108/114/12/R8-4

UMKHOMAZI WATER PROJECT

MODULE 3 – POTABLE WATER MODULE

Detailed Feasibility Study

Geotechnical Investigation Report – Volume 4

(Mapstone Dam Crossing)

Revision 1

October 2015

Planning Services
Engineering & Scientific Services
Umgeni Water

Prepared By:
Knight Piésold CONSULTING
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UMGENI WATER **OCTOBER 2015**

uMkhomazi Water Project

Detailed Feasibility Study - Geotechnical Investigation Report – Volume 4 (Mapstone Dam Crossing)

Report No. 108/114/12/R8-4

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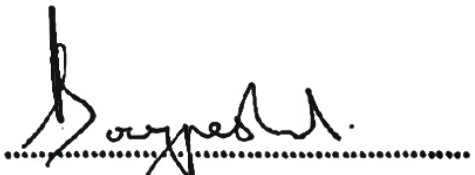

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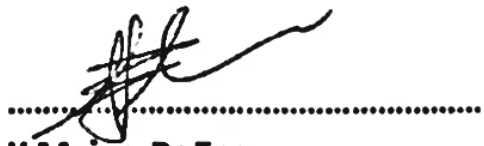


K Meier, Pr Eng
Manager: Planning Services

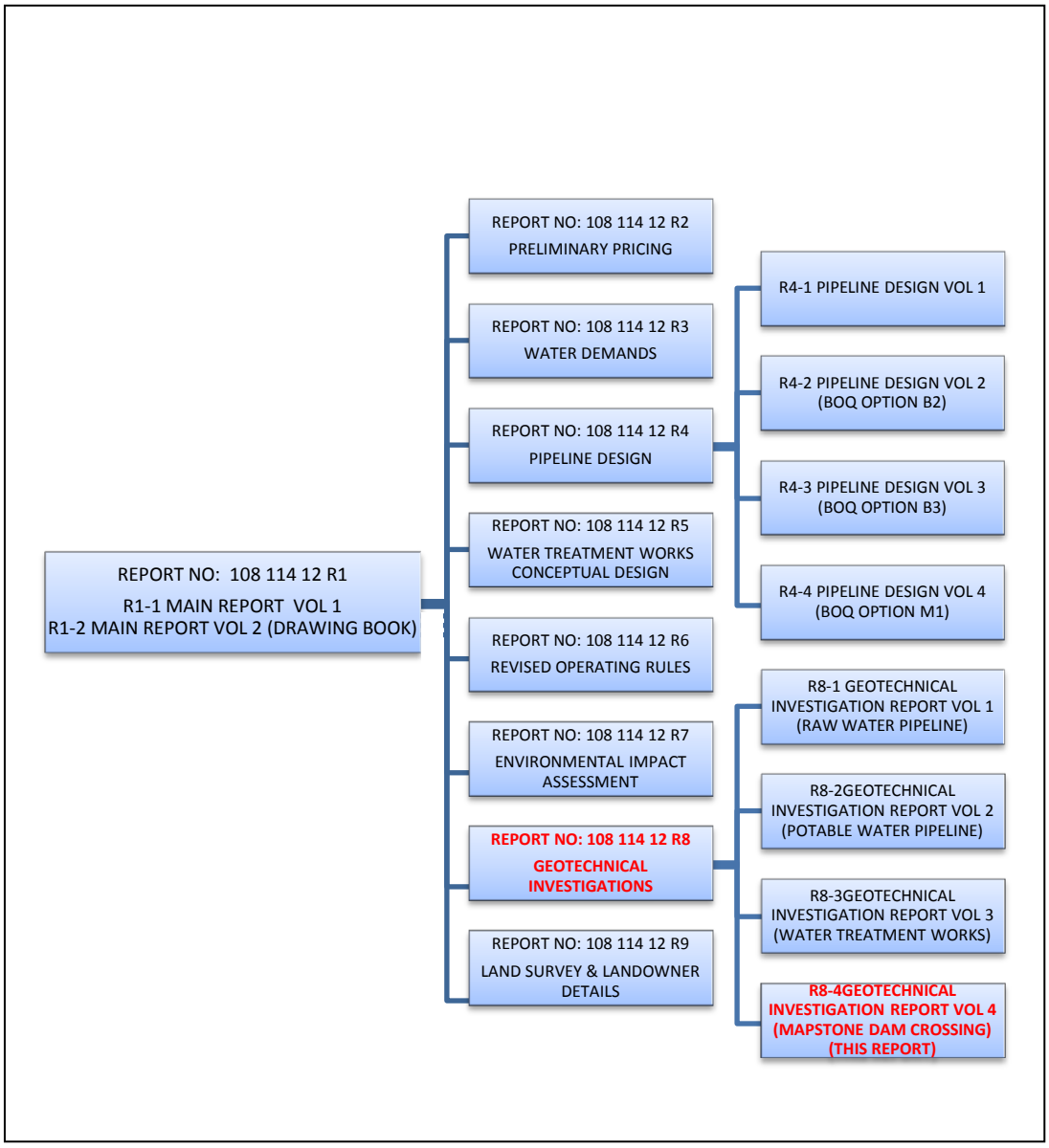
This report is to be referred in bibliographies as:

Umgeni Water (2015). uMkhomazi Water Project. Detailed Feasibility Study, Geotechnical Investigation Report – Volume 4 (Mapstone Dam Crossing). October 2015.

UMKHOMAZI WATER PROJECT

MODULE 3 – POTABLE WATER MODULE

Structure of Suite of Reports



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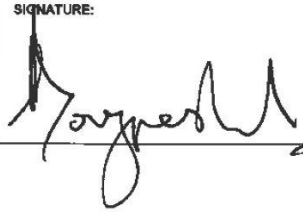
CLIENT APPROVAL	SIGNATURE: 	SIGNATURE: 	SIGNATURE: 

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Contents

List of Tables

List of Figures

List of Appendices

1. Introduction

Knight Piésold (KP) was appointed by Umgeni Water (UW) to perform geotechnical investigations for the proposed Umkhomazi Water Project Phase 1 (uMWP-1). These investigations were undertaken in March 2014. This appointment was extended in November 2014 to include a drilling investigation at the Mapstone Dam to determine the ground conditions along the alignment where the route intersects the dam.

The potable pipeline route intersects the Mapstone Dam between CH 5380 and CH 5510. An alternate route around Mapstone Dam was investigated but although technically feasible, initial cost estimates indicated that crossing Mapstone Dam would be a cheaper option. Various options were proposed to cross Mapstone Dam including a suspension bridge, conventional steel bridge or pipe on concrete piers and laying the pipe on the bed of the dam. To support these options, Umgeni Water decided to carry out geotechnical investigations of the dam basin geology. This led to a drilling investigation in the Mapstone Dam to determine soil profile and bedrock conditions.

This report provides recommendations on founding conditions for the bridge footings and for mass concrete cradles to anchor the pipe along the floor of the dam, The report includes all supporting documentation.

2. Existing Information

The following information was provided to the Geotechnical team:

- Longitudinal topographic section showing the existing and proposed full supply level of Mapstone Dam.
- Design report of the Mapstone Dam by Bradford, Conning & Partners, dated January 1994 [1] .

The proposed pipeline route intersects the dam at a position where the basin is relatively narrow, viz. approximately 140m between existing full supply levels. The results of the existing test pits excavated on dry ground adjacent to the dam, revealed the following [2]:

- Test pit PL20 was excavated on the flat slope west of the dam, approximately 23m from the edge of the water line. It was excavated to a depth of 3,1m in firm to stiff residual tillite soil without having reached TLB refusal. The residual tillite comprised clayey silt.
- Test pit PL21 was excavated on the steep slope to the east of the dam, approximately 25m from the edge of the water line. PL21 refused on tillite bedrock at a depth of 0,5m.

It follows from the above that variable ground conditions can be expected in the basin of the dam. According to the Bradford, Conning & Partners dam design report, conditions in the basin are relatively variable. TLB refusal was often encountered on alluvial boulders at depths of about 2m. It was therefore recommended to drill rotary cored boreholes to distinguish between boulders and bedrock below the water.

3. Method of Investigation

Five rotary cored boreholes at approximately 30m intervals were drilled to depths of between 9m and 13,3m below the dam ground level at the Mapstone dam. Standard Penetration Tests (SPT's) were done at 1,5m intervals where possible to determine the soil consistencies. A total of nine SPT tests were done. Four boreholes were drilled from a barge (BH2 to BH5), while BH1 was drilled from natural ground to the west of the water edge. The water depths at the various borehole positions are given below:

- BH1 – natural ground level
- BH2 – 1,95m
- BH3 – 3,85m
- BH4 – 8m
- BH5 – 1,25m

Access to the dam was from district road D360 which runs past the Mapstone Farmstead located towards the west of the dam. The barge was floated into position and secured to the shore by means of ropes and cables. The barge used had dimensions of approximately 4m x 3m. Drilling of the boreholes positioned over water was performed from the barge. The boreholes were set out by an engineering geologist by means of a small canoe and a handheld GPS. Borehole positions were marked by means of small buoys fixed to the bottom of the dam with fishing line and rock boulders.

All drilling procedures were conducted in accordance with the Standard Specification for Subsurface Investigation published by SANRAL Secretariat (2012 Edition). Water from the dam was used for drilling purposes (cooling of drill stem and removal of drill cuttings). All return water was collected in plastic containers on the barge and was circulated in some instances. Some drill water might have spilled into the dam (leakages at the intersection of the casing with the bed of the dam and from the top of the casing onto the floor of the barge). Drilling water carries sediment but is non-toxic. All drilling additives used were bio-degradable and non-toxic.

Drill samples were collected from core barrels in a cylindrical form and were placed in core boxes of 1,5m in length.

Borehole logs and core photographs are provided in Appendices A and B respectively.

No laboratory testing was done on the core samples.

4. Site description

The proposed potable water pipeline is situated in the uMkhomazi River Catchment and is located between Umlaas Road and Baynesfield, in the Natal Midlands of the KwaZulu-Natal Province. The Midlands are characteristic of undulating and hilly terrain intersected by a well-developed dendritic drainage system comprising well-defined drainage features. The steepest area on the pipeline route occurs just east of the Mapstone Dam, which has an approximate slope of 24° towards the west. The Mapstone Dam wall occurs approximately 1,4km south-west of the pipeline route intersection. The

dam itself has a meander shape with a length of approximately 3,1km. The pipeline route passes Hopewell Village along its northern boundary.

The locality of the site is shown in Figure 1 at the back of the report.

5. Geology

The regional geology of the area is described in detail in the potable pipeline geotechnical report [2], and is not repeated here. For the purpose of this report, the site geology of the pipe crossing is described below.

The entire proposed pipe bridge crossing is underlain by tillite of the Dwyka Group, Karoo Supergroup. The contact with the overlying strata of the Pietermaritzburg Formation (shale, siltstone and sandstone) occurs to the west of the Mapstone Dam. A north-northwest striking fault runs along a portion of the river within Mapstone Dam and it intersects the bridge site in the vicinity of BH5.

A layer of transported soil covers most of the area, particularly to the east of the dam, where it attains a thickness of up to 2m in BH4 and BH5. Elsewhere the transported soil cover is generally 0,3m thick. The transported soil layer is, however, underlain by clayey residual tillite soil to depths of up to 7,5m. This is the result of chemical decomposition associated with the hot and humid climate of the region. The eastern portion of the dam is, however, characterised by a steep valley bank and scattered tillite outcrops.

Although covered by water, alluvial terraces occur in the vicinity of the submerged river channel, but these are expected to be of limited extent only. It is likely that both BH4 and BH5 were drilled into such an alluvial terrace, hence the 2m thick transported soil cover encountered along the eastern portion of the dam.

6. Drilling Results

Since most of the pipe crossing was inundated with water at the time of the investigation, the drilling results are the sole source of information on the subsoil conditions, i.e. no interpretative assistance possible from surface features, satellite imagery, etc.

Results of the five boreholes drilled along the pipe bridge are summarised in Table 1 below, while Figure 3 provides a geological longitudinal section along the alignment.

Table 1: Summary of Rotary Cored Drilling

Borehole No.	Total Depth (m)	Depth of Layers (m) - (m)			
		Transported	Residual Tillite Soil	Tillite Bedrock	
		Colluvium and Alluvium		Highly weathered	Slightly weathered to unweathered
BH1	13,3	0 - 0,4	0,4 - 6,4	6,4 - 7,5	7,5 - 13,3
BH2	12,0	0 - 0,3	0,3 - 4,3	4,3 - 6,2	6,2 - 12,0
BH3	9,0	0 - 0,3	0,3 - 3,8	-	3,8 - 9,0
BH4	9,09	0 - 2,94	-	-	2,94 - 9,09
BH5	9,65	0 - 2,0	2,0 - 3,1	3,1 - 4,4	4,4 - 9,65

Standard Penetration Tests (SPT's) were conducted in the soil layers overlying rock to determine soil consistencies. The results are indicated on the borehole core logs, but are summarised in Table 2 below.

Table 2: Summary of Standard Penetration Test (SPT) Results

Borehole No.	Depth (m) - (m)	Material Description	Origin	Uncorrected SPT N-Value	Soil Consistency
BH1	1,5 - 1,95	Sandy clay	Residual Tillite	7	Firm
	3,0 - 3,45	Sandy silt	Residual Tillite	18	Very Stiff
	4,5 - 4,95	Sandy silt	Residual Tillite	49	Very Stiff
	6,0 - 6,15	Sandy silt	Residual Tillite	Refusal	Very Stiff / Boulders
BH2	1,5 - 1,95	Sandy clay	Residual Tillite	4	Soft
	3,0 - 3,45	Sandy clay	Residual Tillite	15	Stiff
BH3	1,5 - 1,95	Silty clayey sand	Residual Tillite	13	Medium Dense
BH4	1,5 - 1,95	Sandy clay	Residual Tillite	8	Firm
BH5	1,5 - 1,95	Sandy clay	Alluvium	16	Stiff

It follows from the above that the consistency of the residual tillite generally improves with depth, but varies from soft to firm at depths above 2m to stiff and very stiff with depth.

Highly weathered tillite bedrock occurs below the residual tillite soil. This boundary is not considered to be well-defined, but rather represents a gradual transition with depth. The highly weathered tillite rock interface was not encountered in BH3 and BH4, which is in accordance with the irregular nature of the chemically weathered rock mass. This zone should be seen as transition between residual soil and rock. It may therefore contain substantial zones of relatively soft soil within the soft rock.

The highly weathered rock (where present) grades relatively abruptly to slightly weathered and unweathered rock at depths varying below original ground surface between 7,5m (BH1) and 3m (BH4). The shallow depths are possibly related to the original river channel, where the soft, weathered rock/residual soil have been removed by river erosion. Figure 3 provides an interpretative sound rock line along the bridge site, based on the drilling results. The sound rock comprises slightly weathered to unweathered medium jointed hard rock tillite.

7. Geotechnical Considerations

7.1 Bridge Foundation

Pipe bridge foundations will for as long as the Mapstone Dam exists not be subjected to scouring caused by river flow. Erosion is usually the most critical foundation parameter for a bridge over river scenario. For the uMkhomazi study, the safe bearing capacity of the foundations is the main concern.

SPT results indicated that the upper 2m to 3m of the soil horizon comprise soft to firm residual soil with a safe bearing capacity of about 80kPa. The stiff to very stiff (N>15) soil encountered below a depth of 3m in most of the boreholes, will have a safe bearing capacity of at least 150kPa, which is not considered suitable for a large sensitive pipe bridge structure. This is furthermore complicated by the variable thickness of the compressible layer. Therefore, it is recommended that the foundations for the bridge piers be placed on sound rock. Sound rock level is indicated in Figure 3. According to published data on the strength of tillite in KwaZulu-Natal, unweathered tillite has average Uniaxial Compressive Strength (UCS) values of 150MPa [3]. The following rock mass properties can be used for both founding or rock anchoring, assuming the UCS of the sound tillite is at least 100MPa and the minor principle stress amounts to less than 2MPa, i.e. shallow overburden conditions:

Ultimate Bearing Capacity	:	7MPa - 10MPa	
Rock Mass Deformation Modulus	:	18GPa	
Average Rock Mass Shear Strength	:	Cohesion:	1,6MPa
	:	Friction:	55°
Tensile Strength	:	270kPa	

The maximum water depth along the pipe bridge will amount up to 10m at about ch 270m (old river channel). It decreases gradually on the western bank, but the eastern bank is relatively steep (less than 40m long). It follows that it will be possible to provide pier supports along the length of the pipe bridge in areas of relatively shallow water (less than 5m) by means of a piling rig on a barge. Piles should be founded in the sound tillite zone as indicated in Figure 3, where up to 5MPa end bearing pressures can be used. Limited socketing of less than say 0,5m into sound rock will be required to counter for lateral stress caused by wind.

For suspension bridge options, a combination of concrete anchor blocks and rock anchors are proposed. Sound tillite rock has good shear strength properties and will provide suitable material for the installation of rock anchors. It has a dry density of between 2500kg/m³ and 2650kg/m³ [3].

7.2 Pipe Anchoring

A syphon type dam crossing can also be considered whereby the pipe is anchored to the floor of the dam by means of concrete cradles. The pipe trench should be excavated into at least highly weathered tillite and/or doweled into sound tillite rock. This option will, however, require emptying the dam for a considerable time, which may not be acceptable for the neighbouring farming community. Excavations to highly weathered rock will take place in complete saturated conditions and flat excavation slopes will be required, probably 1:2 (V:H). Dewatering will be required during construction. The expected minimum excavation level for founding of the concrete anchoring cradles is indicated as the soil-rock interface level in Figure 3. The safe bearing capacity for highly weathered tillite is in the region of 800kPa.

8. Conclusions and recommendations

A geotechnical investigation was conducted for a pipe crossing over the Mapstone Dam as part of the Umkhomazi Water Project (Potable Water Pipeline). The investigation comprised the drilling of five rotary cored boreholes in November and December 2014. Four of the boreholes were drilled from a barge in the dam.

The entire site is underlain by tillite of the Dwyka Group, Karoo Supergroup, which is characterised by a well-developed mantle of chemical decomposed residual soil. The thickness of this mantle is somewhat variable, which is typical of a chemical decomposed profile, although erosion caused by the river also contributed to thinner soil horizons in the lower-lying river channel areas.

SPT's conducted in the soil horizons as part of the drilling process, indicated that the upper 2m to 3m of the soil profile generally comprises soft to firm clayey soils, which are not considered suitable for foundations for a bridge structure. Where the residual soils extend with depths (up to 6m in places), the residual soil horizon transitions to sandy silt/silty sand with a stiff to very stiff (or medium dense where sandier) material. According to the (limited) SPT results in this horizon, the lower portion of the residual tillite has a safe bearing capacity of about 150kPa.

Slightly weathered to unweathered tillite rock (referred to as sound tillite) occurs at a relatively shallow depth along the pipe bridge alignment, from 7,5m depth at BH1 (drilled from dry ground on western bank of dam) to about 3m to 4m in the old river section area and eastern bank. The eastern bank is steep and characterised by scattered tillite outcrop.

It is recommended that foundations for the bridge piers or suspended bridge abutments be taken down to sound tillite. Rock anchoring for suspended structures can be done in the sound rock, which has good foundation properties, viz.

Ultimate Bearing Capacity	:	7MPa - 10MPa	
Rock Mass Deformation Modulus	:	18GPa	
Average Rock Mass shear strength	:	Cohesion:	1,6MPa
	:	Friction:	55°

It is considered feasible to construct the foundations of the bridge piers from a barge in about 5m deep water using a small piling rig.

Pipe trench excavations along the dam floor will be required for the option to fixing the pipe to the floor of the dam. Concrete cradles will have to be provided, which must be founded on at least highly weathered tillite rock, using 800kPa bearing capacity. The trench excavation will take place in fully saturated clayey soils material. Flattening of cut slopes to at least 1:2 (V:H) will be required in the saturated soils, while the area must be dewatered during construction.

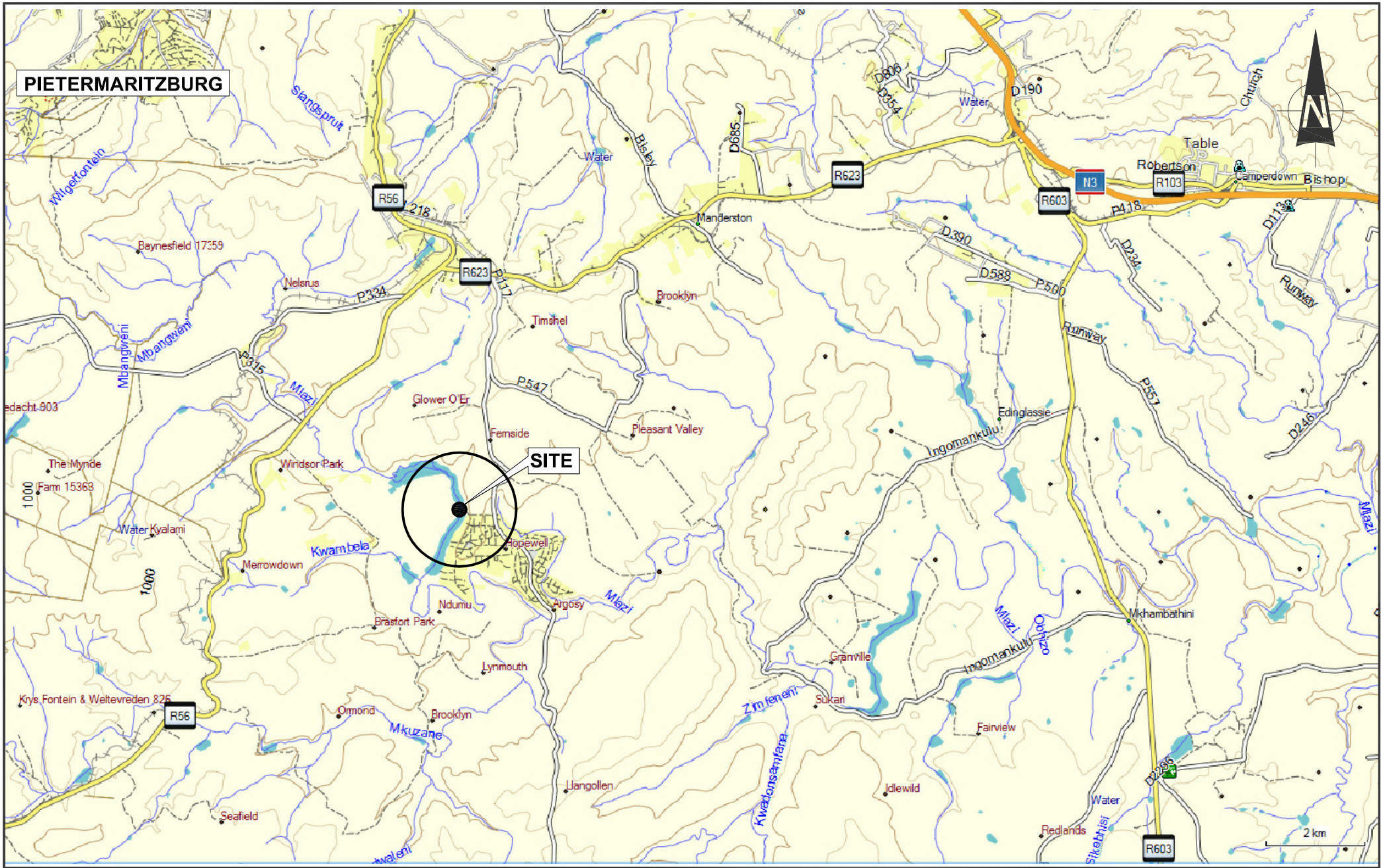
9. References

[1] Umlaas Irrigation Board (1994). Mapstone Dam Final Design Report. Report by Bradford, Conning & Partners.

[2] Umgeni Water (2014). Umkhomazi Water Project Module 3 - Potable Water Modules. Detailed Feasibility Study. Geotechnical Investigation Report by Knight Piésold, Report No. 108/114/12/R6.

[3] Brink, A.B.A. (1980). Engineering Geology of Southern Africa, Volume 3. The Karoo Sequence. Building Publications, Pretoria.

Figure 1: Locality Map



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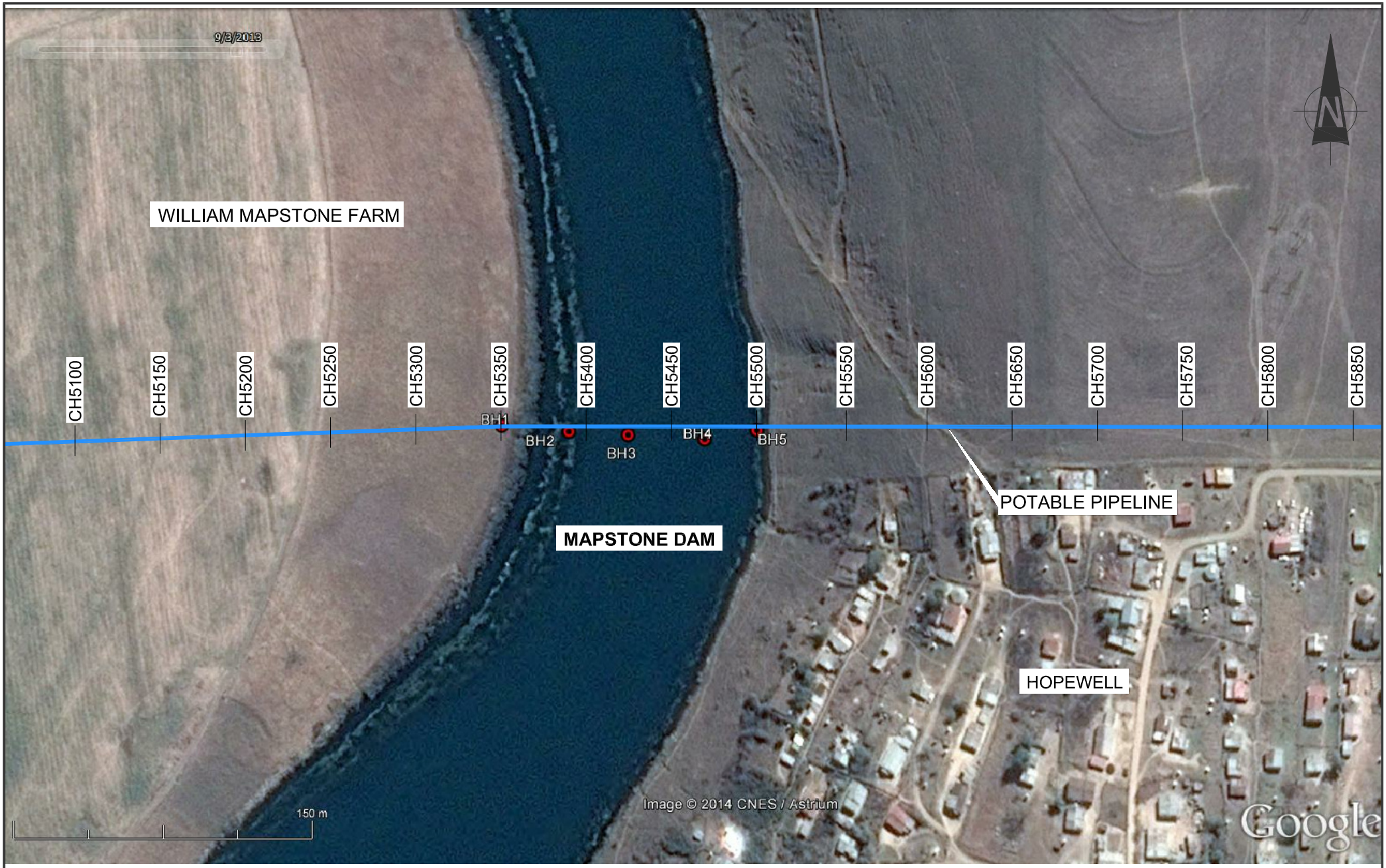
UMKHOMAZI WATER PROJECT - MAPSTONE DAM
GEOTECHNICAL INVESTIGATION
LOCALITY PLAN

PROJECT NO: 30300413/01
FIGURE NO 1
SCALE N.T.S.

Figure 2: Site Plan



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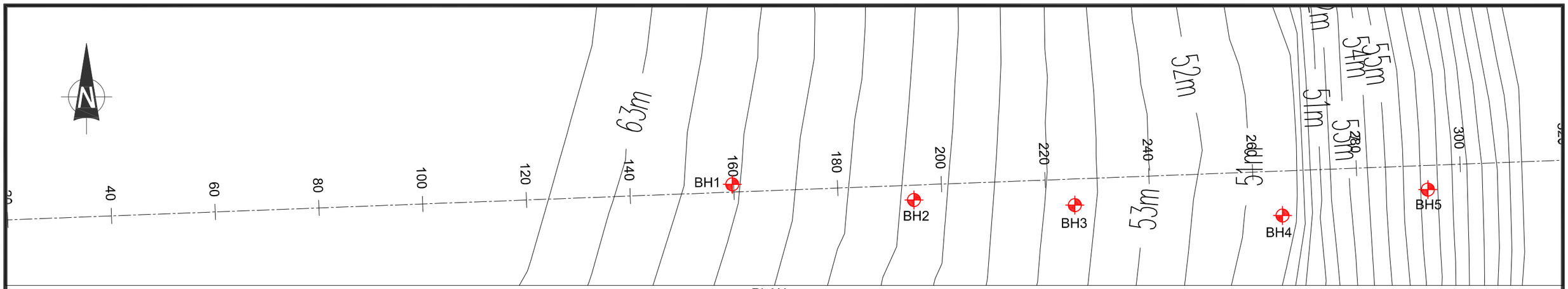
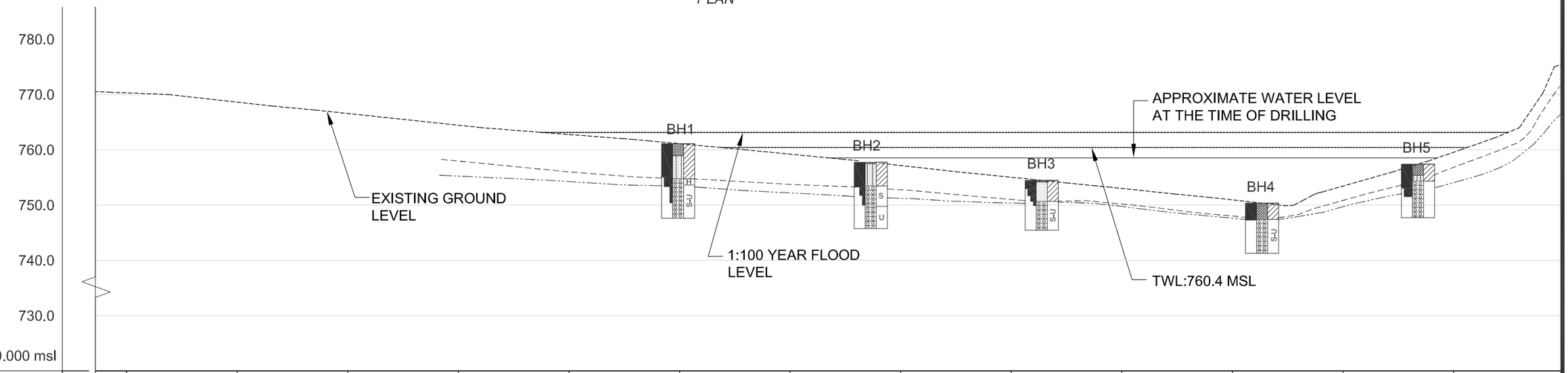
UMKHOMAZI WATER PROJECT - MAPSTONE DAM
GEOTECHNICAL INVESTIGATION
SITE PLAN SHOWING BOREHOLE POSITIONS

PROJECT NO: 30300413/01
FIGURE NO 2
SCALE N.T.S.

Figure 3: Longitudinal Geological Section



PLAN

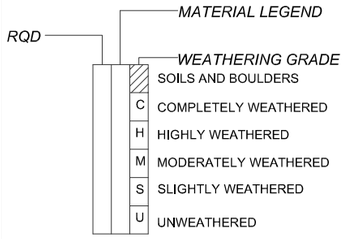


PEG DISTANCE (m)	0.000	60.000	80.000	100.000	120.000	140.000	160.000	180.000	200.000	220.000	240.000	260.000	280.000	300.000	320.000
GROUND LEVEL (m)	772.943	770.298	768.614	766.560	764.444	762.761	761.096	759.205	757.145	755.027	753.002	750.930	753.415	759.555	775.604

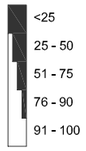
GEOLOGICAL LONGITUDINAL SECTION

LEGEND:

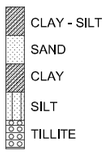
BOREHOLE LEGEND



RQD LEGEND



BOREHOLE MATERIAL LEGEND



INTERPRETATION BETWEEN BOREHOLES

SOUND TILLITE ROCK LEVEL
SOIL-ROCK INTERFACE

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UMKHOMAZI WATER PROJECT - MAPSTONE DAM
GEOTECHNICAL INVESTIGATION

GEOLOGICAL LONGITUDINAL SECTION AND PLAN

PROJECT NO: 30300413/01

FIGURE NO 3

SCALE 1 : 750

Appendix A: Borehole Logs

HOLE No: BH1
Sheet 1 of 1

JOB: 3030041301

ROCK FABRIC
MF -massive
BF -bedded
FF -foliated
CF -cleaved
SF -schistose
GF -gneissose
LF -laminated

GRAIN SIZE
FG -fine grained
MG -medium grain
CG -coarse grain

JOINT SPACING
VCJ-very close spacg
CJ -close spacing
MJ -medium spacing
WJ -wide spacing
VWJ-very wide spacng

JOINT ROUGHNESS
SLJ-slickensided
SJ -smooth
RJ -rough

JOINT SHAPE
CUR-curvilinear
PLA-planar
UND-undulating
STE-stepped
IRR-irregular

ROCK HARDNESS
EHR-extremely hard rock
VHR-very hard rock
HR -hard rock
MHR-medium hard rock
SR -soft rock
VSR-very soft rock

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UMKHOMAZI PROJECT
MAPSTONE DAM DRILLING INVESTIGATION

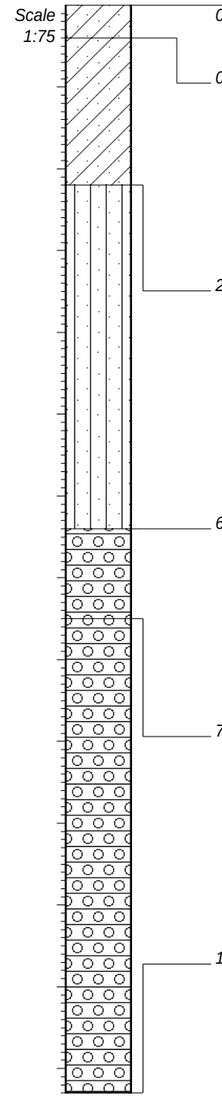
GEOTECHNICAL INVESTIGATION

HOLE No: BH1
Sheet 1 of 1

JOB: 3030041301

Grain Size	Rock Fabric	Fabric Spac (mm)	Fabric Inc (deg)	Joint Set No.	Joint Inc (Deg)	Joint Spac	Micro Roughness	Joint Filling	Fill Thickness (mm)	Depth m	Mat recov %	Rock recov %	RQD %	Frac Freq No/m
NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1,5	60	0	0	NA
										1,95	SPT	N=7		
NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3	71	0	0	NA
										3,45	SPT	N=18		
NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4,5	78	0	0	NA
										4,95	SPT	N=49		
										6	100	0	0	NA
										6,15	SPT	N=Ref		
FG	BF	-	-	0 1 2	70-90 20-40 40-60	MJ MJ WJ	RJ RJ RJ	Clayey Silt Stained Stained	40 - -	7,5	95	82	37	6
FG	BF	-	-	0 1 2	70-90 40-60 20-40	MJ-WJ WJ VWJ	RJ RJ RJ	Stained Stained Stained	- - -	9	100	100	77	6
										10,5	100	100	90	3
										12	100	100	100	1
										13,3	100	100	91	2

DEPTH Scale 1:75



0.00 – 0.40: Reddish brown blotched dark brown, sandy CLAY. **COLLUVIUM**.

0.40 – 2.20: Reddish brown mottled yellow and black, sandy CLAY. **RESIDUAL TILLITE**.

Note:
Minor core losses due to washing out of fines.

2.20 – 6.40: Yellow speckled white stained black, sandy SILT. **RESIDUAL TILLITE**.

Note:
Minor core losses due to washing out of fines.

6.40 – 7.50: Highly weathered, olive brown stained black, closely jointed, soft rock TILLITE.

Note:
Contains a thin band of yellow sandy clayey silt.

7.50 – 13.30: Grey stained brown blotched pink and bluish white, slightly weathered to unweathered, generally moderately jointed, hard rock TILLITE.

Note:
Contains inclusions of granite clasts.

NOTES

1) NA: Not applicable.

2) NM: Not measured.

3) Drilled at natural ground level.

CONTRACTOR : Diabor
MACHINE :
DRILLED BY :
PROFILED BY : AvdM

TYPE SET BY : EM
SETUP FILE : KPBHCOO.SET

INCLINATION : 90 degrees
DIAM :
DATE : 18 Nov - 5 Dec 2014
DATE : 8 Dec 2014

DATE : 12/12/2014 09:05
TEXT : ..P51\PROFILES\MJVAVDM.TXT

COORDINATE SYSTEM : WGS84 (Lo31)
X-COORD : S29 47 16.7
Y-COORD : E30 23 25.8

HOLE No: BH1

HOLE No: BH2
Sheet 1 of 1

JOB: 3030041301

ROCK FABRIC
MF -massive
BF -bedded
FF -foliated
CF -cleaved
SF -schistose
GF -gneissose
LF -laminated

GRAIN SIZE
FG -fine grained
MG -medium grain
CG -coarse grain

JOINT SPACING
VCJ-very close spacg
CJ -close spacing
MJ -medium spacing
WJ -wide spacing
VWJ-very wide spacng

JOINT ROUGHNESS
SLJ-slickensided
SJ -smooth
RJ -rough

JOINT SHAPE
CUR-curvilinear
PLA-planar
UND-undulating
STE-stepped
IRR-irregular

ROCK HARDNESS
EHR-extremely hard rock
VHR-very hard rock
HR -hard rock
MHR-medium hard rock
SR -soft rock
VSR-very soft rock

Knight Piésold CONSULTING

UMKHOMAZI PROJECT
MAPSTONE DAM DRILLING INVESTIGATION

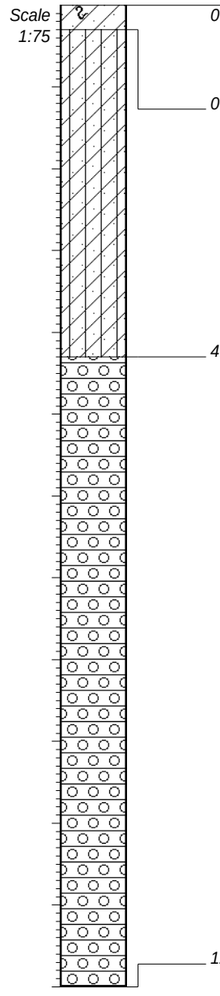
GEOTECHNICAL INVESTIGATION

HOLE No: BH2
Sheet 1 of 1

JOB: 3030041301

Grain Size	Rock Fabric	Fabric Spac (mm)	Fabric Inc (deg)	Joint Set No.	Joint Inc (Deg)	Joint Spac	Micro Roughness	Joint Filling	Fill Thickness (mm)	Depth m	Mat recov %	Rock recov %	RQD %	Frac Freq No/m
NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1,5	54	0	0	NA
										1,95	SPT	N=4		
NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3	89	0	0	NA
										3,45	SPT	N=15		
										4,5	78	20	0	4
										6	88	88	51	7
FG	BF	-	-	0 1 2	70-90 40-60 30-50	CJ-MJ WJ CJ	RJ RJ RJ	Stained - Stained silt	- - <2	7,5	95	95	73	3
										9	100	100	87	1
										10,5	100	100	100	1
										12	100	100	100	-

DEPTH Scale 1:75



Orange brown blotched black and yellow, sandy CLAY, with roots. **COLLUVIUM**.

Reddish brown mottled yellow and red becoming yellow stained black from 2,7m, sandy CLAY to clayey SILT. **RESIDUAL TILLITE**.

Note:
Minor core losses due to washing out of fines.

Slightly weathered becoming unweathered from 8m, bluish grey stained brown mottled and blotched white, moderately to widely jointed, hard rock TILLITE.

Note:
1. Completely to highly weathered, very closely jointed, soft rock tillite from 5,5m to 6,2m depth. Interpreted that minor core losses encountered in this weathered zone where fines were washed out.
2. Contains inclusions of granite clasts.

NOTES

1) NA: Not applicable.

2) NM: Not measured.

3) Water depth of dam: 1,95m.

CONTRACTOR : Diabor
MACHINE :
DRILLED BY :
PROFILED BY : AvdM

TYPE SET BY : EM
SETUP FILE : KPBHCOO.SET

INCLINATION : 90 degrees
DIAM :
DATE : 18 Nov - 5 Dec 2014
DATE : 8 Dec 2014

DATE : 12/12/2014 09:05
TEXT : ..P51\PROFILES\MJVAVDM.TXT

COORDINATE SYSTEM : WGS84 (Lo31)
X-COORD : S29 47 16.8
Y-COORD : E30 23 27.1

HOLE No: BH2

HOLE No: BH3
Sheet 1 of 1

JOB: 3030041301

ROCK FABRIC
MF -massive
BF -bedded
FF -foliated
CF -cleaved
SF -schistose
GF -gneissose
LF -laminated

GRAIN SIZE
FG -fine grained
MG -medium grain
CG -coarse grain

JOINT SPACING
VCJ-very close spacg
CJ -close spacing
MJ -medium spacing
WJ -wide spacing
VWJ-very wide spacng

JOINT ROUGHNESS
SLJ-slickensided
SJ -smooth
RJ -rough

JOINT SHAPE
CUR-curvilinear
PLA-planar
UND-undulating
STE-stepped
IRR-irregular

ROCK HARDNESS
EHR-extremely hard rock
VHR-very hard rock
HR -hard rock
MHR-medium hard rock
SR -soft rock
VSR-very soft rock

Knight Piésold CONSULTING

UMKHOMAZI PROJECT
MAPSTONE DAM DRILLING INVESTIGATION

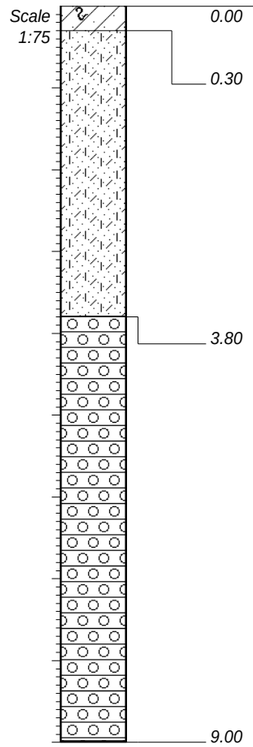
GEOTECHNICAL INVESTIGATION

HOLE No: BH3
Sheet 1 of 1

JOB: 3030041301

Grain Size	Rock Fabric	Fabric Spac (mm)	Fabric Inc (deg)	Joint Set No.	Joint Inc (Deg)	Joint Spac	Micro Rough ness	Joint Filling	Fill Thickness (mm)	Depth m	Mat recov %	Rock recov %	RQD %	Frac Freq No/m
NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1,5	79	0	0	NA
NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1,95	SPT	N=13		
										3	77	29	24	4
										3,9	74	52	52	2
FG	BF	-	-	0 1	70-90 50-70	MJ-WJ WJ	RJ RJ	Stained silt Stained silt	<2 <2	4,5	100	100	60	10
										6	100	100	78	5
										7,5	100	100	93	3
										9	100	100	100	1

DEPTH Scale 1:75



Dark brown, sandy CLAY, with roots. **COLLUVIUM**.

Orange to reddish brown blotched yellow and black, silty clayey SAND, with an isolated slightly weathered, hard rock tillite boulder at 2,6m depth. **RESIDUAL TILLITE**.

Note:
Minor core losses due to washing out of fines.

Bluish grey stained brown blotched pink and white, slightly weathered to unweathered, generally moderately to widely jointed, hard rock TILLITE.

Note:
Rock contains inclusions of granite and other clasts.

NOTES

1) NA: Not applicable.

2) NM: Not measured.

3) Water depth of dam: 8m.

CONTRACTOR : Diabor
MACHINE :
DRILLED BY :
PROFILED BY : AvdM

TYPE SET BY : EM
SETUP FILE : KPBHCOO.SET

INCLINATION : 90 degrees
DIAM :
DATE : 18 Nov - 5 Dec 2014
DATE : 8 Dec 2014

DATE : 12/12/2014 09:05
TEXT : ..P51\PROFILES\MJVAVDM.TXT

COORDINATE SYSTEM : WGS84 (Lo31)
X-COORD : S29 47 16.9
Y-COORD : E30 23 28.2

HOLE No: BH3

HOLE No: BH4
Sheet 1 of 1

JOB: 3030041301

ROCK FABRIC
MF -massive
BF -bedded
FF -foliated
CF -cleaved
SF -schistose
GF -gneissose
LF -laminated

GRAIN SIZE
FG -fine grained
MG -medium grain
CG -coarse grain

JOINT SPACING
VCJ-very close spacg
CJ -close spacing
MJ -medium spacing
WJ -wide spacing
VWJ-very wide spacng

JOINT ROUGHNESS
SLJ-slickensided
SJ -smooth
RJ -rough

JOINT SHAPE
CUR-curvilinear
PLA-planar
UND-undulating
STE-stepped
IRR-irregular

ROCK HARDNESS
EHR-extremely hard rock
VHR-very hard rock
HR -hard rock
MHR-medium hard rock
SR -soft rock
VSR-very soft rock

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UMKHOMAZI PROJECT
MAPSTONE DAM DRILLING INVESTIGATION

GEOTECHNICAL INVESTIGATION

HOLE No: BH4
Sheet 1 of 1

JOB: 3030041301

Grain Size	Rock Fabric	Fabric Spac (mm)	Fabric Inc (deg)	Joint Set No.	Joint Inc (Deg)	Joint Spac	Micro Roughness	Joint Filling	Fill Thickness (mm)	Depth m	Mat recov %	Rock recov %	RQD %	Frac Freq No/m
NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1,5	33	0	0	NA
										1,95	SPT	N=8		
										3	50	6	0	NA
FG	BF	-	-	0 1 2	70-90 30-50 40-60	MJ WJ WJ	RJ RJ RJ	Stained Calcite -	- <5 -	4,5	98	98	86	3
										5,52	100	100	100	2
										6,09	100	100	100	2
										7,59	100	100	100	1
										9,09	100	100	100	0

DEPTH Scale 1:75

Scale 1:75

0.00 — Dark brown mottled yellow and black, sandy CLAY, with sand patches. **COLLUVIUM**.

2.94 — Grey becoming bluish grey mottled and blotched white, streaked white from 6m, slightly weathered to unweathered, generally widely jointed, hard rock TILLITE.

Notes:
1. Contains vertical bands of calcite <4mm in thickness.
2. Contain inclusions of granite clasts.

9.09

NOTES

1) NA: Not applicable.

2) NM: Not measured.

3) Water depth of dam: 3,85m.

CONTRACTOR : Diabor
MACHINE :
DRILLED BY :
PROFILED BY : AvdM

TYPE SET BY : EM
SETUP FILE : KPBHCOO.SET

INCLINATION : 90 degrees
DIAM :
DATE : 18 Nov - 5 Dec 2014
DATE : 8 Dec 2014

DATE : 12/12/2014 09:05
TEXT : ..P51\PROFILES\MJVAVDM.TXT

COORDINATE SYSTEM : WGS84 (Lo31)
X-COORD : S29 47 16.9
Y-COORD : E30 23 29.7

HOLE No: BH4

HOLE No: BH5
Sheet 1 of 2

JOB: 3030041301

ROCK FABRIC
MF -massive
BF -bedded
FF -foliated
CF -cleaved
SF -schistose
GF -gneissose
LF -laminated

GRAIN SIZE
FG -fine grained
MG -medium grain
CG -coarse grain

JOINT SPACING
VCJ-very close spacg
CJ -close spacing
MJ -medium spacing
WJ -wide spacing
VWJ-very wide spacng

JOINT ROUGHNESS
SLJ-slickensided
SJ -smooth
RJ -rough

JOINT SHAPE
CUR-curvilinear
PLA-planar
UND-undulating
STE-stepped
IRR-irregular

ROCK HARDNESS
EHR-extremely hard rock
VHR-very hard rock
HR -hard rock
MHR-medium hard rock
SR -soft rock
VSR-very soft rock

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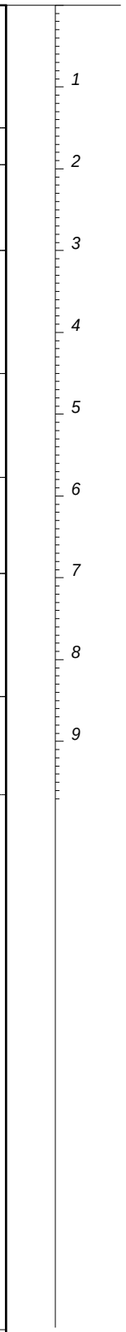
UMKHOMAZI PROJECT
MAPSTONE DAM DRILLING INVESTIGATION

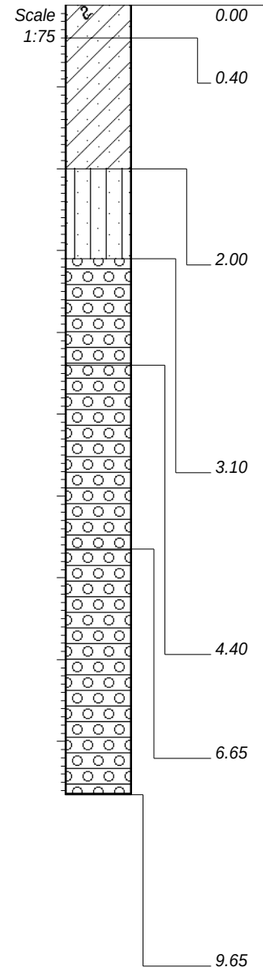
GEOTECHNICAL INVESTIGATION

HOLE No: BH5
Sheet 1 of 2

JOB: 3030041301

Grain Size	Rock Fabric	Fabric Spac (mm)	Fabric Inc (deg)	Joint Set No.	Joint Inc (Deg)	Joint Spac	Micro Roughness	Joint Filling	Fill Thickness (mm)	Depth m	Mat recov %	Rock recov %	RQD %	Frac Freq No/m
NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1,5	31	0	0	NA
NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1,95	SPT	N=16		
NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3	44	0	0	NA
FG	BF	-	-	NM	NM	NM	NM	NM		4,5	42	7	0	NA
FG	BF	-	-	1 2 3	10-30 30-40 50-70	WJ MJ-WJ WJ	RJ RJ RJ	Stained Calcite Stained	- 5 -	5,77	100	100	27	6
FG	BF									6,95	100	100	81	3
										8,45	100	100	100	1
										9,65	100	100	100	1





Dark brown, sandy CLAY, with roots. **COLLUVIUM**.

Olive yellowish brown stained black, sandy CLAY. **COLLUVIUM**.

Note:
Major core losses due to washing out of fines.

Yellowish brown stained black, sandy SILT, with minor very soft rounded tillite gravel. **RESIDUAL TILLITE**.

Note:
Major core losses due to washing out of fines.

Poor core recovery. Recovered as medium and coarse Gravel. Interpreted as highly weathered, yellowish brown to olive brown stained black, very closely jointed, soft rock TILLITE.

Slightly weathered, grey stained brown streaked white, closely to moderately jointed, hard rock TILLITE.

Unweathered, dark bluish grey blotched white and pink, generally widely jointed, hard rock TILLITE.

Note:
Contains inclusions of granite and other gravel.

HOLE No: BH5
Sheet 2 of 2

JOB: 3030041301

ROCK FABRIC	GRAIN SIZE	JOINT ROUGHNESS	ROCK HARDNESS
MF -massive	FG -fine grained	SLJ-slickensided	EHR-extremely hard rock
BF -bedded	MG -medium grain	SJ -smooth	VHR-very hard rock
FF -foliated	CG -coarse grain	RJ -rough	HR -hard rock
CF -cleaved			MHR-medium hard rock
SF -schistose	JOINT SPACING	JOINT SHAPE	SR -soft rock
GF -gneissose	VCJ-very close spacg	CUR-curvilinear	VSR-very soft rock
LF -laminated	CJ -close spacing	PLA-planar	
	MJ -medium spacing	UND-undulating	
	WJ -wide spacing	STE-stepped	
	VWJ-very wide spacng	IRR-irregular	

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UMKHOMAZI PROJECT
MAPSTONE DAM DRILLING INVESTIGATION

GEOTECHNICAL INVESTIGATION

HOLE No: BH5
Sheet 2 of 2

JOB: 3030041301

NOTES

1) NA: Not applicable.

2) NM: Not measured.

3) Water depth of dam: 1,25m.

Grain Size	Rock Fabric	Fabric Spac (mm)	Fabric Inc (deg)	Joint Set No.	Joint Inc (Deg)	Joint Spac	Micro Roughness	Joint Filling	Fill Thickness (mm)	Depth m	Mat recov %	Rock recov %	RQD %	Frac Freq No/m	DEPTH Scale 1:75

CONTRACTOR : Diabor
MACHINE :
DRILLED BY :
PROFILED BY : AvdM

TYPE SET BY : EM
SETUP FILE : KPBHCOO.SET

INCLINATION : 90 degrees
DIAM :
DATE : 18 Nov - 5 Dec 2014
DATE : 8 Dec 2014

DATE : 12/12/2014 09:05
TEXT : ..P51\PROFILES\MJVAVDM.TXT

COORDINATE SYSTEM : WGS84 (Lo31)
X-COORD : S29 47 16.8
Y-COORD : E30 23 30.8

HOLE No: BH5

Appendix B: Borehole Core Photographs

BH1

BH2

BH3


0.00
1.2.3.3.3.3
SPT 1.95
TNW 1.50
TNW 3.00
TNW 3.90
TNW 4.50
TNW 6.00
7.26
TNW 7.50

BH4


0.00
1.2.2.2.3
TNW 1.50
SPT 1.95
TNW 3.00
TNW 4.50
TNW 5.59
TNW 6.09
TNW 7.59
TNW 9.09

BH5


NWD4
1.50
3/4/3/5/16
SPT
1.95
NWD4
3.00
NWD4
4.50
TNW
5.77
TNW
6.95
TNW
8.45
TNW
9.65