Table 3: Suitability of granular backfill material. Of the samples analysed the compactability factor ranges from 0.29 to 0.47, with most being less than 0.40 (i.e. usable for bedding in terms of Table 3).

A summary of the laboratory test results for each borrow pit is given in Annexure B1.

The borrow pits are commented on individually as follows.

a) BP 28. The materials in this borrow pit are too clayey (generally classifying as an A6 in terms of the AASHTO/TRB classes) for use as granular bedding and backfill and are thus not further discussed; and
b) BP 33. This source is located on the Remainder of the farm Ruigtevley 97KQ and is in the north-western quadrant of the intersection of the R510 and the railway line. It is thus west of and adjacent to the pipeline and was accessed from the rail service road. It is located in an area cleared of bush and is covered mostly by grass. It is estimated that there is in excess of 100,000 $m^3$ of material present. Ferricrete gravel occurs beneath the sand.

The material present is a silty sand and classifies predominantly as an A2-4 with some A2-6 (and occasional A6) present. The sand is about 2 m thick on average. The grading modulus (GM) ranges from 0.9 to 1.4, but is generally about 1.1. The Compactability ranges from a Factor (CF) of 0.29 to 0.40, but averages about 0.36. In only 1 test pit of the 22 dug on the site, was oversize material (>9.5 mm) encountered in a sample.

c) BP41. This source is located on Portion 37 of Groenrivier 95KQ, about 800 m west of the railway line. It is accessed along a fence line leading from an overpass to the rail line (at about Chainage 23,150 m). The site is covered in bush with grass. It is estimated that there is in excess of 100,000 $m^3$ of material present.

The sand probably averages about 1,5 m thick, but may be more than 3 m thick in places. It is underlain by gravel. The sand classifies as an A2-4 (in places a fine gravel - A1-b). Seven of the 42 test pits dug showed some oversize material.

d) BP38. The materials in this borrow pit are too clayey (generally classifying as an A2-6 or A6) for use as granular bedding and backfill and are thus not further discussed.

e) BP39. This source is located about 500 m north of the Matlabas River. It abuts the rail reserve fence on the eastern side of the railway line. It is located on two properties (Remainder of Rietfontein 15KQ and Portion 2 of Schoonwater 14KQ). It is long and narrow, located between the rail reserve fence and a sub-parallel farm fence. A level crossing over the rail line is located just south of the site and it was accessed from the rail service road. It is estimated that there is in excess of 100,000 $m^3$ of material present. The site is covered by fairly thick bush and grass.

The material is silty sand, classifying as an A2-4, GM about 1.15 and PI nowhere exceeding 4. The sand is up to 4 m thick and has a CF between 0.3 and 0.38. In 3 of the 15 test pits sampled, oversize material was encountered. Gravel occurs beneath the sand.

f) BP42. This source is located on the eastern side of the railway line on Portion 1 of the farm Inkermann 10KQ. It is reported that there are no rail reserve fences in this area. The site was accessed from the rail service road. The site is covered in fairly sparse bush and grass.

The material is silty sand (A2-4) or fine gravel (A1-b) and is more than 4 m thick in places. Its GM ranges from 1.19 to 1.49, probably averaging about 1.2. Its CF ranges from 0.35 to 0.40. No oversize material was encountered in any samples, nor was gravel encountered.

g) BP44. This source is located on the farm Diepspruit 386LQ and is about 100 m west of the rail line. It is accessed from a farm track leading from the D1925 road (to Steenbokpan). It is estimated that there is in excess of 100,000 $m^3$ of material present. The site is covered by bush and grass.

The material is a silty sand, classifying as an A2-4, GM about 1.15 and PI less than 5. The sand is up to 3.8m thick and has a CF between 0.34 and 0.47, but averaging greater than 0.40. A single sample yielded oversize material. Gravel occurs below the sand.

h) BP43. This source is located on Portion 2 of Zandfontein 382KQ and is about 200 m west of the rail line. It is accessed off the D1925 along a farm road and then via the rail service road. It is estimated that there is in excess of 100,000 $m^3$ of material present. The site is covered by fairly sparse bush and grass.

The material is silty sand, classifying as an A2-4 (or A1-b), GM about 1.15 and PI less than 5. The sand is between 2 and 4 m thick and has a CF between 0.32 and 0.39. A single sample yielded oversize material and ferricrete occurs below the sand.

### 6.4.2 Sulphate Reducing Bacteria

The sulphide levels recorded at BP33 (test pits 01, 05 and 72) are elevated, indicating that SRB are active and present in these soils. Elevated sulphide levels were also recorded in BP38 (test pits 22, 26 and 56), but the materials from this site have proven unsuitable and the source will probably not be utilised.

### 6.4.3 Contribution of Gravel for Haul and Access Roads

No specific sources of gravel for use on haul and access roads have been identified. In certain cases gravel occurs below the bedding sand and it is assumed that this will be utilised once the sand has been extracted. The results of the testing on these are given in Annexure B. The sources identified are summarised in Table 17.

**Table 17: Gravel borrow sources**

| BP no. | Location (WGS84 Lo27) | | Chainage (m) | Offset to pipeline (m) | Estimated volume ($m^3$) | Comments |
|---|---|---|---|---|---|---|
| | Y | X | | | | |
| 33 | -045 410 | 2 687 900 | 17,900 | 100 L | 20,000+ | Ferricrete and sand |
| 41 | -044 850 | 2 682 930 | 23,100 | 600 L | 25,000+ | Ferricrete and gravel |
| 39 | -042 250 | 2 663 800 | 42,900 | 70 R | 10,000+ | Ferricrete and gravel |
| 44 | -039 920 | 2 651 500 | 54,800 | 100 L | 5,000+ | Ferricrete |
| 43 | -040 400 | 2 645 700 | 63,000 | 200 L | 5,000+ | Ferricrete and gravel |

### 6.4.4 Commercial Sources of Construction Materials

The nearest known commercial sources of stone and sand aggregate for concrete are in the vicinity of Lephalale and Thabazimbi.

These are discussed separately.

- Thabazimbi area

  Stone is crushed commercially to produce crushed stone and crusher sand at mines south and east of Thabazimbi. “Calcite” and hornfels quartzite is crushed at Swartklip and Leeupoort respectively. At Swartklip the supplier refers to the rock as “calcite”, but inspection of the crushed rock suggests that it should be referred to as “anorthosite”. Details of the suppliers and results of laboratory testing of the material are included in Annexure B2.6. Haul distances to the southern end of the Stage, are about 99 km from Swartklip and about 82 km from Leeupoort.

- Lephalale area

  The stone aggregate comprises two distinct materials; well-rounded alluvial gravels and crushed sandstone. Sand is dredged from nearby river courses, and is usually suitable for use as fine concrete aggregate and also as bedding and selected backfill material. Details of the suppliers and results of laboratory testing of the material are included in Annexure B2.6. Haul distance from Lephalale to Thabazimbi is approximately 120 km. The haul distance from Lephalale to the Operational Reservoir is about 65 km.

- Thabazimbi Iron Ore mine

  Low grade iron ore crushed to <25 mm size may be available from the mine. There is plentiful waste (overburden) rock which may be available from the mine.

### 6.4.5 Chemical Analyses

The chemical analyses show that the pH of the soils tested from borrow pits ranges from 4.15 to 8.15, and the conductivity from 0.001 to 0.317 S/m. The results are given in Annexure B2.1.

## 6.5 Spoil Sites

In addition to the potential borrow sources discussed in Section 6.4.1, potential spoil sites (old borrow sites from construction of the railway line and roads) were identified. These are listed in Table 18 and are shown on Figure 1: Phase 2 Locality Map (Drawing No. 2A-G3-020).

**Table 18: Potential spoil sites**

| Site no. | Co-ordinates (WGS84, Lo27) | | Approx. Chainage (m) | Estimated volume ($m^3$) | Comments |
|---|---|---|---|---|---|
| | Y | X | | | |
| D | -045 491 | 2 698 008 | 7,800 | 80,000 | Old BP |
| E | -045543 | 2 693 229 | 12,700 | 20,000 | Old BP |
| F | -045 760 | 2 687 880 | 18,000 | 80,000 | Old BP(E of railway) |
| G | -045 734 | 2 686 134 | 19,800 | 50,000 | Old BP(E of railway) |
| H | -045 603 | 2 682 846 | 23,100 | 45,000 | Old BP |

| Site no. | Co-ordinates (WGS84, Lo27) | | Approx. Chainage (m) | Estimated volume ($m^3$) | Comments |
|---|---|---|---|---|---|
| | Y | X | | | |
| I | -045 385 | 2 677 101 | 28,800 | 45,000 | Old BP |
| J | -044 873 | 2 675 751 | 30,300 | 70,000 | Old BP |
| K | -041 476 | 2 659 299 | 47,100 | 15,000 | Old BP(E of railway) |
| L | 040 900 | 2 656 731 | 49,800 | 20,000 | Old BP |

Note: Sites A to C are located on Phase 2, Stage 2.

It must be noted that negotiations have not yet been initiated with the owners of these sites regarding their use as spoil sites.

### 6.6 Excavatability Basis

The excavatability of the materials encountered in the centreline test pits is based on the performance of the TLB used to excavate them (see Table 2 in Volume 1). The depth to refusal for each test pit is summarised in Annexure A1 and is shown on the profiles bound into Annexure A2. In certain areas where extensive outcrop occurs, no test pits were dug. The extent of such areas is shown on Drawings 2E-G7-006 to -034 included in Annexure E in Volume 2.3.

### 6.7 Observed Groundwater Levels

A total of 269 test pits were dug along the pipeline route and in only one was groundwater encountered – slight seepage at 2.1 m depth in test pit CC/202. Caving of the sides of the test pit occurred, preventing measurement of an overnight water rest level.

No significant occurrences of hydrophilic vegetation, which might be indicative of shallow groundwater conditions, were observed along the route.

## 7 SUMMARY AND CONCLUSIONS

The investigation for the pipeline and borrow pits was undertaken by means of test pitting, with a TLB. The pits were excavated at nominal 200 m spacing along the pipeline route, and at a nominal spacing of 30 m at borrow pit locations. Boreholes were drilled at various road crossings, Matlabas River crossing and the Operational Reservoir site.

The geology of the area comprises Waterberg sandstone over most of the route, except for limited outcrops of granite in the south and intrusions of diabase into the sandstones and granite south of the Matlabas River. Extensive occurrences of Quaternary sand occur north of the Matlabas River.

# 8 INTERPRETATION

An interpretation of the findings of the geotechnical investigations has been carried out in order to assist in the design process and to aid Tenderers in their pricing of the project. The interpretation is given in Volume 3 of this Report.

# 9 REFERENCES

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