REPORT NUMBER: P RSA A000/00/8409

**Department of Water and Environmental Affairs**

Chief Directorate: Integrated Water Resource Planning
Directorate: Options Analysis

# MOKOLO AND CROCODILE RIVER (WEST) WATER AUGMENTATION PROJECT (MCWAP) FEASIBILITY STUDY: TECHNICAL MODULE

Project No. WP9528

## SUPPORTING REPORT NO. 8A
## DETAIL GEOTECHNICAL INVESTIGATIONS

## PHASE 1

FINAL

**Lead Consultant:** Africon

**In association with:** KV3, VELA VKE

## LIST OF REPORTS

| REPORT NO | DESCRIPTION | REPORT NAME |
|---|---|---|
| **FEASIBILITY STAGE** | | |
| *P RSA A000/00/8109* | Main Report | MCWAP FEASIBILITY STUDY TECHNICAL MODULE SUMMARY REPORT |
| ***P RSA A000/00/8409*** | **Supporting Report 8A** | **GEOTECHNICAL INVESTIGATIONS PHASE 1** |
| *P RSA A000/00/8709* | Supporting Report 8B | GEOTECHNICAL INVESTIGATIONS PHASE 2 |
| *P RSA A000/008509* | Supporting Report 9 | TOPOGRAPHICAL SURVEYS |
| *P RSA A000/00/8609* | Supporting Report 10 | REQUIREMENTS FOR THE SUSTAINABLE DELIVERY OF WATER |
| *P RSA A000/00/8209* | Supporting Report 11 | PHASE 1 FEASIBILITY STAGE |
| *P RSA A000/00/8309* | Supporting Report 12 | PHASE 2 FEASIBILITY STAGE |
| **PRE-FEASIBILITY STAGE** | | |
| *P RSA A000/00/8809* | Supporting Report 1 | WATER REQUIREMENTS |
| *P RSA A000/00/8909* | Supporting Report 2 | WATER RESOURCES |
| *P RSA A000/00/9009* | Supporting Report 3 | GUIDELINES FOR PRELIMINARY SIZING, COSTING AND ECONOMIC EVALUATION OF DEVELOPMENT OPTIONS |
| *P RSA A000/00/9109* | Supporting Report 4 | DAMS, ABSTRACTION WEIRS AND RIVER WORKS |
| *P RSA A000/00/9209* | Supporting Report 5 | MOKOLO RIVER DEVELOPMENT OPTIONS |
| *P RSA A000/00/9309* | Supporting Report 6 | WATER TRANSFER SCHEME OPTIONS |
| *P RSA A000/00/9409* | Supporting Report 7 | SOCIAL AND ENVIRONMENTAL SCREENING |
| **INCEPTION STAGE** | | |
| *P RSA A000/00/9609* | Inception | INCEPTION REPORT |

## REFERENCE

This report is to be referred to in bibliographies as:

Department: Water Affairs, South Africa, 2008. Mokolo and Crocodile River (West) Water Augmentation Project (MCWAP) Feasibility Study. Report 8, Detail Geotechnical Investigations, Phase 1. Prepared by Africon in association with Kwezi V3 Engineers, Vela VKE, WRP Consulting Engineers and specialists.

***DWA Report No.*** **P RSA A000/00/8209**

## REPORT DETAILS PAGE

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## PREFACE

The Mokolo (Mogol) River catchment is part of the Limpopo Water Management Area (WMA). The Mokolo River originates close to Modimolle (Nylstroom) and then drains to the north into the Limpopo River. The Mokolo Dam (formerly known as the Hans Strijdom Dam) is the largest dam in the catchment. The dam was constructed in the late 1970s and completed in July 1980, to supply water to Matimba Power Station, Grootegeluk Mine, Lephalale (Ellisras) Municipality and for irrigation downstream of the dam. Based on the water infrastructure, the current water availability and water use allows only limited spare yield existing for future allocations for the anticipated surge in economic development in the area.

There are a number of planned and anticipated consequential developments in the Lephalale area associated with the rich coal reserves in the Waterberg coal field for which additional water will be required. These developments include inter alia the development of further power stations by Eskom, the potential development of coal to liquid fuel facilities by Sasol and the associated growth in mining activities and residential development.

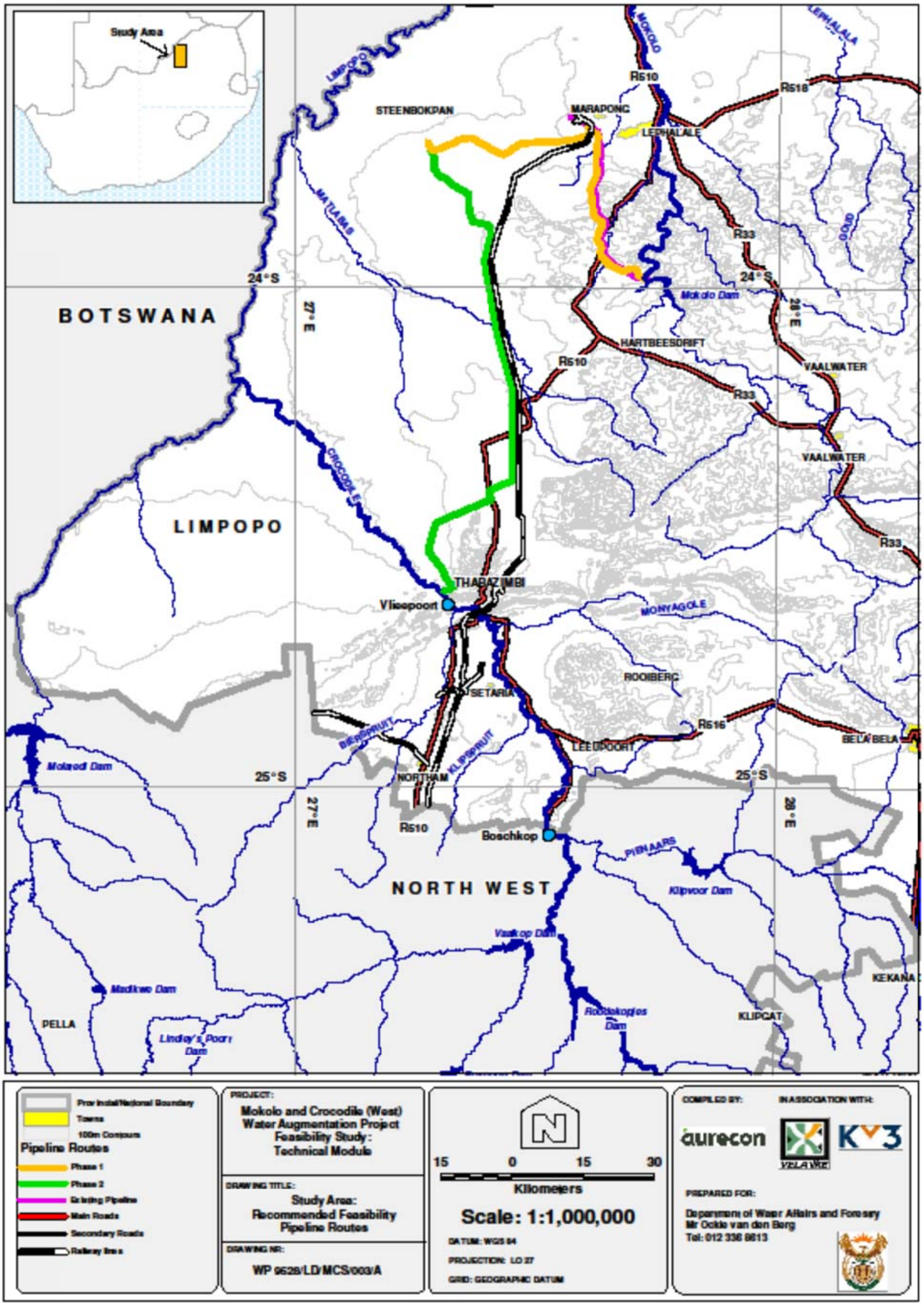
The development of new power stations is of high strategic importance with tight timeframes. Commissioning of the first generation unit will start in September 2010 and additional water needs to be available by mid-2011 according to the expected water requirements. A solution addressing the water needs of the Lephalale area must be pursued. The options to augment existing water supplies include transferring surplus effluent return flows from the Crocodile River (West) / Marico WMA to Lephalale and the area around Steenbokpan shown on the map indicating the study area on the following page.

The Department of Water Affairs (DWA) commissioned the Mokolo and Crocodile River (West) Water Augmentation Project (MCWAP) to analyse the options for transferring water from the Crocodile River (West). In April 2008, the Technical Module of this study was awarded to Africon in association with Kwezi V3, Vela VKE and specialists. The focus of the Technical Module is to investigate the feasibility of options to:

- Phase 1: Augment the supply from Mokolo Dam to supply in the growing water requirement for the interim period until a transfer pipeline from the Crocodile River (West) can be implemented. The solution must, over the long term, optimally utilise the full yield from Mokolo Dam.
- Phase 2: Transfer water from the Crocodile River (West) to the Lephalale area. Options to phase the capacity of the transfer pipeline (Phases 2A and 2B) must be investigated.

The Technical Module has been programmed to be executed at a Pre-feasibility level of investigation to identify different options and recommend the preferred schemes, which was followed by a Feasibility level investigation of the preferred water schemes. Recommendation on the preferred options for Phase 1 and Phase 2 Schemes 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 a draft Feasibility Report during October 2009 to the MCWAP Main Report in November 2009.

This report (Report 8A – Feasibility Stage, (P RSA A000/00/8409) covers the detail geotechnical investigations that have been performed for Phase I of the MCWAP. These include the pump station site, pipeline route and borrow pits.


Study Area
BOTSWANA
LIMPOPO
NORTH WEST
STEENBOKPAN
MARAPONG
LEPHALALE
HARTBEESDRIFT
VAALWATER
THABAZIMBI
Vlieepoort
SETARIA
ROOIBERG
LEEUPOORT
BELA BELA
NORTHAM
Boschkop
PELLA
KLIPGAT
KEKANA
Mokolo Dam
Molatedi Dam
Madikwe Dam
Lindley's Poort Dam
Vaalkop Dam
Roodekopjes Dam
Klipvoor Dam
LIMPOPO
MOKOLO
LEPHALALA
MATLABAS
CROCODILE
MONYAGOLE
BIERSPRUIT
KLIPSPRUIT
PIENAARS
R510
R518
R33
R516
24°S
25°S
27°E
28°E
Provincial/National Boundary
Towns
100m Contours
Pipeline Routes
Phase 1
Phase 2
Existing Pipeline
Main Roads
Secondary Roads
Railway lines
PROJECT:
Mokolo and Crocodile (West) Water Augmentation Project Feasibility Study: Technical Module
DRAWING TITLE:
Study Area: Recommended Feasibility Pipeline Routes
DRAWING NR:
WP 9528/LD/MCS/003/A
15 0 15 30
Kilometers
Scale: 1:1,000,000
DATUM: WGS 84
PROJECTION: LO 27
GRID: GEOGRAPHIC DATUM
COMPILED BY:
IN ASSOCIATION WITH:
aurecon
VELA VKE
KV3
PREPARED FOR:
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# MOKOLO AND CROCODILE RIVER (WEST) WATER AUGMENTATION PROJECT FEASIBILITY STUDY:

# TECHNICAL MODULE

# DETAIL GEOTECHNICAL INVESTIGATIONS – PHASE 1

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| ABP | Allowable Bearing Pressure |
| DPL | Dynamic Penetrometer Light |
| DWA | Department of Water Affairs |
| MCWAP | Mokolo and Crocodile River (West) Water Augmentation Project |
| MM | Mokolo-Mathimba |
| MS | Mathimba-Steenbokpan |
| NE | North-East |
| NW | North-West |
| RI | Road Indicator |
| RWR | Raw Water Reservoir |
| TLB | Tractor-Loader-Backhoe |
| WMA | Water Management Area |

# 1. BACKGROUND AND INTRODUCTION

## 1.1 Scope of the Investigations of this Report

The project entails two separate phases, Phase 1 and Phase 2A.

Phase 1 comprises expansion of the pumping station at the Mokolo Dam, a pipeline to the delivery area at Mathimba Raw Water Reservoir (RWR), near Lephalale, and a pipeline extending west from a point approximately 2 km south-east of the delivery area to Steenbokpan.

Phase 2A which describes abstraction from the Crocodile River at the Vlieepoort site, and transfer via a pipeline to link up with the western leg of the Phase 1 pipeline near Steenbokpan, the flow of which will be reversed to accommodate transfer to the delivery area near Lephalale. These two phases are reported in separate reports, with this report dealing with Phase 1.

This report presents the findings of the Feasibility level geotechnical investigations conducted for the various components of Phase 1 of the project, namely:

- Pipeline routes;
- Pump station; and
- Borrow pits.

The layout of the scheme is shown on Figure 1-1 (included with maps at the end of this report as annexures). It must be noted that, since the time that the geotechnical investigations were carried out and compilation of this report, the alignment of the pipelines has changed (but not yet necessarily finalised). This report thus deals with the alignment as it was at the time of the investigation, and shown in Figure 1-1. Any additional investigations occasioned by changes to this alignment will have to be carried out in the future and the findings used as Addenda to this report.

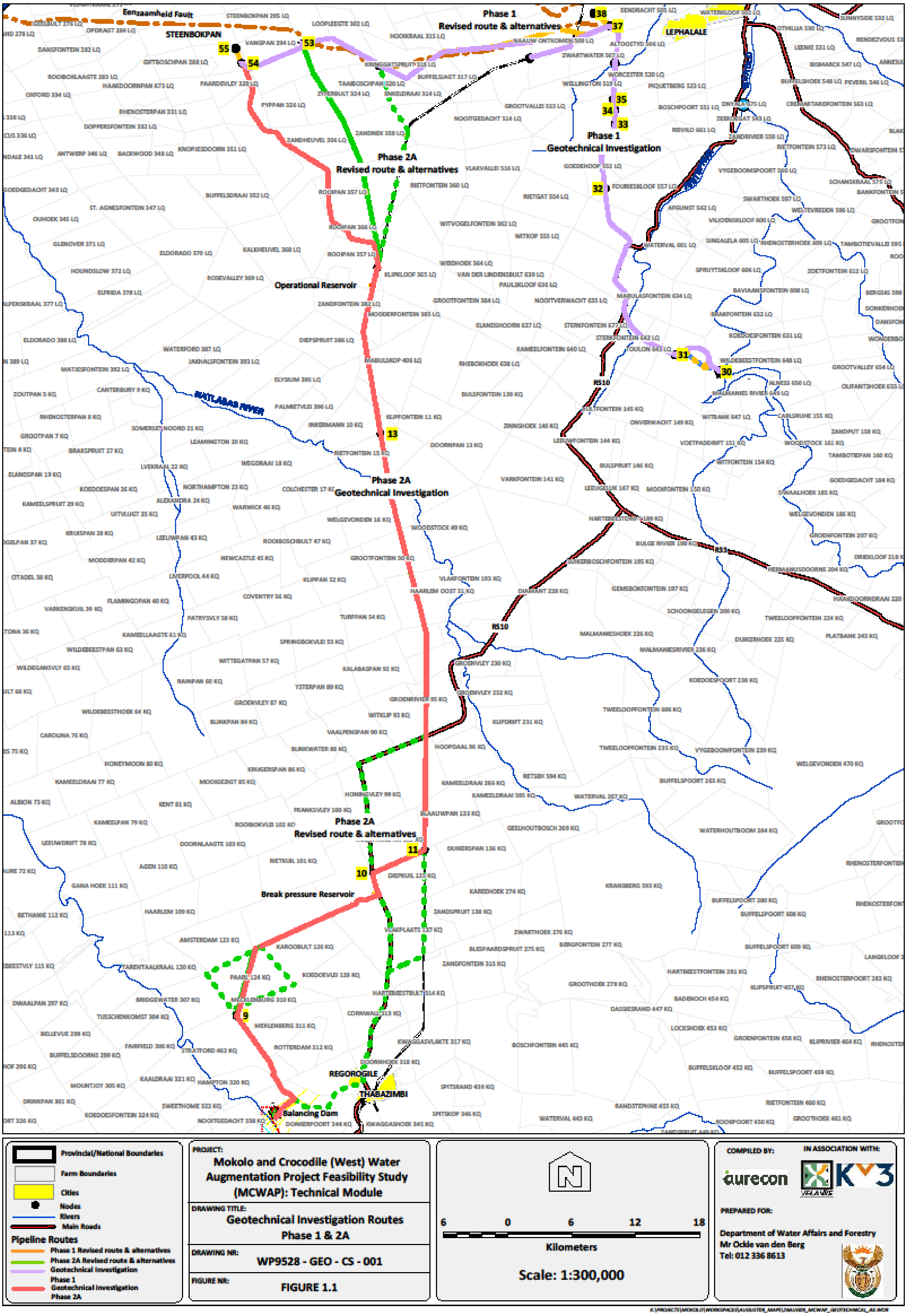



**Figure 1-1: Geotechnical Investigation Routes – Phases 1 & 2A**

## 1.2 Geotechnical Introduction

The study commenced with a desk study of available information; the findings of which were presented in the Project Inception Report and the parts relevant to Phase 1 are summarised hereunder:

- Consultation with Exxaro personnel – no geotechnical records on the existing Mokolo – Mathimba pipeline
- Mokolo Dam pump station – no geotechnical records on the existing pump station
- Researching documented geology on published geological maps

The various abstraction and conveyance options were subsequently briefly visited by the Technical Team. These preliminary geotechnical assessments of the various possible components for the respective routes were then considered in the selection of the favoured options for further geotechnical study.

Further geotechnical investigations were then conducted for the favoured options; the results of which are presented in this report. Geotechnical investigations were conducted for the following components:

- Mokolo pump station
- Mokolo – Mathimba RWR pipeline
- Mathimba – Steenbokpan pipeline
- Borrow areas for both pipeline sections

The Phase 1 investigations were carried out to a more detailed level than that for the Phase 2 works. For example, test pits were excavated along the pipeline routes at nominal 200 m spacing for Phase 1 and at nominal 5 km spacing for Phase 2A. Furthermore, borrow areas were not investigated for the Phase 2A alignment. The reasons for this were that design data was needed more urgently for Phase 1 than for Phase 2. In addition, there were budgetary constraints to carrying out a more detailed investigation for Phase 2.

## 1.3 Previous Investigations and Available Information

Available geological information included the published 1:250 000 scale geological maps (Council for Geoscience). The relevant sheets comprised the following:

- Sheet 2326 Ellisras
- Sheet 2426 Thabazimbi

A number of previous investigations had been conducted for the Mokolo Dam, but these did not make specific reference to the pumping station.

No records of previous geotechnical investigations for the existing Mokolo – Mathimba RWR pipeline could be sourced. This is unfortunate, as the new pipeline will run parallel to the existing pipeline for the majority of this section.

# 2. INVESTIGATION METHODOLOGY

## 2.1 Outline

A broad outline of the geotechnical investigations conducted for these feasibility studies is presented below. These geotechnical studies comprised the following:

- Assessment of climate and weathering
- Desk study of available information
- Field verification of the geology
- Rotary core drilling
- Test pitting
- Test pitting in potential borrow pits
- Identification of commercial sources of fine and coarse concrete aggregate in the area
- Dynamic Penetrometer Light (DPL) tests (often referred to as DCP tests)
- Laboratory testing
- Seismic hazard assessment

## 2.2 Desk Study

Available geological and geotechnical data was assessed. On a broad level, the published geological maps (Council for Geoscience) were studied, as well as published orthophotos (Chief Directorate: Surveys and Mapping) and images from Google Earth, while on a more detailed level previous site investigation reports were studied.

The available sources of information are listed above (Section 1.2).

## 2.3 Field Verification of the Geology

Brief site visits were undertaken, during which a visual inspection of rock outcrops was carried out and areas of outcrop were marked up on aerial photographs.

The coordinates of test pits and boreholes drilled along the conveyance routes and at the pump station site were picked up using a hand-held GPS instrument, and the usual allowances for accuracy should be made. Coordinates comply with the WGS84 coordinate system, utilising the Hartebeeshoek94 Datum (Lo 27). No detailed levelling of the borehole or test pit positions was conducted, i.e. no reliable information on the elevations was recorded.

## 2.4 Rotary Core Drilling

Boreholes were also drilled at the Mokolo Dam pump station and at a limited number of locations along the pipeline route where refusal had been encountered on hardpan ferricrete or calcrete, in order to determine the nature of the material underlying it. The core drilling was carried out by Weppelmann Geotechnical Drilling in the period March to May 2009.

Borehole cores were logged by engineering geologists in accordance with accepted South African practice (ABA Brink and RMH Bruin, 2002) and photographed. Borehole logs were prepared using Winlog® software and are included in **Appendix B**. Photographs of the borehole cores are included in **Appendix C**.
Borehole details are listed below in Table 2-1.

**Table 2-1: Borehole Details**

| Borehole No | Coordinates (WG27) | | BH depth (m) | Remarks |
|---|---|---|---|---|
| | Y | X | | |
| **Mokolo pump station** | | | | |
| PH01 | -73 105 | 2 653 366 | 6.7 | Boreholes drilled at approximately the corners of the pump station |
| PH02 | -73 123 | 2 653 370 | 5.8 | |
| PH03 | -73 110 | 2 653 428 | 6.5 | |
| PH04 | -73 120 | 2 653 420 | 6.3 | |
| **Phase 1A pipeline** | | | | |
| 7/01 | -63 042 | 2 620 956 | 5.1 | km 41 on MM* pipeline (section 7) |
| 25A/01 | -35 410 | 2 622 400 | 5.1 | km 29 on MS* pipeline (section 25A) |
| 25C/01 | -33 225 | 2 623 350 | 5.1 | km 32 on MS* pipeline (section 25C) |

MM* = Mokolo – Mathimba MS* = Mathimba – Steenbokpan

## 2.5 Test Pitting

Test pits were dug along the pipeline routes in order to assess the depths and quality of the in-situ material. The test pits were dug using a Hydromek 102B tractor-loader-backhoe (TLB) as this would give a direct assessment of the excavatability of the materials present and allow their inspection in an undisturbed state. The characteristics of this TLB are: overall power 74 kW, breakout force 62 kN, bucket width 600 mm. The profile encountered was logged by a geospecialist and samples were taken of representative horizons. Test pit profiles appear in **Appendix D**. These are numbered with the pipe section as a prefix.

After logging and sampling the holes were immediately backfilled using the TLB. Where appropriate, DCP tests were carried out in order to obtain a quantitative assessment of the consistency of the soils encountered. The DCP soundings are bound into **Appendix F** and have also been reduced to equivalent SPT N-values (blows per 300 mm penetrated) and presented graphically as N-value versus depth on the test pit profiles.

Where seepage had been encountered, and it was safe to do so, holes were left open for 24 hours to allow the water level to be measured before the hole was closed up. This provided a more quantitative assessment of the inflow that may be expected during construction and where under-drains may be required.

Holes were generally dug to a depth of 4 m or to refusal of the TLB. As the size of the pipeline was not known at the time of investigation, it was accordingly decided to dig to a maximum of 4 m in order to ensure that the holes were deep enough. The pipeline is now known to be about 900 mm, so the depth of trenching should have been a maximum of about 2.3 m.

Disturbed samples were recovered for laboratory testing (see Section 2.7 below for details of the tests carried out). Testing was carried out by Civilab Pty Ltd.

At the time of profiling, a visual assessment of the conditions encountered in the hole was made in order to allow interpolation between the sites of laboratory test results and notes 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.
- Any other observations relevant to construction of the pipeline.

Soft backfill will be placed directly on top of the pipes, compared to the general backfill (which can be of a lower quality) that will comprise the upper metre, further away from the pipe. Should lumps of clay or other spoil material be encountered during excavation of the pipe trench, the contractor will not be expected to use selective methods of excavating (SABS 1200 LB 3.4.1 and SABS 1200 DB 3.7). The contractor may, if he so wishes wash, screen or otherwise treat the material in order to produce material suitable for backfill.

The criteria that were adopted to determine the suitability of excavated material from the pipeline route for use as bedding or soft backfill are the same as discussed in Section 2.6.

## 2.6 Borrow Sources

Sources of material suitable for use as bedding or soft backfill to the pipe were identified at a nominal spacing of 5 km along the pipeline. The target volume of material was 50,000 $m^3$ per borrow pit. This approximates to 200% of the volume of material required as bedding/backfill for 5 km of pipeline. This is obviously a conservative approach, as it ignores the fact that much of the backfill could come from the pipe trench, except for rocky areas. However, it does allow for material and depth variability and for backup in the event that certain of the sources will not, for various reasons (environmental, socio-political, financial, etc.) be available during construction and will allow the distribution of sources that are actually employed during construction to be optimised.

SABS 1200 LB and SABS 0120: Part 3 LB give the standard specifications for selected granular material (used in construction of Class B, C and D bedding cradles) as follows:

- Grading requirements:
  - No material retained on 37.5 mm sieve
  - Less than 5% material retained on 19 mm sieve
  - More than 95% material retained on 0.6 mm sieve
- Compatibility requirements:
  - Up to and including 0.1: material suitable
  - Over 0.1 up to and including 0.4: material suitable (except for flexible pipes that may be subject to waterlogged conditions), but require extra care in compaction
  - Over 0.4: material unsuitable

Selected fill material as defined in SABS 1200 LB is defined as material that has a PI not exceeding 6 and is free from vegetation and lumps and stones of diameter 30 mm.

It was decided that these specifications are too stringent and would exclude most if not all of the material excavated from the pipe trench and borrow pits, requiring the sourcing of all selected granular and fill material from commercial sources (i.e. washed sand), thus increasing the cost of the project exponentially. Therefore, for this project the specification applied to the bedding and selected backfill material is that the maximum particle size is 10 mm and the maximum PI is 12. The compact requirements for the selected granular material, however, remain the same.

In addition to the borrow sources located, information was obtained of commercial sources of construction materials (crushed stone and sand for use in concrete).

The results of the investigation are given in **Appendix H**.

## 2.7 Laboratory Testing

All laboratory testing was carried out by Civilab Pty Ltd. The materials were generally tested according to the TMH1 (or other appropriate) standards. The individual standards employed are shown on the test results. The following tests were carried out:

- Road indicator tests (sieve grading and Atterberg Limit determinations)
- Compactability test and moisture content
- pH and conductivity
- Water soluble salts

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

- **Appendix F** – Laboratory test results
- **Appendix H** – Borrow pit investigation

# 3. GENERAL GEOLOGICAL SETTING

## 3.1 Lithology and Stratigraphy

The southern and central portion of the study area is underlain by the sandstones of the Waterberg Group which are considered to be between 1700 and 2000 million years in age (Johnson *et. al.,* 2006).

The northern portion of the study area is underlain by rocks of the Karoo Supergroup which comprise a succession of sandstone, siltstone, shale and mudstone and are approximately 150 to 270 million years in age.

Diabase intrusions occur in the central portion of the study area where they are seen to have intruded the sandstones of the Waterberg Group.

Extensive areas, particularly in the north, are covered by Quaternary Age sands which are younger than 1.8 million years.

Karoo sediments (sandstone, shale, mudrock) occur north of the Eenzaamheid Fault and it is from this assemblage that coal is mined.

The regional geology is shown on Figure 3-1.

## 3.2 Structural Geology

The sandstones of the Waterberg Group are almost horizontal bedded with a very shallow dip towards the north. Prominent NE- and NW-striking lineaments are recognized and likely represent intrusive diabase dykes.

The sedimentary strata of the Karoo Supergroup are essentially sub-horizontally bedded, but are extensively faulted. Some of the faults may be traced for significant distances.

## 3.3 Economic Geology

Extensive coal deposits are present in the Karoo Supergroup. These form the Waterberg Coalfield and are the impetus for the development in the region.

## 3.4 Seismic Hazard

According to Fernandez and Guzman, the area investigated is classified as having a seismic intensity of about VI on the modified Mercalli scale (MMS) with a 90% probability of not being exceeded during a 100 year recurrence period.

## 3.5 Climate and Weathering

The study area straddles the climatic N = 5 line (Weinert, 1980) which indicates that neither chemical decomposition nor mechanical disintegration are dominant modes of weathering; and that both modes of weathering are likely to have an influence.

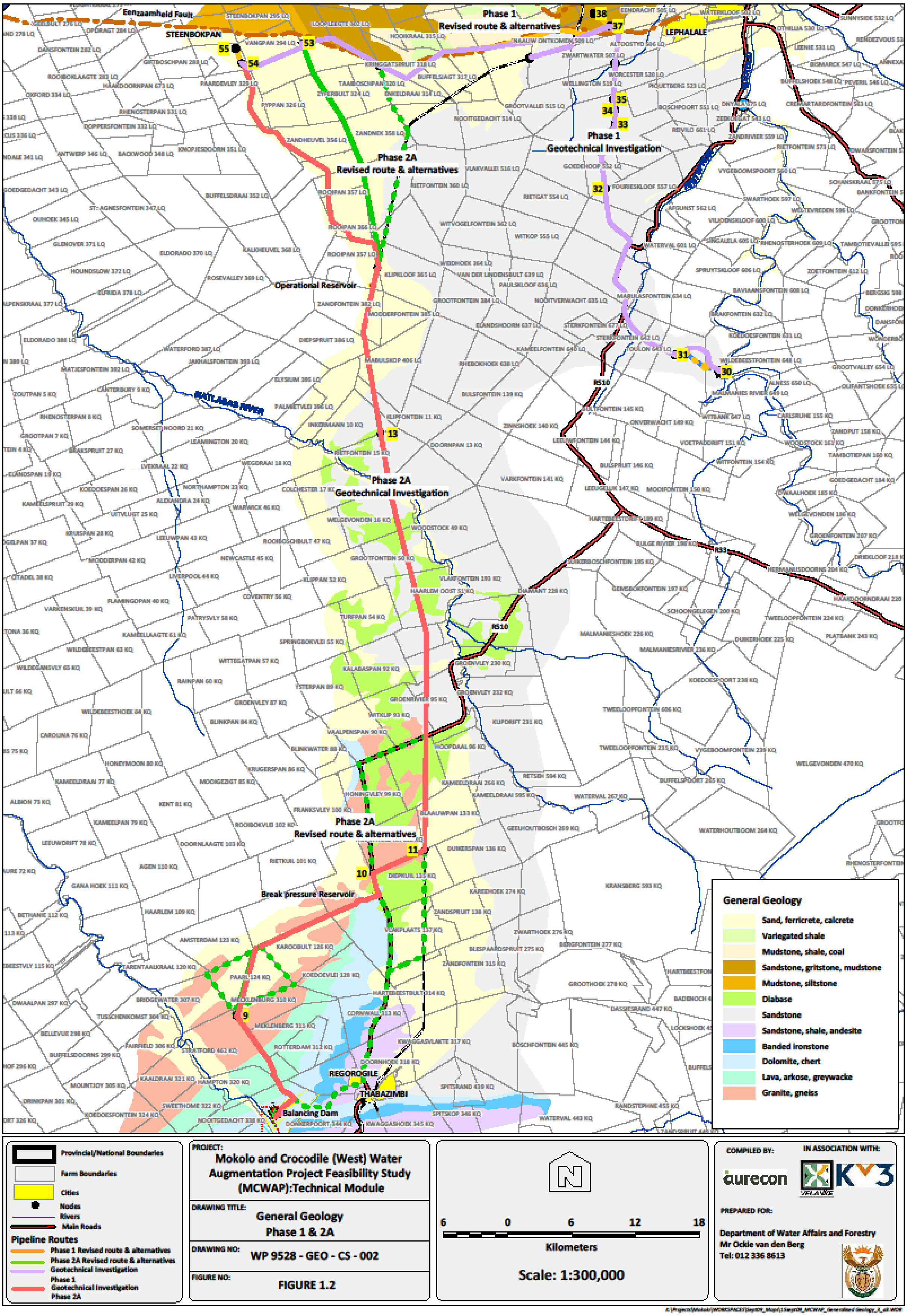



**Figure 3-1: General Geology – Phases 1 & 2**

# 4. INVESTIGATION FINDINGS

## 4.1 Introduction

This pipeline consists of two legs, one running roughly north-south from Mokolo Dam to the Mathimba RWR (about 43 km) and the second running east-west from Mathimba to Steenbokpan (about 38 km). For ease of reference, these are discussed separately and are referred to as the MM and MS pipelines, respectively.

## 4.2 General Geology

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

**Table 4-1: Geology of Phase 1**

| Rock Types | Formation | Group | Supergroup |
|---|---|---|---|
| Sand, ferricrete, calcrete | | | Quaternary |
| Variegated shale | Eendrachtpan | | Karoo Supergoup |
| Mudstone, shale, coal | Grootegeluk | | |
| Sandstone, gritstone, mudstone | Swartrant | | |
| Diabase | | | |
| Sandstone | Mogalakwena | Waterberg Group | |

The Karoo sediments are confined to the northern extremity of the route where they are downfaulted on the Eenzaamheid Fault into contact with the older Waterberg Group. The MS section of the pipeline has been routed just south of the fault (on the Waterberg Group) in order to avoid sterilising any coal deposits. However, in restricting the pipeline route to run along existing road alignments and farm boundaries, minor intrusions onto the Karoo Supergroup have occurred.

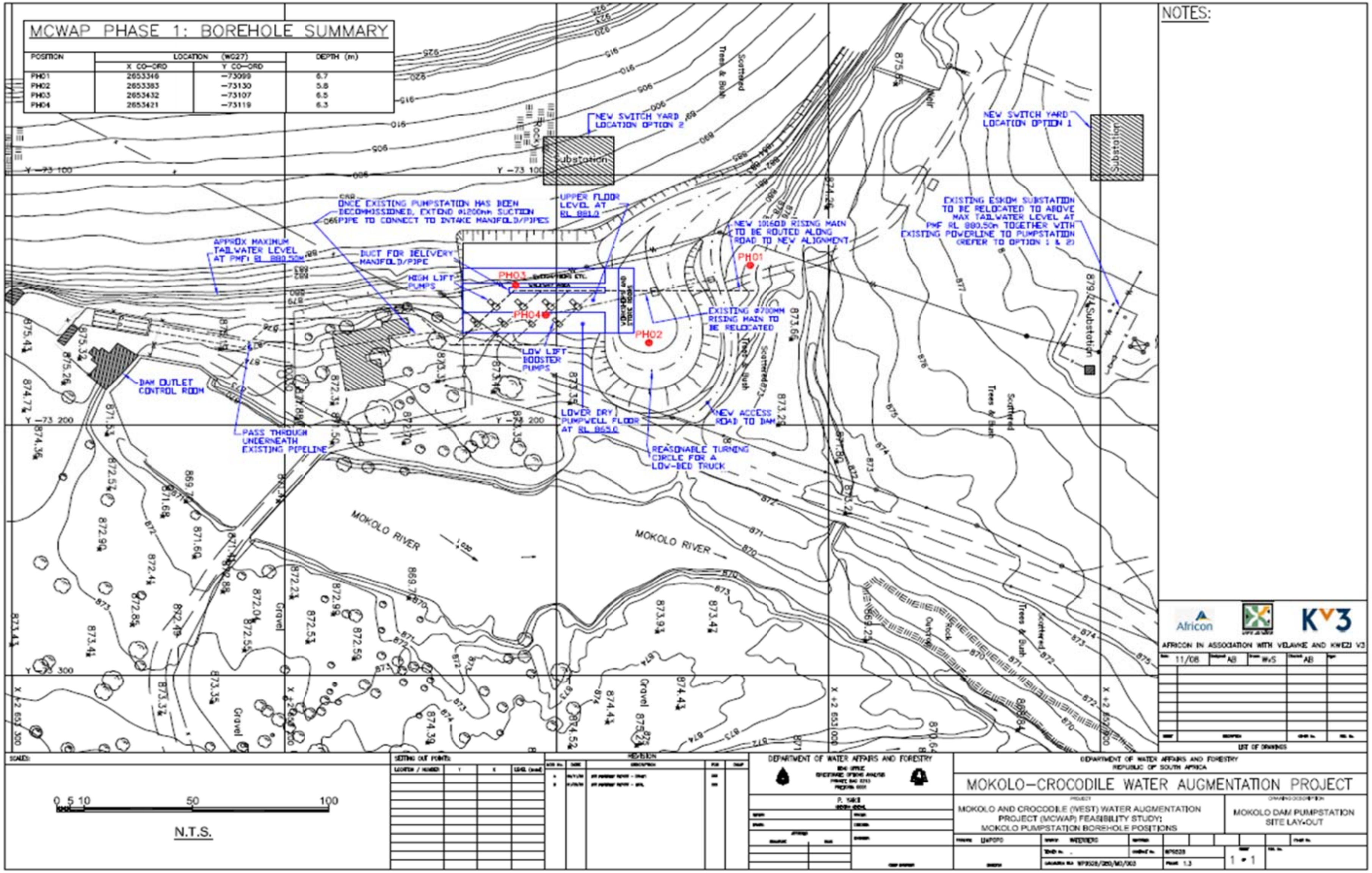
The whole length of the pipeline route is thus effectively underlain by Waterberg sandstones. These outcrop extensively up to about the Zeeland Works (km 33), but are blanketed by Quaternary Age deposits (sand, calcrete, ferricrete) north of this.

Diabase (generally in the form of narrow ENE trending dykes, but less frequently as thin sills) is intruded into the Waterberg Group and occurs mainly only in the Phase 2A area.

## 4.3 Abstraction Works

The proposed pump station will be located at the southern end of the pipeline at Mokolo Dam, next to the existing pump station.

Four boreholes were drilled at this location to depths of up to 6.67 m. The logs of the boreholes are given in **Appendix B**. The positions are indicated on Figure 4-1 and were positioned to test conditions at the corners of the planned structure.




| POSITION | LOCATION (WG27) X CO-ORD | Y CO-ORD | DEPTH (m) |
|---|---|---|---|
| PH01 | 2653316 | −73099 | 6.7 |
| PH02 | 2653383 | −73130 | 5.8 |
| PH03 | 2653432 | −73107 | 6.5 |
| PH04 | 2653421 | −73119 | 6.3 |

**Figure 4-1: Mokolo Pump Station Borehole Positions**

The succession within the boreholes comprises sandstone over the full depth, with a thin surface layer of sand in PH03. The sandstone is initially encountered as weathered at the surface, which was recovered as cobbles and gravel in a sand matrix, with hard, competent rock encountered at depths of between 1.2 and 1.8 m.

Due to the local topography at the position of the proposed building footprint, significant excavation into the sandstone will have to be undertaken. Therefore, to prevent differential settlement of the pumping station building, it is recommended that the foundations bear on the unweathered sandstone. An Allowable Bearing Pressure (ABP) of 1 MPa may be assumed for the highly to moderately jointed unweathered sandstone for design purposes. The actual bearing pressure of the in-situ rock will in fact be higher, but a bearing pressure of 1 MPA is assumed since this is within the usual design range.

The sandstone is very hard and excavations will have to be blasted. Precautions will be required to prevent vibration damage to the existing pump station and its equipment. Except for the thin, overlying weathered material, excavations may be safely cut vertically.

## 4.4 Centreline and Borrowpit Investigation

Test pits were excavated at a nominal spacing of 200 m along the routes of both pipeline sections. Locations where excavation was not possible due to rock outcrop or inaccessible areas, it was recorded and is shown on Figures 4-6 to 4-11. Furthermore, where the observed profile was sufficiently consistent, the pits were excavated at a nominal spacing of 400 m, reverting to the 200 m spacing where a variable profile was encountered. The test pit profiles are given in **Appendix D** and the photographs in **Appendix E**.

Pits were excavated, using a TLB (Hidromek 102B) and profiled by a geospecialist in accordance with the standards given in the Geoterminology Workshop 1990 (Brink and Bruin, 2002). The terms used are defined in **Appendix A**. Dynamic Penetrometer Light (DPL) soundings were undertaken adjacent to the test pits in order to provide a quantitative assessment of the consistency of the in-situ materials. These soundings are shown graphically as equivalent SPT N-values (blows per 300 mm penetrated) on the relevant soil profiles.

Following the excavation of the test pits, boreholes were drilled at three locations (7/01 at km 41 on the Mokolo – Mathimba (MM) pipeline route, 25A/01 at km 29 and 25C/01 at km 32 on the Mathimba – Steenbokpan (MS) pipeline route) where the pits terminated on hard material other than rock (calcrete, ferricrete), to determine what these deposits were underlain by. In all cases, the calcrete or ferricrete was found to be directly underlain by sandstone. The logs of these boreholes are given in **Appendix B**.

Laboratory testing comprising Road Indicator (RI), compactability and chemical analyses (pH and conductivity) were undertaken on samples recovered from the test pits. The results of the tests are given in **Appendix F**. The results of the RIs were compared against the specification for bedding and soft backfill material (PI <12 and maximum particle size of 10 mm as described in Section 2.6), and the depths of the suitable soils annotated on the individual test pit profile sheets. A summary of the ground conditions at each test pit position along the pipeline routes is given on spread sheets in **Appendix G**. Graphical representations of the excavation depth and inferred percentage utilisation, along with interpolated averages for these are also included as Figure 4-2 and are duplicated below as Figures 4-3 and 4-4.

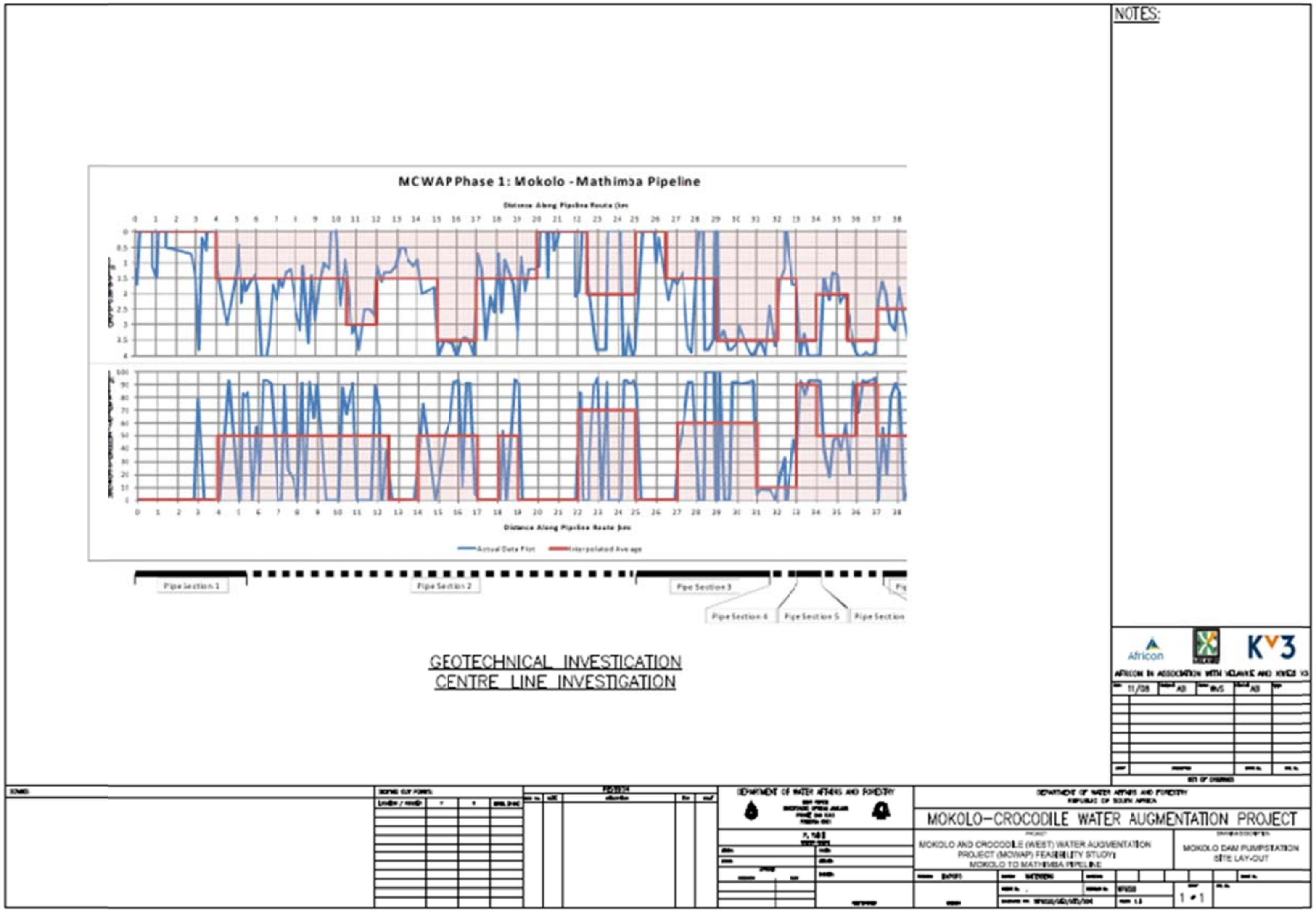



**Figure 4-2: Centreline Investigation: Summary Data – Mokolo to Matimba Pipeline**

### 4.4.1 Mokolo – Mathimba RWR Pipeline

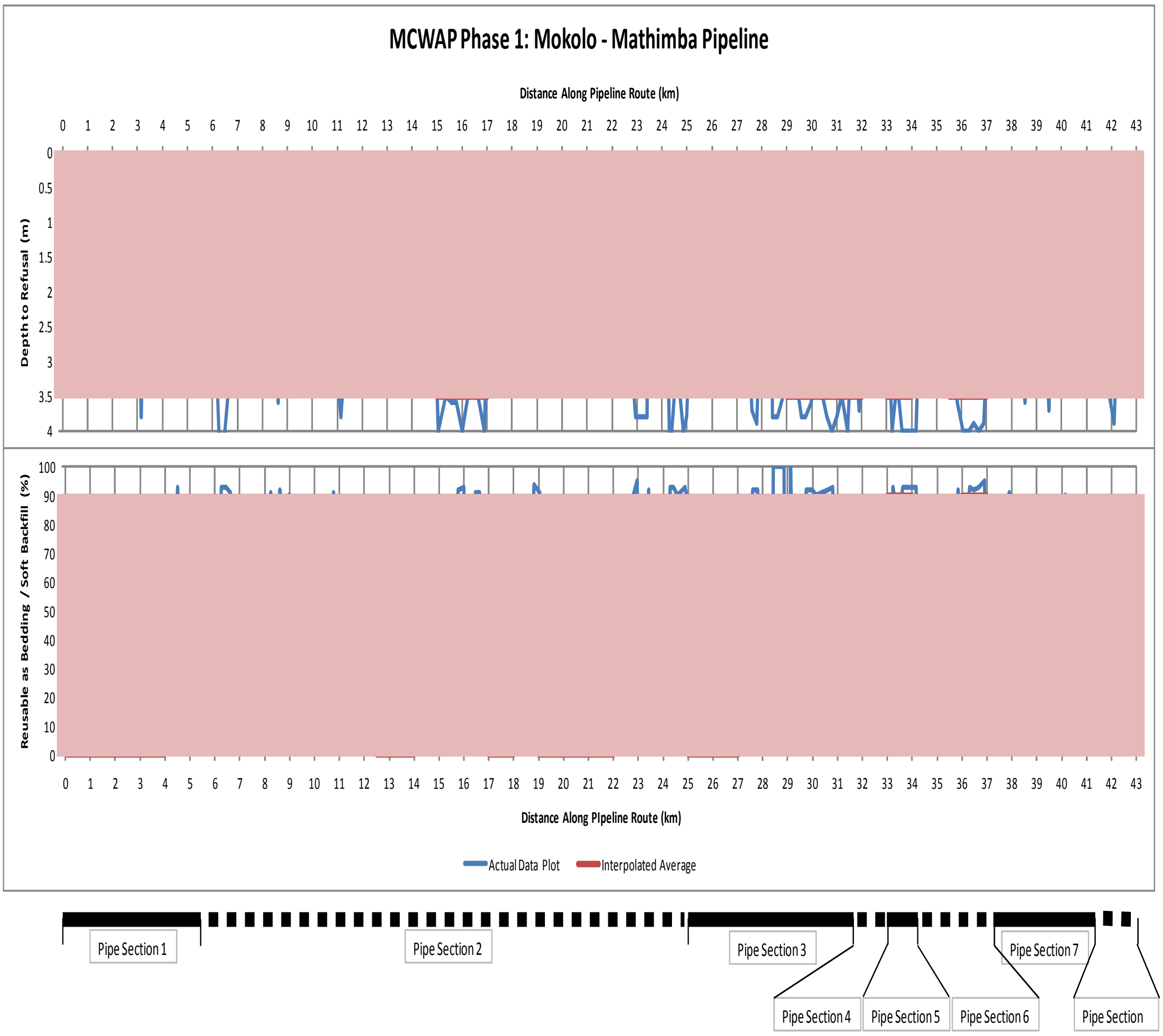



**Figure 4-3: Summary of Profile Data: MM Pipeline**

Figure 4-1 indicates there are significant stretches of the MM pipeline route where rock outcrops, particularly over the first 4 km from Mokolo Dam and where the pipeline route traverses the mountains (approximately 15-33 km). Furthermore, at the majority of positions where a significant percentage of material is identified as being suitable for bedding and soft backfill, the depth to refusal is generally much less than 4 m. Therefore, much of the pipeline trench excavation cannot be relied upon to supply adequate quantities of bedding and soft backfill material, and will have to be supplemented from borrow pits, particularly over the first 30 km of the route.

Groundwater was also intermittently present over the MM pipeline route and was generally encountered at locations where the pipeline route traverses or runs close to watercourses. A moderate seepage flow rate was generally encountered, with the standing level monitored after approximately 24 hours. Some slower flow rates were observed within a minority of pits, but, due to the lack of significant inflow, were not monitored. At two locations, one adjacent to a dam (approximately 11-12 km) and another extending either side of a significant river (approximately 14-15 km), sufficient water was present to create running sand, which caused the sides of the test pits to collapse almost immediately. Dewatering during construction will have to be undertaken at these locations. Full details of the groundwater encountered within the pits are given on the individual profile sheets in **Appendix C**, and summary spread sheets in **Appendix G**. In sections where the invert level of the pipe will be below the water table and a risk of floating occurs, the installation of anti-floating devices (such as concrete blocks placed on the pipes) should be considered.

The MM pipeline passes a large ash dump at 37-41 km. Intermittent seepage and surface water run-off was observed emanating from the direction of the dump, and it should be assumed that significant leaching of potentially corrosive contaminants from the ash dump, into surrounding soils may have taken place over the operational lifespan of the dump. This assumption is largely confirmed by the conductivity testing of these soils, particularly by samples analysed from pits C7/04-C7/11, which display consistently elevated values.

Whilst the majority of the pits were stable with vertical sides, this is based on an assessment of test pits of limited length and probably does not give an accurate assessment of the stability of the long trenches required for a pipeline. A more accurate assessment of the stability of the soils may be determined from the angle of repose at which the spoil from the pit stood at following excavation. It is this observation that has been used to derive the anticipated stable slopes. On this basis, with the exception of locations where running sand was encountered, the stability of excavation slopes is anticipated at 1:1 (VH). Excavations in running sand should be stable at 1:3.

The DPL soundings indicate the soils to be generally loose to medium dense. Where drier, clayey soils were encountered, these generally show a stiffer consistency.

The majority of the pits along the MM pipeline route terminated on hard sandstone. The TLB used was able to excavate into the weathered zone of the sandstone, but refused when hard, unweathered rock was encountered. At locations where the pit was abandoned due to slow progress (i.e. dense soils or slightly weathered rock), it should be possible to excavate more efficiently by using a larger machine (say 20 t excavator), but excavations into the unweathered rock will not be possible. Blasting will be required to install the pipeline for these sections. This is supported by the evidence of blasted rock that occurs frequently along the existing pipeline. The new pipeline runs immediately parallel to the existing pipeline and blasting will have to be controlled in order not to damage it.

The results of the compactability tests undertaken on samples recovered from the centreline investigation are annotated on the individual profile sheets. Of the samples analysed, eight (8) had a compactability factor of 0.5 (i.e. unsuitable for bedding) or higher and 22 had a compactability of 0.4 or lower (i.e. suitable for bedding). Therefore, the majority of the selected material identified along the MM pipeline alignment is suitable for bedding. However, these sources are not all in one location, and contractors are advised to consult the individual profile sheets for compliance with the criteria.

More detailed analysis of the ground conditions may be gained from consulting the individual profile sheets and laboratory test data.

### 4.4.2 Mathimba – Steenbokpan Pipeline

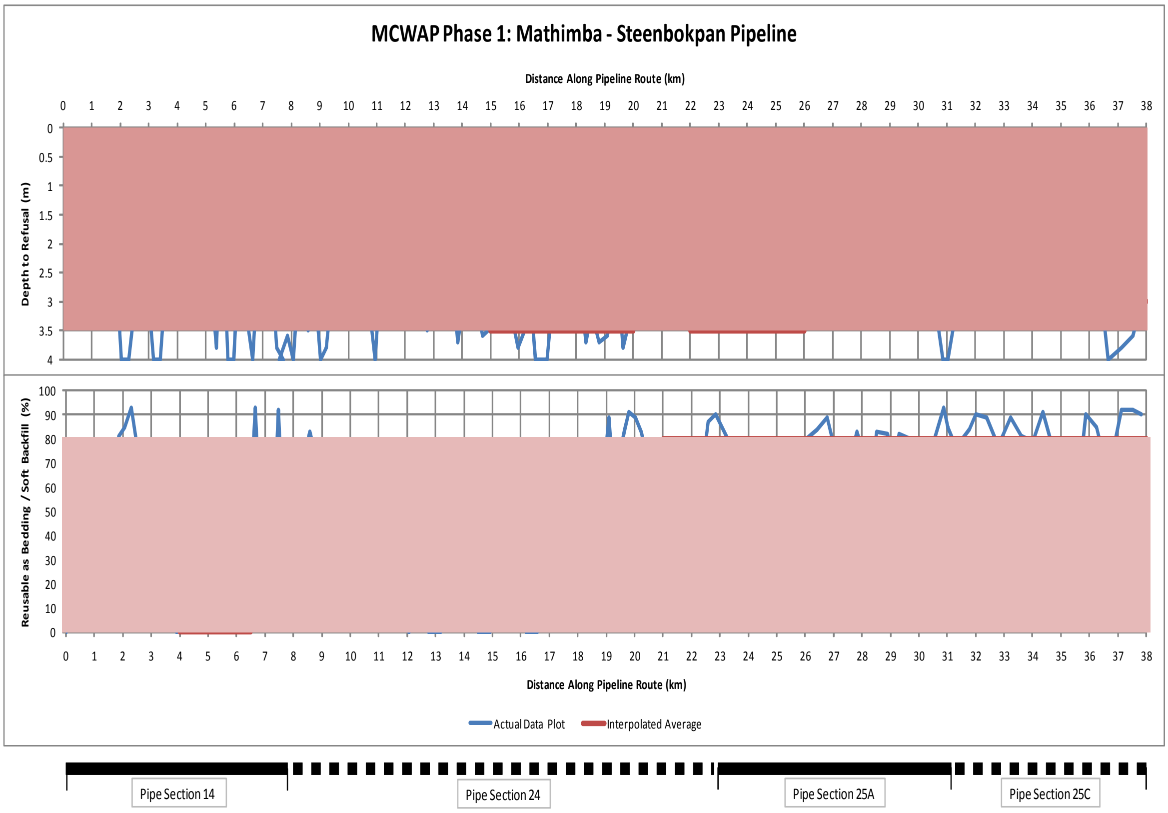



**Figure 4-4: Figure Summary of Profile Data: MS Pipeline**

Figure 4-2 indicates much more favourable conditions than the MM pipeline route, as significant quantities of suitable bedding and soft backfill material were encountered along the pipeline route, especially from 17 km. From this point, it is likely that the pipeline excavation will yield enough suitable material. Borrow pits may be necessary to supplement the selected material over the first 17 km of the pipeline route.

Apart from one location where the pipeline route crosses the railway line (approximately 3.7 km), no significant water inflows were observed.

Whilst the majority of the pits were stable with vertical sides, this is based on an assessment of test pits of limited length and probably does not give an accurate assessment of the long trenches required for a pipeline. A more accurate assessment of the stability of the soils may be determined from the angle of repose at which the spoil from the pit stood at following excavation. It is this observation that has been used to derive the anticipated stable slopes. On this basis, the stability of excavation slopes is anticipated at 1:1.

The DPL soundings indicate the soils to be generally loose to medium dense. Where drier, clayey soils were encountered, these generally show a stiffer consistency. Over the first 17 km of the pipeline route the pits generally terminated on sandstone, or occasionally mudstone. From 17 km, the pits generally terminated on strongly cemented ferricrete, which, from boreholes drilled along this route, was shown to directly overlie sandstone. In places, softer sandstone, assumed to be of the Karoo, was encountered and it was possible to excavate about 1 to 2 m into it. However, the TLB used, was not able to excavate into the hard Waterberg sandstone.

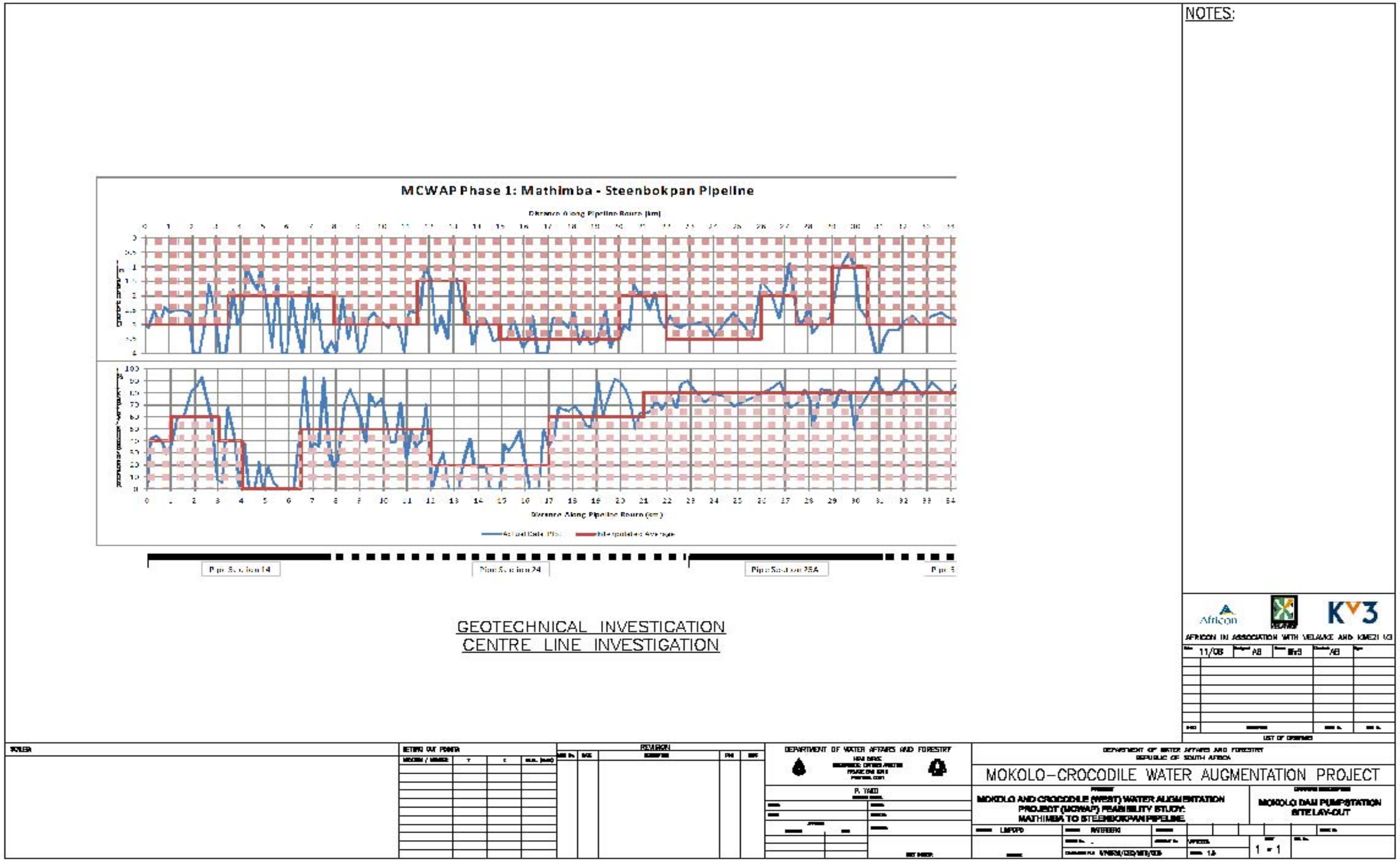



**Figure 4-5: Centreline Investigation: Summary Data – Matimba to Steenbokpan Pipeline**

Furthermore, at locations where strongly cemented ferricrete or calcrete was encountered, deeper excavation was not possible with the machine used. It may be possible to excavate into the ferricrete, calcrete or Karoo rocks by using a larger machine to an estimated maximum of 1m below the depth of refusal shown on the test pit profiles. However, bearing in mind that the ferricrete and calcrete directly overlie Waterberg sandstone, which will, in all probability have to be blasted. These locations must be considered to allow for intermediate and hard rock excavation (as per SABS 1200 D 3.1.2) during construction.

The results of the compactability tests undertaken on samples recovered from the centreline investigation are annotated on the individual profile sheets. Of the samples analysed, eight (8) had a compactability factor of 0.5 (i.e. unsuitable for bedding) or higher and seven (7) had a compactability of 0.4 or lower (i.e. suitable for bedding). Therefore, the approximately half of the selected material identified along the MS pipeline alignment is suitable for bedding. However, these sources are not all in one location, and contractors are advised to consult the individual profile sheets for compliance with the criteria.

More detailed analysis of the ground conditions may be gained from consulting the individual profile sheets and laboratory test data.

### 4.4.3 Borrow Materials

In order to provide additional quantities of suitable bedding and soft backfill material for both pipeline sections, a borrow pit investigation was undertaken. It was intended to locate borrow pits at a nominal spacing of 5 km, each capable of providing a nominal 50,000 $m^3$ of material. The results of this investigation are presented in **Appendix G**, and include location plans, test pit profiles, and results of laboratory testing, and are summarised hereunder in Table 4-2.

**Table 4-2: MM Pipeline Borrow Pit Summary**

| No. | Location (WG27) | | Est. volume bedding / soft backfill ($m^3$) | Compactability Factor | Offset to pipeline (km) | Stake value (km) |
|---|---|---|---|---|---|---|
| | Y | X | | | | |
| BP16 | -66 264 | 2 650 424 | 64,000 | 0.5 | 0 | 8.6 |
| BP7 | -64 808 | 2 647 919 | 40,000 | 0.4-0.5 | 0.5 | 11.7 |
| BP6 | -63 338 | 2 644 766 | 14,000 | 0.4-0.5 | 0.2 | 15.3 |
| BP8 | -61 908 | 2 636 582 | 120,000 | 0.4 | 0.9 | 25.0 |
| BP10 | -63 369 | 2 628 509 | 38,000 | 0.4 | 0.5 | 33.2 |
| BP11 | -61 489 | 2 623 808 | 44,000 | 0.4-0.5 | 1.8 | 37.7 |

Borrow pit locations were investigated over the length of the MM pipeline, but not all of these proved to be workable, particularly over the first 8.6 km (to BP16) and the section which traverses the mountains, i.e. between BP6 at 15.3 km and BP10 at 33.2 km. A combination of unsuitable ground conditions (i.e. unsuitable material or insufficient quantities), and borrow pits not being permitted on certain farms, means that the spacing between BP6, BP8 and BP10 is approximately 10 km. Therefore, additional haulage, over and above the proposed 5 km spacing, will have to be undertaken in these areas. This is particularly the case at the start of the pipeline, where material will have to be hauled southwards from BP16 at 8.6 km. Furthermore, contractors should be aware of the difficulties of transporting the material from the borrow pits to the pipeline section that traverses the mountains, due to the topography along the proposed pipeline route, with particular emphasis on the haul barriers (steep slopes) to the north and south of BP8 (at 25.5 and 22 km, respectively).

A number of potential sites were investigated south of BP16, but were abandoned as being unsuitable, as shown on Table 4-3 (BP1, BP2, BP3, and BP4).

**Table 4-3: Abandoned Borrow Sites – MM Pipeline**

| Site no. | Location (WG27) | | Comments |
|---|---|---|---|
| | Y | X | |
| BP1 | -73,427 | 2 652 949 | Some investigation carried out at these sites, but abandoned due to being unworkable (material unsuitable, insufficient volume, landowner indicated alternative site, etc.) |
| BP2 | -71,204 | 2 651 194 | |
| BP3 | -70,997 | 2 651 204 | |
| BP4 | -68,376 | 2 651 519 | |
| BP5 | -64,596 | 2 648 660 | |
| BP9 | -62,018 | 2 634 641 | |

Along the MS pipeline, suitable material is readily available and borrow pits were identified at the sites shown in Table 4-4.

**Table 4-4: MS Pipeline Borrow Pit Summary**

| No. | Location (WG27) | | Est. volume bedding / soft backfill ($m^3$) | Compactability factor | Offset to pipeline (km) | Stake value (km) |
|---|---|---|---|---|---|---|
| | Y | X | | | | |
| BP11 | -61,489 | 2 623 808 | 44,000 | 0.4-0.5 | 2.3 | 2 |
| BP12 | -55,295 | 2 623 914 | 98,000 | 0.4 | 0.8 | 7.6 |
| BP14 | -50,845 | 2 623 559 | 73,000 | 0.5 | 0.4 | 12.5 |
| BP13 | -46,805 | 2 625 479 | 100,000 | 0.4-0.5 | 1.8 | 18.3 |
| BP15 | -29,168 | 2 625 031 | 135,000 | 0.5 | 0 | 36.7 |

The majority of the MS pipeline route follows the existing Lephalale – Steenbokpan road and borrow material is readily available at the desired 5 km intervals. Therefore, haulage of material will not be an issue. Furthermore, as stated above, from approximately 17 km the pipeline excavation will probably frequently yield sufficient material suitable for bedding and soft backfill and it will probably not be necessary to haul in material.

Of the samples analysed for compactability, 35 had a compactability factor of 0.5 (i.e. unsuitable for bedding) or higher and 41 had a compactability of 0.4 or lower (i.e. suitable for bedding). Therefore, slightly more than half of the selected material identified within the borrow pits is suitable for bedding. However, only borrow pits BP8, BP12 and BP13 display compliance with the criteria, as all the samples analysed from the test pits on these borrow pits have a compactability factor of 0.4 or lower. The other borrow pits are either partially wholly unsuitable for sources of bedding material.

Therefore, if further sources of suitable bedding material cannot be found, commercial sources must be sought. . The assessment criteria are given in Section 2.6 and repeated hereunder in Table 4-5.

**Table 4-5: Compactability Assessment**

| Compactability Factor | Suitability |
|---|---|
| <0.1 | Suitable for bedding |
| 0.1-0.4 | Suitable for bedding (extra care with compaction for flexible pipes and saturated conditions) |
| >0.4 | Unsuitable for bedding |

The borrow pit material is further assessed against the criteria given in SABS 0120: Part 3 LB in Table4-6 below.

**Table 4-6: Assessment of Borrow Pit Material in Accordance with SABS 0120**

| Borrow Pit | Compactability Factor | % passing sieve (mm) | | | Comments |
|---|---|---|---|---|---|
| | | 37.5 (100%) | 19 (>95%) | 0.425 (<5%) | |
| BP16 | 0.5 | 100 | 100 | 53-61 | Too fine |
| BP7 | 0.4-0.5 | 100 | 100 | 42-78 | Too fine |
| BP6 | 0.4-0.5 | 100 | 100 | 50-66 | Too fine |
| BP8 | 0.4 | 100 | 100 | 45-50 | Too fine |
| BP10 | 0.4 | 100 | 100 | 43-62 | Too fine |
| BP11 | 0.4-0.5 | 100 | 100 | 48-69 | Too fine |
| BP12 | 0.4 | 100 | 100 | 30-67 | Too fine |
| BP14 | 0.5 | 100 | 100 | 61-73 | Too fine |
| BP13 | 0.4-0.5 | 100 | 100 | 65-75 | Too fine |
| BP15 | 0.5 | 100 | 100 | 65-68 | Too fine |

Given the criteria for the grading is less than 5% passing 0.6 mm sieve, it can be seen that all the material is too fine to classify as selected granular material in accordance with SABS 0120: Part 3 LB.

Due to the large amount of borrow material that fails the compactability requirements and the financial constraints on the project, making the sourcing of bedding material from commercial sources uneconomical, another solution must be sought. The solution to this problem may lie in the requirement for blasting of the Waterberg quartzite, and the environmental constraints on dumping the blasted rock at ground level. SABS 0120: Part 3 LB gives examples of tests undertaken on various soil types from the Durban area. One of these soils types is quartzite crusher run, which gives a compactability factor of 0.35.

Therefore, it may be possible to generate large amounts of suitable bedding material by crushing the blasted rock on site, although testing samples of the rock should be undertaken prior to construction to ensure the rock meets the required grading. This method should provide more than enough bedding material (soft backfill material can be sourced from the borrow pits and pipeline excavation) for most of the MM pipeline alignment. Depending on haul costs and the cost of suitable commercially sourced material, it may be preferable to use the surplus crushed rock material for the northern part of the MM pipeline and MS pipeline routes, where quartzite occurs less frequently or at greater depth.

It is unlikely that the Karoo rocks will be suitable for this method, as they are softer and will generate more fines when crushed, which are likely to lead to compactability test failures. They may also have too high a PI.

However, SABS 0120 is a very stringent standard and the sand sourced from borrow pits and the pipe trench excavation will probably be suitable for bedding. Further testing of this sand for E moduli, etc. will be carried out in the detailed design phase to confirm its suitability.

#### 4.4.4 Commercial Sources of Construction Materials

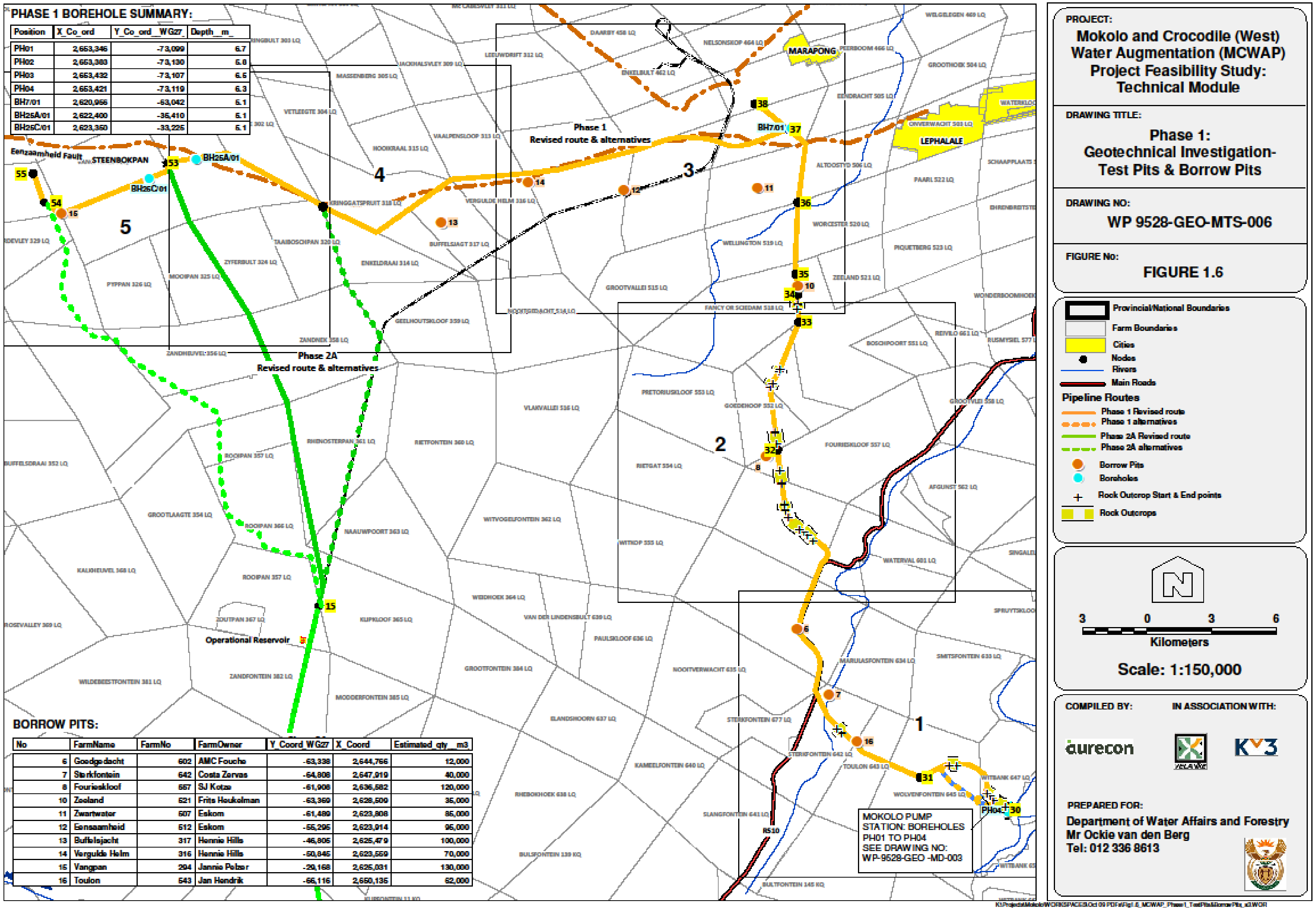
Four commercial sources of stone and sand aggregate for concrete have been identified in the vicinity of Lephalale. The stone aggregate is likely to comprise two distinct materials; well-rounded alluvial gravels and crushed sandstone. The alluvial gravels will probably only be suitable for low strength concrete, as the smooth surfaces of the gravel do not bond effectively with the concrete. The rough faces of the crushed rock, however, provide an ideal bonding surface, making it suitable for both low and high strength concrete. The sand is likely to be dredged from nearby riverbeds, and also be suitable for use as bedding and soft backfill material. Details of the suppliers and results of laboratory testing indicating the suitability of the material are included in **Appendix H**.

#### 4.4.5 Chemical Analyses

The chemical analyses show that the pH of the soils tested ranges from 4.7 to 7.9, and the conductivity from 8.2 to 2642.6µS/cm. These indicate that the steel pipe must be protected against corrosion from contact with the soils along both pipeline sections and from the material encountered within the identified borrow pits.

### 4.5 Terminal Reservoirs

Terminal reservoirs were not investigated during this investigation, as they did not form part of the brief.




PHASE 1 BOREHOLE SUMMARY:

| Position | X_Co_ord | Y_Co_ord__WG27_ | Depth__m_ |
|---|---|---|---|
| PH01 | 2,653,346 | -73,099 | 6.7 |
| PH02 | 2,653,383 | -73,130 | 5.8 |
| PH03 | 2,653,432 | -73,107 | 6.5 |
| PH04 | 2,653,421 | -73,119 | 6.3 |
| BH7/01 | 2,620,966 | -63,042 | 5.1 |
| BH25A/01 | 2,622,400 | -35,410 | 5.1 |
| BH25C/01 | 2,623,350 | -33,225 | 5.1 |

BORROW PITS:

| No | FarmName | FarmNo | FarmOwner | Y_Coord_WG27 | X_Coord | Estimated_qty__m3 |
|---|---|---|---|---|---|---|
| 6 | Goedgedacht | 602 | AMC Fouche | -63,338 | 2,644,766 | 12,000 |
| 7 | Starkfontein | 642 | Costa Zervas | -64,808 | 2,647,919 | 40,000 |
| 8 | Fourieskloof | 557 | SJ Kotze | -61,908 | 2,636,582 | 120,000 |
| 10 | Zeeland | 521 | Frits Heukelman | -63,369 | 2,628,509 | 35,000 |
| 11 | Zwartwater | 507 | Eskom | -61,489 | 2,623,808 | 85,000 |
| 12 | Eensaamheid | 512 | Eskom | -55,296 | 2,623,914 | 95,000 |
| 13 | Buffelsjacht | 317 | Hennie Hills | -46,805 | 2,625,479 | 100,000 |
| 14 | Vergulde Helm | 316 | Hennie Hills | -50,845 | 2,623,559 | 70,000 |
| 15 | Vangpan | 294 | Jannie Pelser | -29,168 | 2,625,031 | 130,000 |
| 16 | Toulon | 543 | Jan Hendrik | -66,116 | 2,650,135 | 62,000 |

**Figure 4-6: Location of Test Pits & Borrow Pits – Phase 1 Key Map**

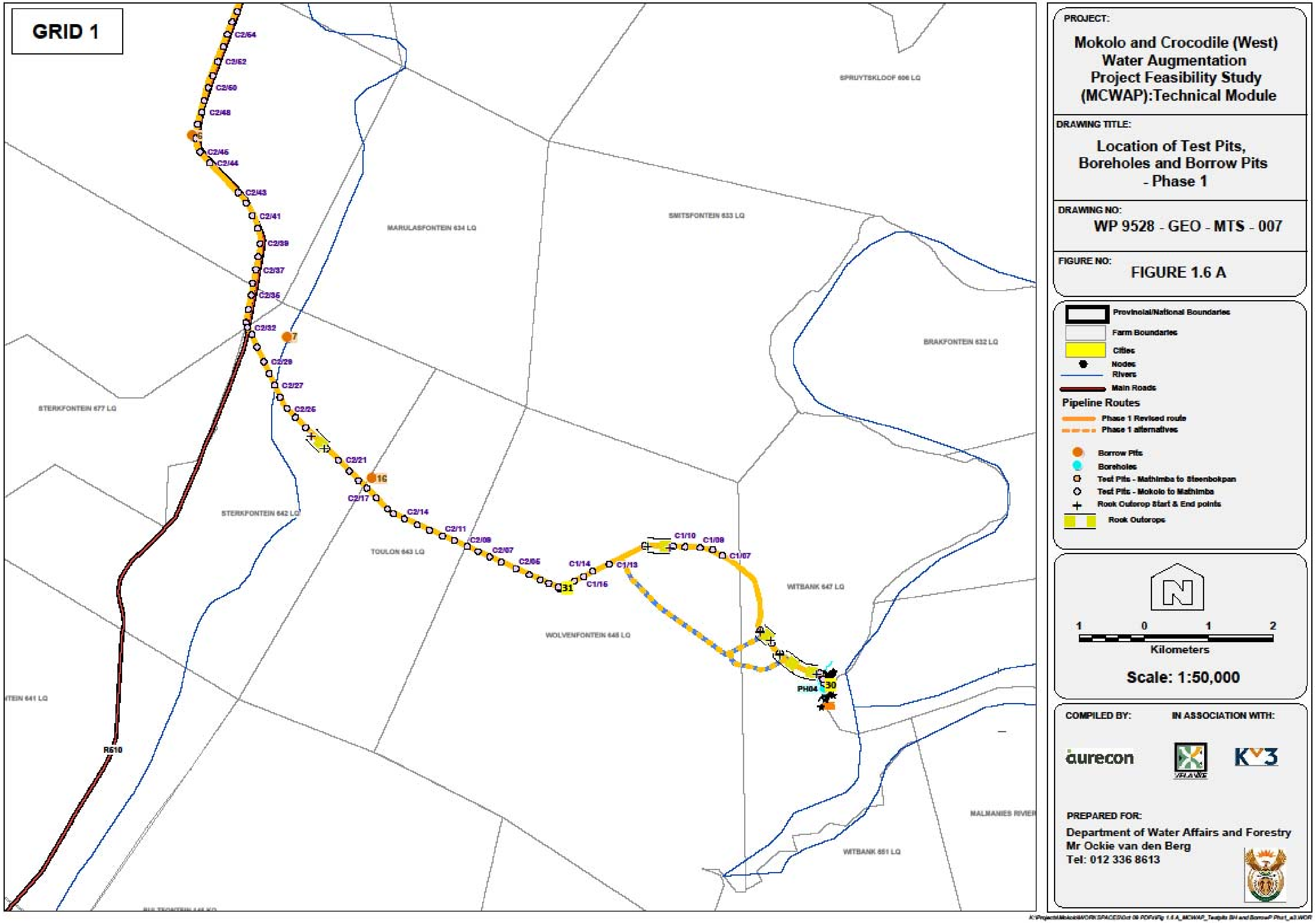



**Figure 4-7: Allocation of Test Pits Boreholes & Borrow Pits – Phase 1 Key Map 1**

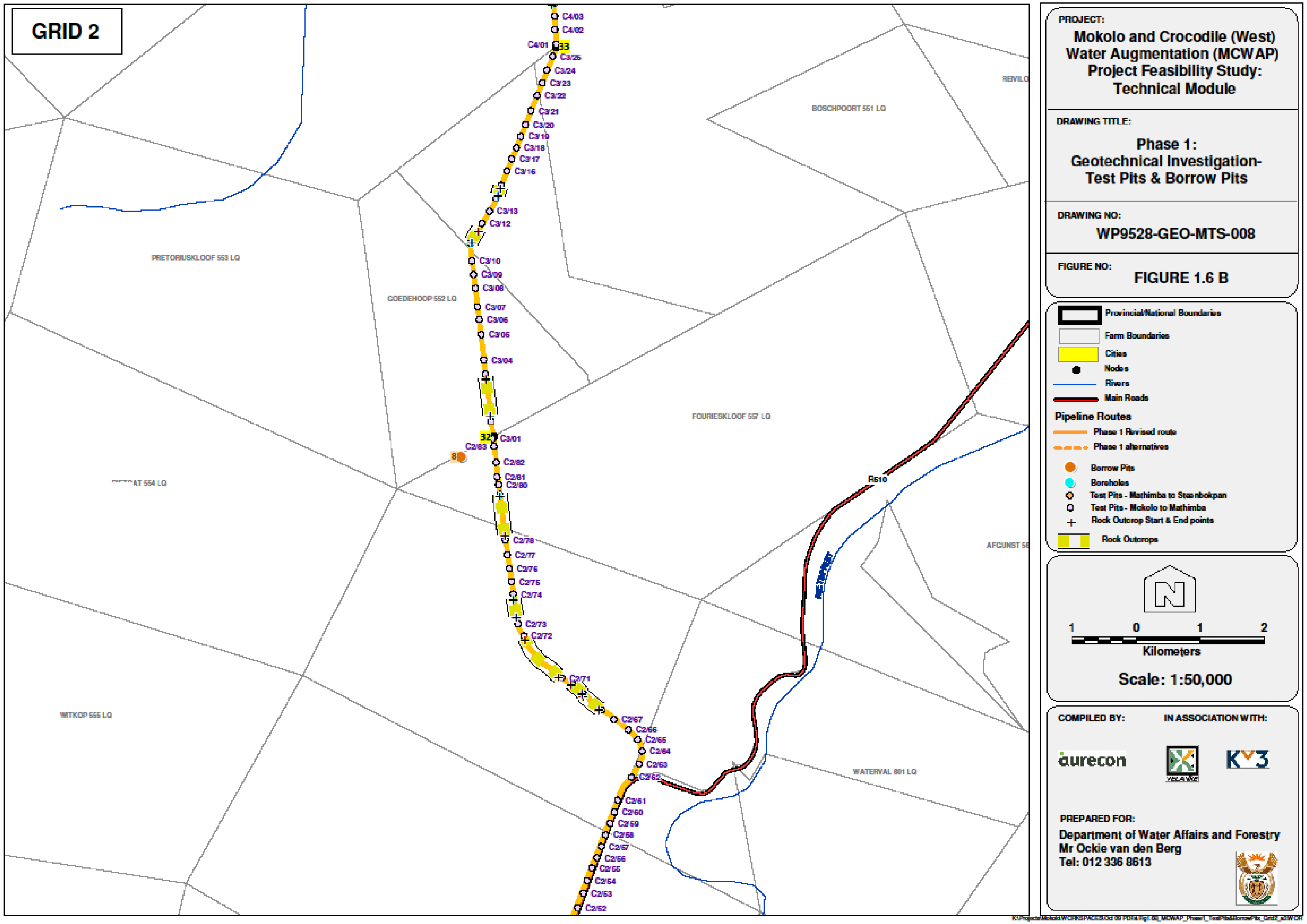



**Figure 4-8: Geotechnical Investigation: Test Pits & Burrow Pits – Phase 1 Key Map 2**

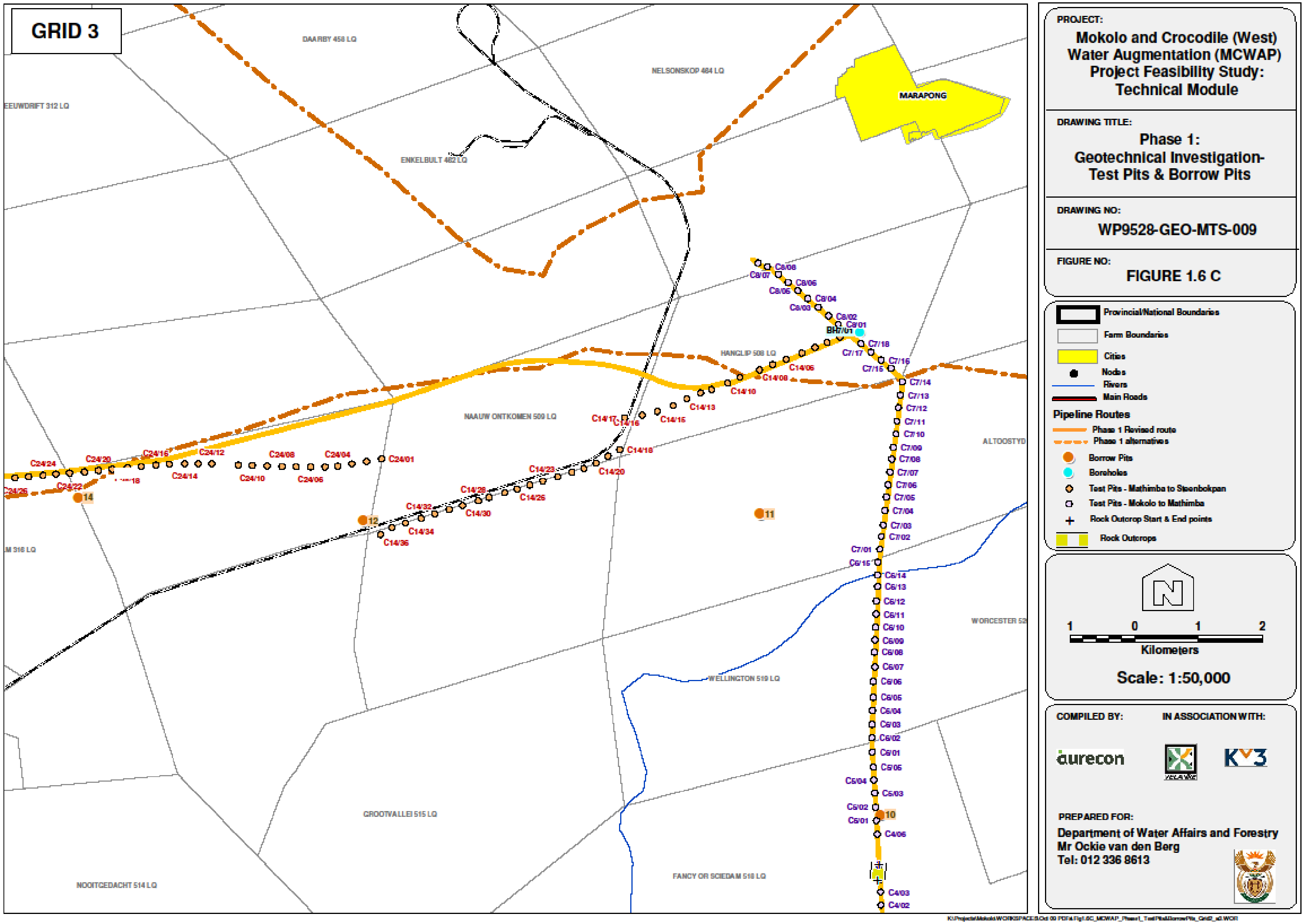



**Figure 4-9: Geotechnical Investigation: Test Pits & Burrow Pits – Phase 1 Key Map 3**

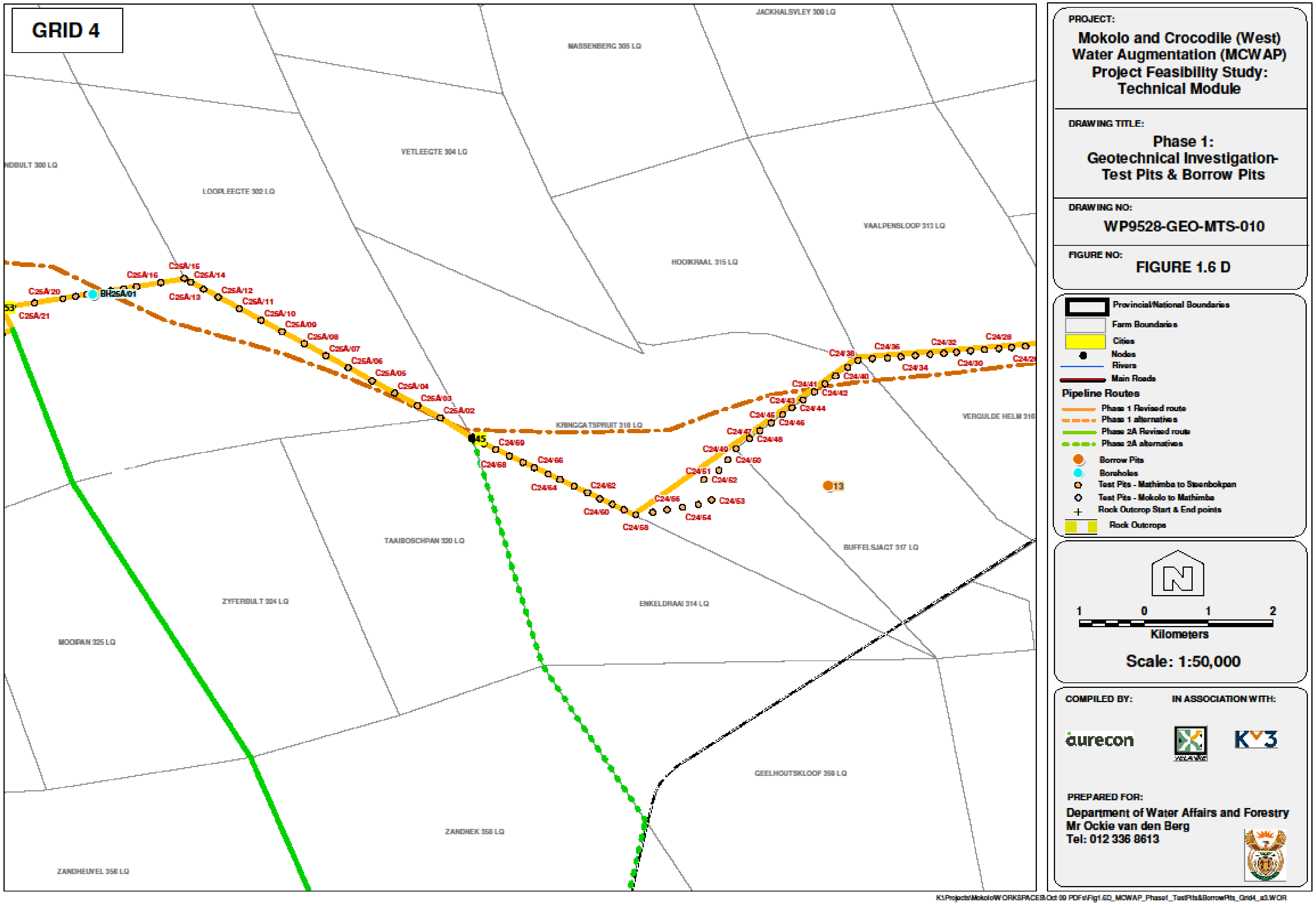
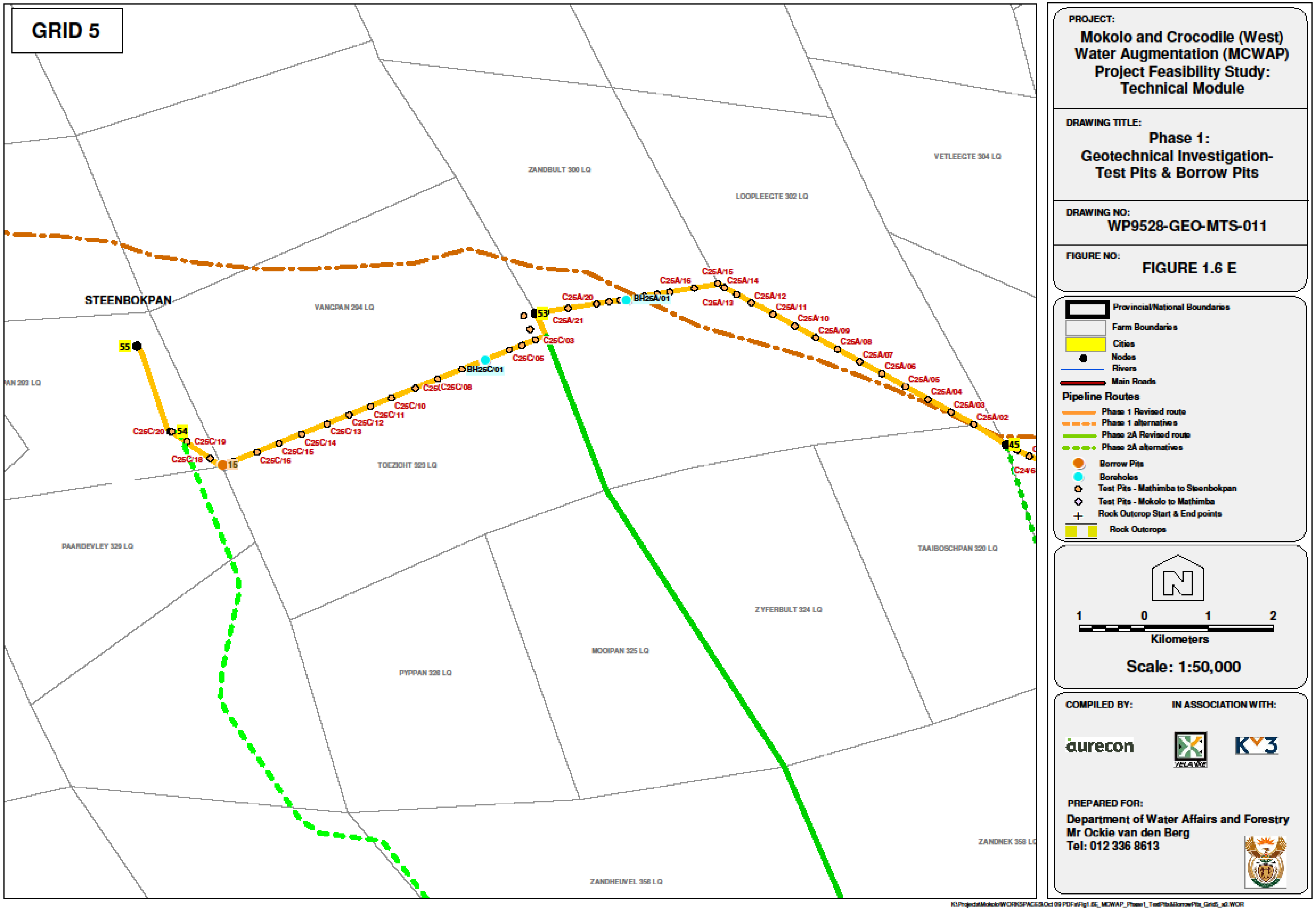



**Figure 4-10: Geotechnical Investigation: Test Pits & Borrow Pits – Phase 1 Key Map 4**




## Figure 4-11: Geotechnical Investigation: Test Pits & Burrow Pits – Phase 1 Key Map 5

# 5. SUMMARY AND CONCLUSIONS

The investigation for the proposed Phase 1 pipelines, borrow pits and pump station was undertaken by way of test pitting, with a TLB, along the pipeline routes and potential borrow pit locations, and borehole drilling at the pump station. The pits were excavated at nominal 200 m spacing along the pipeline routes, and at approximate 100 m spacing at potential borrow pit locations.

The geology of the area under investigation generally comprises Quaternary sands (large deposits of which are present in the north), overlying Waterberg sandstone. Significant deposits of calcrete and ferricrete are also present in the north. Along the Mathimba – Steenbokpan pipeline, rocks of the Karoo Supergroup are also present. These comprise a succession of sandstone, siltstone, shale and mudstone, and are generally softer than the Waterberg sandstone. The Eenzaamheid Fault forms the boundary between the Waterberg and Karoo rocks. Boreholes drilled at the location of the proposed pump station at Mokolo Dam encountered unweathered highly to moderately jointed sandstone at shallow depth, on which the building is recommended to be founded. An ABP of 1MPa may be assumed for the highly to moderately jointed unweathered sandstone for design purposes. Blasting of the sandstone will be required to excavate it. Care must be exercised to prevent vibration damage to the existing pump station and equipment.

The investigation of the Mokolo – Mathimba RWR pipeline encountered large sections of outcropping and shallow rock, specifically the first 4 km and the section that traverses the mountains (15 – 33 km), and blasting will be required to install the pipeline. Blasting will have to be controlled in order not to damage the existing pipeline, which runs parallel to the proposed route. For most of its length it is unlikely that sufficient quantities of suitable bedding and soft backfill material will be generated by the pipeline excavation. Furthermore, the availability of significant quantities of suitable bedding and soft backfill material is limited, such that borrow pit locations exceed the proposed 5 km spacing over the first 8.6 km, where no potential borrow pit could be located, and 15 – 33 km, where the spacing is approximately 10 km. Therefore, additional haulage will have to be undertaken in these areas (i.e. southwards from the borrow pit at 8.6 km, and approximately 5 km between km 15 and km 33). It should be noted that km 15 - 33 traverses the mountains and, due to local topography, actual haul distances will exceed 5 km, particularly as haul barriers in the form of steep slopes are present to the immediate north and about 3 km south of BP8.

The investigation of the Mathimba – Steenbokpan pipeline revealed much more favourable conditions, with the majority of the pipeline route able to be excavated to depths of 2 – 3 m. However, refusal of the TLB occurred on bedrock and on hardpan ferricrete and calcrete over the section from km 0 to km 17. Core drilling revealed that the ferricrete/calcrete directly overlies bedrock. Therefore, blasting will still be necessary to progress the excavation to the required depth, although further excavation may be possible into the softer Karoo rocks and ferricrete/calcrete with a larger machine (say 20 t excavator). Much of the spoil from the test pits was found to be suitable bedding and soft backfill material. This is particularly the case from km 17, where it is likely that the pipeline excavation will yield sufficient suitable material over much of the pipeline length such that borrow pits may not be required. Over the first 17 km the excavated material will have to be supplemented by borrow pits, potential locations of which were identified at km 2, km 7, km 12 and km 18.

The stability of excavations over both pipelines is anticipated at 1:1 (V:H) within the soft material and vertical within rock. At several locations groundwater was encountered, occasionally occurring in sufficient amounts to cause running sand, excavations into which will require dewatering and should be stable at 1:3.

The compactability tests indicate that most of the selected material from the MM pipeline alignment is suitable for bedding. However, only half of the selected material from the borrow pits and MS pipeline is suitable for bedding. Furthermore, only borrow pits BP8, BP12 and BP13 were wholly suitable. Therefore, if further sources of bedding material cannot be found, commercial sources must be sought to supplement the material identified. This problem may be solved by crushing the hard Waterberg quartzite, which will be blasted along the MM alignment, provided that it meets the PI requirement. This will generate a surplus of suitable bedding material, which could be used to supplement bedding material along the northern section of the MM alignment and MS alignment, where quartzite rock occurs more infrequently or is at greater depth. This will depend on the cost of haul compared with the cost of suitable commercially sources bedding material. However, SABS 0120 is very stringent and the sand sourced from the borrow pits and pipeline excavation will probably be suitable for bedding, confirmation of which will be undertaken in the detailed design phase.

Chemical analyses indicate that the pipes will have to be protected against corrosion.

The investigated pipeline routes were correct at the time when the fieldwork was undertaken. However, minor amendments to those routes have since been made. Therefore, additional investigation will have to be undertaken for the Mathimba – Steenbokpan pipeline, which has been realigned to pass to the north of Medupi Power Station (currently under construction). This alignment follows the route of a new bypass road, which was under construction at the time of the investigation. Furthermore, possible realignment of the Mokolo – Mathimba pipeline just north of the Mokolo Dam is currently under discussion.

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# APPENDIX A:

# SUMMARY OF SOIL AND ROCK PROFILE DESCRIPTION TERMINOLOGY

# APPENDIX B:

# BOREHOLE LOGS

# APPENDIX C:

# CORE PHOTOGRAPHS

# APPENDIX D:

# SOIL PROFILES

# APPENDIX E:

# TEST PIT PHOTOGRAPHS

# APPENDIX F:

# LABORATORY TEST RESULTS

# APPENDIX G:

# TEST PIT SUMMARY SPREADSHEETS

# APPENDIX H:

# BORROW PIT INVESTIGATIONS

## REPORT DETAILS PAGE

| | |
|---|---|
| *Project name:* | ***Mokolo and Crocodile River (West) Water Augmentation Project (MCWAP)*** |
| *Report Title:* | **Feasibility Study Report 8A – Detail Geotechnical Investigations Phase 1 Report** |
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