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Siyanda Ferrochrome Project

Siyanda Ferrochrome Project
Groundwater Impact Assessment

SLR Project No.: 710.19057.00005
Report No.: 01
Revision No.: 01

September 2016

Siyanda Chrome Smelting Company (Pty) Limited

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DOCUMENT INFORMATION

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Client	Siyanda Chrome Smelting Company (Pty) Limited
Date last printed	2016/09/14 11:11:00 AM
Date last saved	2016/09/14 09:32:00 AM
Comments	
Keywords	Ferrochrome, EIA, groundwater, slag, baghouse dust
Project Number	710.19057.00005
Report Number	01
Revision Number	Revision No.: 01
Status	FINAL
Issue Date	September 2016

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EXECUTIVE SUMMARY

Siyanda Chrome Smelting Company (Pty) Limited ("SCSC") is proposing a new ferrochrome smelter near Northam in Limpopo Province. Incoming material will likely be sourced from the neighbouring Union Section Mine and possibly from other nearby mines in future. Two types of waste will be generated from the process (a slag and a baghouse dust) and these will be disposed of at two separate waste facilities on site. The slag will be disposed of as a molten material onto a designated slag disposal facility and the baghouse dust (BHD) will be will be deposited as slurry (some of which will be in permeable bags) in a slurry facility.

Water will be required for both potable and process requirements. The operational phase water requirements are expected to be 86m^3/day (potable water) and 133m^3/day (process water). It is expected that SCSC will source make up water from the municipal supply scheme, however SCSC is also considering using water from one on-site borehole however this will be for emergency backup purposes only.

As part of the Environmental Impact Assessment (EIA) and Water Use License Application (WULA) processes, an assessment of the groundwater regime is required. This report details the works undertaken in respect to groundwater and assesses the potential impact of the proposed project on the surrounding groundwater regime.

The works undertaken as part of this assessment included:

- Collation and review of existing data.
- Consultation with authorities and IAPs.
- Site investigations – including geophysical survey, drilling of boreholes and pumping tests.
- Development of a Conceptual Site Model (CSM).
- Development of groundwater numerical model.
- Impact Assessment.

The geology of the area comprises of the Rustenburg Layered Suite (RLS) of the Bushveld Igneous Complex (BIC). The RLS is a sequence of layered mafic intrusions, comprising gabbros, norites, anorthosites and pyroxenites. The orebodies within the BIC include the chromite rich Upper Group 2 (UG2) reef and the platinum-bearing Merensky Reef.

As indicated by the geological map of the area and the drilling of five (5) boreholes undertaken as part of this assessment, the geology directly beneath the Siyanda Project area includes:

- Bierkraal Magnetite Gabbro.
- Pyramid Gabbro-norite.
- Mathlagame Norite-anorthosite.

The drilling of boreholes on site was for three purposes: to confirm geology, determine aquifer parameters and to act as long term monitoring boreholes. Details of the boreholes are provided in Table A. Key information obtained through drilling:

- Weathered unit extends from surface to between 9m and 13m.
- Borehole SIY-BH01 (shallow and deep) was the only borehole to extend through magnetite rich gabbro.
- Boreholes SIY-BH02 (shallow and deep) and BH03 extended only through Gabbro Norite. It is noted that the geological map suggested that both of these boreholes are on magnetite rich gabbro. It is likely that boreholes are on the contact of the two lithologies.
- Even though the water strike in boreholes SIY-BH02S and SIY-BH02D were shallow, water strikes are typically associated with fractures.

TABLE A: DETAILS OF NEWLY DRILLED BOREHOLES

Borehole ID	SIY-BH01S	SIY-BH01D	SIY-BH02S	SIY-BH02D	SIY-BH03
Latitude	-24.926063	-24.92609	-24.92745	-24.927444	-24.9204
Longitude	27.187590	27.18756	27.18443	27.18434	27.17774
Drilled Date	31st July 2015	28th July 2015	31st July 2015	28th July 2015	30th July 2015
Borehole Depth (mbgl)	12	60	18	50	60
General Geology	Weathered Magnetite Gabbro	Magnetite Gabbro	Weathered Gabbro Norite	Gabbro Norite	Gabbro Norite
Water Strike (mbgl)	None	None	12 (fracture) 15 (fracture)	11 (fracture) 14 (fracture) 16 (fracture)	34 (fracture)
Static Water Level (mbgl)	Dry	32	6	6	18
Blow Yield (L/s)	-	None	0.9 1.9	0.7 0.4 1.1	0.3
Plain Casing (mbgl)	0-6	0-12	0-6	0-24	0-30
Slotted Casing (mbgl)	6-12	-	6-18	-	30-36
Open Hole (mbgl)	-	12-60	-	24-50	36-60

The assessment suggests that there are two types of aquifer systems, both of which are considered to be minor aquifers:

- A shallow weathered aquifer system formed as a result of intensive, in-situ chemical weathering processes of the underlying bedrock. Groundwater flow is typically intergranular and may be laterally connected to alluvial aquifers associated with river systems.

- A deep un-weathered aquifer system with negligible matrix porosity and permeability but contains planes of discontinuity in the rock matrix, including both faults and joint planes (collectively referred to as fractures). The infiltration and flow of groundwater in such systems is controlled by the prevailing complex fracture network and can vary in space and time. Such conditions relate to structurally controlled flow systems.

Based on literature and pumping tests undertaken on one borehole drilled for the project (SIY-BH02S), borehole yields generally range between 0.5 – 5.0 L/s regardless of geology. The transmissivity of the aquifer determined through pumping tests was calculated to be 80 m^2/day.

A hydrocensus was undertaken by SLR as part of the groundwater assessment. The hydrocensus identified groundwater and surface water users near the project area. In total, sixteen (16) sites were visited; thirteen (13) groundwater monitoring points and three (3) surface water monitoring points.

Key observations include:

- The depth of boreholes ranged from 10 m to over 100 m.
- Recorded groundwater levels ranged between 7.3 mbgl and 19.4 mbgl. Due to the geology of the area, boreholes and their yield are associated with fractures.
- Primary groundwater and surface water uses at identified sites include domestic use and drinking water for livestock (cattle / game).
- Surface watercourses and dams were dry during the hydrocensus. Surface watercourses in the area are ephemeral and flow only during times of rainfall.
- Based on samples collected and comparison of results against water quality standards, the following elements were considered to be chemicals of concern; arsenic (As) iron (Fe), manganese (Mn), sodium (Na), nickel (Ni), electrical conductivity (EC), total dissolved solids (TDS), chloride (Cl), sulphate (SO_4) and ammonia (NH_4-N).
- The water quality results of the samples taken from Johan Young's property (Johan Young BH1 and BH2) show very different chemistries, even though they are approximately 300 m apart. Concentrations of calcium (Ca), potassium (K), magnesium (Mg), sodium (Na), TDS, chloride (Cl) and sulphate (SO4) were significantly higher in Johan Young BH1. It is noted that the boreholes are drilled to same depth and both are high yielding.

Based on the data collected through the desk review and site investigations, a conceptual site model (CSM) was developed for the site. Key aspects are:

- A weathered unit exists from surface to approximately 13 m irrespective of geology (magnetite gabbro and pyramid gabbro norite).

- Shallow groundwater can occur in the weathered unit (groundwater was encountered at shallow depths within borehole SIY-BH02), but predominantly associated with fractures and geological contacts.
- Yields are in the range of 0.2 L/s to 5 L/s.

To assess the potential impact of the Siyanda waste disposal facilities on the local groundwater system, SLR used the CSM to develop a numerical groundwater flow model using the FEFLOW code. The objectives of the modelling were to:

- Determine the distribution of hydraulic heads and assess the potential impact on groundwater levels during, and post-operation, in response to groundwater abstraction for water supply.
- Predict the extent and magnitude of a possible contaminant plume, and assess the potential impact from the slag, baghouse dust waste disposal facility and pollution control dam (PCD) during, and post-operation.

The source term concentration considered for the Siyanda Project was determined through a geochemical assessment (SLR, 2016c). As informed by the geochemical assessment, the main contaminant exceeding the prescribed groundwater quality limits and identified as per the water contact quality statement was iron (Fe).

Based on the numerical groundwater flow model and the impact assessment undertaken the following conclusions are made:

1. Groundwater Levels

The possible abstraction of water from an on-site borehole for the use as potable and/or process water has the potential to cause a lowering of groundwater levels. Lowering of groundwater levels through abstraction may cause a loss in water supply to third party borehole users and may impact base flow of the Brakspruit tributary.

Based on the results of the groundwater study, which simulated abstraction from borehole SIY-BH02S at a sustainable pumping rate of 3 L/s for a period of 12 hrs/day, it is not expected that there be any impact on the groundwater levels, thus negligible impact on or third party water users or base flow of the Brakspruit tributary as a result of borehole abstraction.

If additional boreholes are drilled and used for groundwater abstraction, then an update of the groundwater model must be run to include the new boreholes and impacts reassessed.

No mitigation measures are required; however, it is recommended that monitoring of groundwater levels is undertaken through the different phases of the project to ensure the project is not causing negative impact. In the unlikely event that any project related loss of water supply is experienced by the surrounding borehole users, SCSC will provide compensation that could include an alternative water supply of equivalent quantity and water quality.

Groundwater may be abstracted from SIY-BH-02S for industrial purposes only.

2. Groundwater Contamination

There are a number of sources that have the potential to pollute groundwater and impact surrounding groundwater users. The most significant potential sources include the slag disposal facility, baghouse dust slurry facility and pollution control dam (PCD).

The groundwater model (which conservatively assumed a Class C liner for the slag disposal facility, baghouse dust slurry facility and PCD) predicts that an iron plume could migrate 216 m from these sources over a period of 100 years. The simulated iron concentrations migrating from the storage facilities are presented in Table B below. The model concluded that the iron contaminant plume migrates towards the north-north-east following the general groundwater flow direction.

Although the plume shows an increased distance vs. time, the iron concentrations show a decreasing trend in time, after the termination of the sources (20 years). This plume is not predicted to reach third party boreholes, and although the model shows the maximum plume extent situated marginally before the Brakspruit tributary, there is a possibility that the plume could extend under it which is unlikely to have any implications in the dry season, however, there may be limited impacts on the tributary in the wet season if the unsaturated groundwater zone is contaminated and interacts with the tributary flow.

When a Class A liner is modelled for the baghouse dust slurry facility and PCD (mitigation measure), no plume is expected to extend in the vicinity of the tributary.

TABLE B: SIYANDA MAXIMUM EXTENT OF FE PLUME

Source concentration, Fe, mg/l	Year	Plume migration (up to 0 mg/l concentration)	Max. plume concentration, Fe, mg/l
Slag: 0.31 BHD: 13.1 PCD: 13.1	1	126m	13.1
Slag: 0.31 BHD: 13.1 PCD: 13.1	10	142m	13.1
Slag: 0.31 BHD: 13.1	20	211m	13.1

Source concentration, Fe, mg/l	Year	Plume migration (up to 0 mg/l concentration)	Max. plume concentration, Fe, mg/l
PCD: 13.1			
-	50	239m	0.6
-	100	216m	0.1

Various mitigation measures are recommended to prevent pollution of groundwater resources and related harm to water users (people, animals and biodiversity) and include:

- Class A liner for the baghouse dust slurry facility and PCD.
- Monitoring of ground and surface water quality during all phases and comparing results to baseline data (see below).
- Figure A presents a safety buffer at 0 mg/l limit concentration added to existing groundwater as a consequence of waste source term around the maximum extent for the contaminant plumes developed during time. SLR recommends that no domestic groundwater water supply borehole be drilled within the buffer zone.

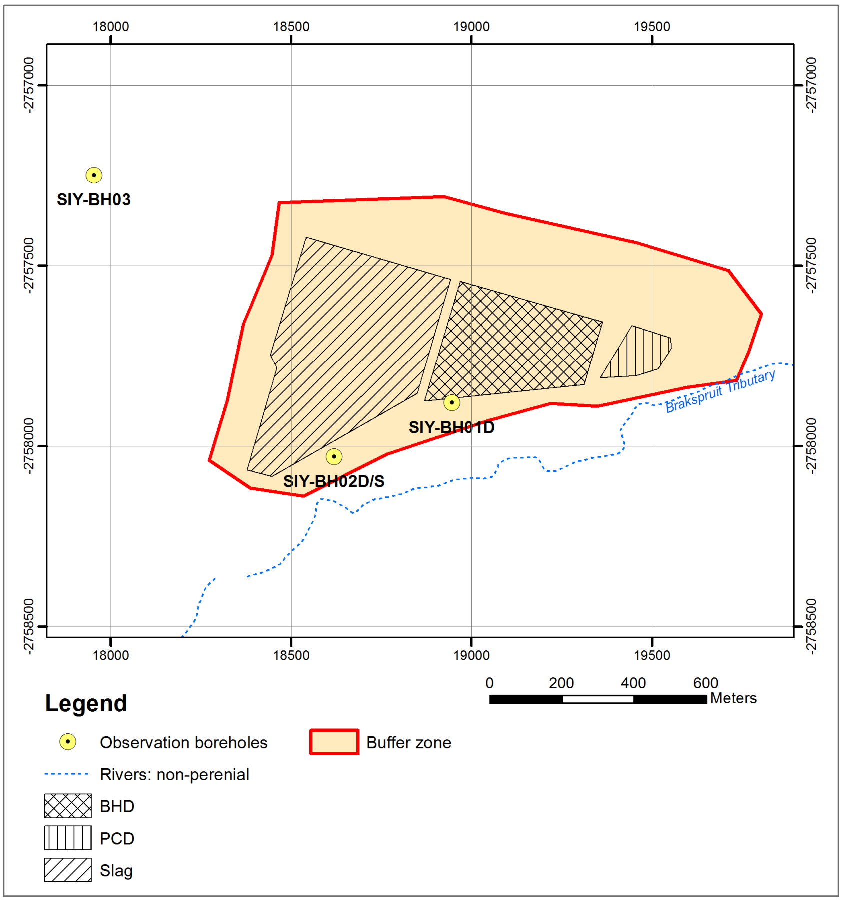

FIGURE A: SIYANDA GROUNDWATER PROTECTION ZONE 1

The results of this assessment are considered acceptable for the purpose of this level of assessment and there is no reason not to proceed with the project provided that the waste facility design and any impact mitigation measures, as recommended, are implemented.

It is recommended that monitoring of water is undertaken in order to assess potential impacts of the ferrochrome smelter and associated infrastructure on the surrounding water resources. The measurement of environmental parameters (groundwater levels and ground- surface water quality) prior to development allows the range of variation of the system to be determined and allows reference points to be established against which changes in the future can be measured. A baseline monitoring programme was set up for the Siyanda Project following the hydrocensus and commenced in March 2016.

The monitoring programme includes eight (8) groundwater monitoring points and three (3) surface water monitoring points which are monitored on a quarterly basis (groundwater levels were monitored initially on a monthly basis).

The data collected to date (since March 2016) indicate the following:

- Groundwater levels range between 5.65 mbgl (SIY0BH02S) and 31.87 mbgl (SIY-BH01D).
- Groundwater levels have remained stable.
- When compared to relevant water quality standards, the following chemicals of concern were identified for groundwater: iron (Fe), manganese (Mn), sodium (Na), electrical conductivity (EC), total dissolved solids (TDS), chloride (Cl) and sulphate (SO_4) and is consistent with the hydrocensus results.
- Surface water in the area is ephemeral. Spruits are generally dry. During times of rainfall, in which spruits may flow, the site is inaccessible by vehicle (due to black cotton soils). The level of water within the dams varies significantly.
- When compared to relevant water quality standards, the following chemicals of concern were identified in surface water: aluminium (Al), iron (Fe), manganese (Mn).

SIYANDA FERROCHROME PROJECT

GROUNDWATER IMPACT ASSESSMENT

CONTENTS

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ACRONYMS AND ABBREVIATIONS

Below a list of acronyms and abbreviations used in this report.

Acronyms / Abbreviations	Definition
BHD	Baghouse Dust
BIC	Bushveld Igneous Complex
CoC	Chemicals of Concern
DWAF	Department of Water, Agriculture and Forestry
DWS	Department of Water and Sanitation
EIA	Environmental Impact Assessment
EMPr	Environmental Management Programme
IAP	Interested and Affected Parties
mamsl	Metres above mean sea level
MAP	Mean Annual Precipitation
mbgl	Metres below ground level
NEMA	National Environmental management Act
NRMSE	Normalized Residual Mean Square Error
PCD	Pollution Control Dam
PGM	Platinum Group Metals
RLS	Rustenburg Layered Suite
RMSE	Residual Mean Square Error
SANAS	South African National Accreditation System
SANS	South African National Standards
SDT	Step Drawdown Test
TSF	Tailings Storage Facility
TWQR	Target Water Quality Range
WRC	Water Resource Commission
WUL	Water Use Licence
WULA	Water Use Licence Application

NATIONAL ENVIRONMENTAL MANAGEMENT ACT (NEMA) REGULATIONS (2014) APPENDIX 6: SPECIALIST REPORTING REQUIREMENTS CHECKLIST

Below is a checklist showing information required by specialists in terms of Appendix 6 of NEMA

Item	NEMA Regulations (2014): Appendix 6	Relevant Section in Report
1(a)(i)	Details of the specialist who prepared the report	Section 13, Page 66
1(a)(ii)	The expertise of that person to compile a specialist report including a curriculum vitae	Appendix A
1(b	A declaration that the person is independent in a form as may be specified by the competent authority	Section 13, Page 66
1(c)	An indication of the scope of, and the purpose for which, the report was prepared	Section 1.2, Page 2
1(d)	The date and season of the site investigation and the relevance of the season to the outcome of the assessment	Section 5.8.2, Page 22
1(e)	A description of the methodology adopted in preparing the report or carrying out the specialised process	Section 1.3, Page 2
1(f)	The specific identified sensitivity of the site related to the activity and its associated structures and infrastructure	Section 8.3, Page 55
1(g)	An identification of any areas to be avoided, including buffers	Section 8.3, Page 55
1(h)	A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Figure 8-1, Page 55
1(i)	A description of any assumptions made and any uncertainties or gaps in knowledge;	Section 11, Page 64
1(j)	A description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives, on the environment	Section 7.3.2, Page33
1(k)	Any mitigation measures for inclusion in the EMPr	Section 8, Page 49
1(l)	Any conditions for inclusion in the environmental authorisation	N/A
1(m)	Any monitoring requirements for inclusion in the EMPr or environmental authorisation	Section 9, Page 56
1(n)(i)	A reasoned opinion as to whether the proposed activity or portions thereof should be authorised and	Section 10, Page 63
1(n)(ii)	If the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan	Section 10, Page 63
1(o)	A description of any consultation process that was undertaken during the course of carrying out the study	Section 3, Page 7
1(p)	A summary and copies if any comments that were received during any consultation process	Section 3, Page 7
1(q)	Any other information requested by the competent authority.	N/A

SIYANDA FERROCHROME PROJECT
GROUNDWATER IMPACT ASSESSMENT

1 INTRODUCTION

SLR Consulting (Africa) (Pty) Limited ("SLR") has been appointed by Siyanda Chrome Smelting Company (Pty) Limited ("SCSC") to undertake a groundwater impact assessment for the proposed ferrochrome smelter located near Northam in Limpopo Province.

The groundwater assessment will support the Environmental Impact Assessment (EIA) for the site.

1.1 PROJECT BACKGROUND AND PROCESS OVERVIEW

SCSC is proposing to construct a new ferrochrome smelter on portion 3 of the Farm Grootkuil 409 KQ, located approximately 8 km north-west of Northam in Limpopo Province.

The project will comprise two 70 megawatt (MW) direct current (DC) furnaces, a crushing and screening plant, waste storage facilities, material stockpiles and various support infrastructure and services.

At this stage in project planning, it is expected that incoming material will be sourced from Union Section Mine and possibly also from other mines in future. The proposed process is presented in Figure 1-1.

The two (2) waste types generated through the ferrochrome smelting process (a slag and a baghouse dust (BHD)) will be disposed of at two separate waste facilities:

- **Slag** will be disposed of as molten material to a standalone waste facility of approximately 21.5 hectares (ha).
- **BHD** will be deposited as slurry (some of which will be in permeable bags) in a slurry facility of approximately 9.4 ha.

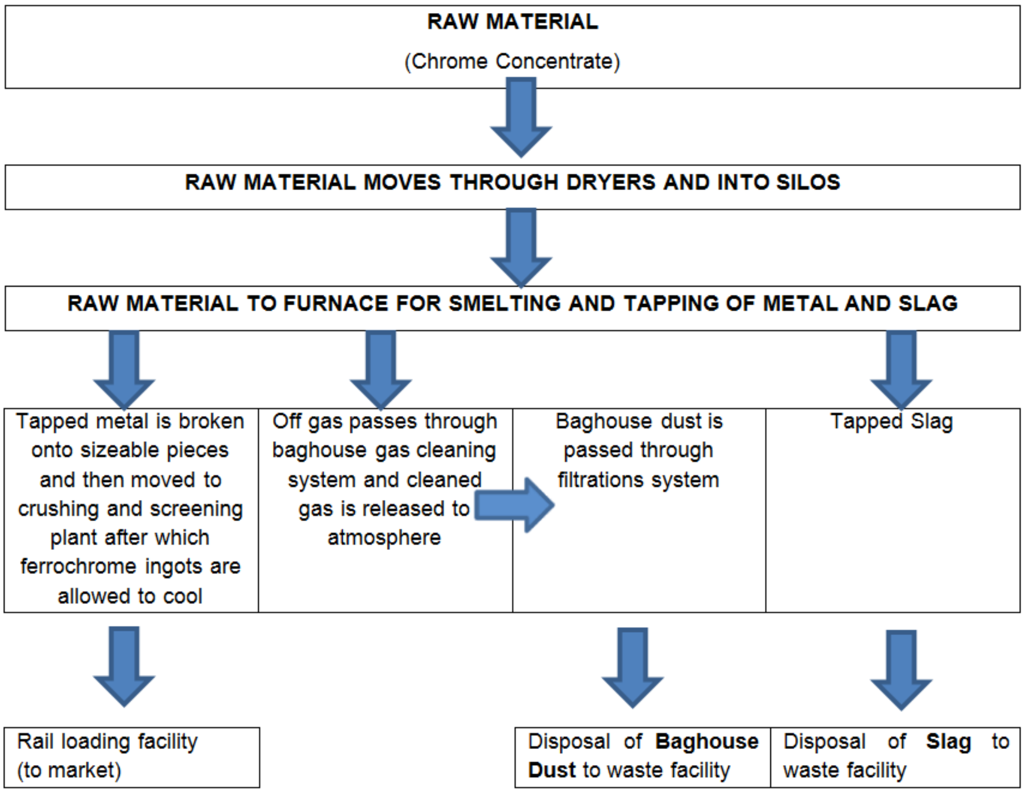


FIGURE 1-1: FLOW DIAGRAM FOR PROPOSED PROCESS

1.2 OBJECTIVES

The objectives of this report are:

- To characterise the groundwater regime at the site.
- To assess the potential impact of the proposed project on the groundwater regime.

1.3 METHODOLOGY

The objectives of the groundwater assessment have been completed by undertaking the following works:

- Desk review – reviewing published data for the area, including geological and hydrogeological maps.
- Consultation with authorities and Interested Affected Parties (IAPs).
- Site investigations – including geophysical survey, drilling of boreholes and pumping tests.
- Development of a Conceptual Site Model (CSM).
- Development of groundwater numerical model.
- Impact Assessment.

1.4 REPORT STRUCTURE

The report has been divided accordingly:

- Section 2 describes the site setting and baseline conditions.
- Section 3 presents the consultation process.
- Section 4 describes the geological setting.
- Section 5 describes the hydrogeological setting.
- Section 6 presents the hydrogeological conceptual site model.
- Section 7 presents the groundwater numerical model.
- Section 8 presents the groundwater impact assessment.
- Section 9 presents baseline monitoring programme.
- Section 10 concludes the report and presents recommendations.
- Section 11 presents the assumptions and limitations of the project.

2 BASELINE CONDITIONS

This section presents a brief review of the baseline conditions of the Siyanda Project.

2.1 LOCATION OF PROJECT AREA

The project area is located on portion 3 of the Farm Grootkuil 409 KQ, located approximately 8 km north-west of Northam in Limpopo Province (Figure 2-1) and immediately adjacent (south-east) of the existing Union Section Mine.

2.2 TOPOGRAPHY

The elevation of the project area is approximately 1000 metres above mean sea level mamsl. The site slopes gently to the east, towards drainage channels (Brakspruit tributary), with a relatively low gradient of 1:100 (SLR, 2016a).

2.3 CLIMATE

Climatic data is presented fully in the Surface Water Study (SLR, 2016a). In summary:

- The adopted Mean Annual Precipitation (MAP) for the project area, obtained from the Northam station totals 571 mm.
- Although MAP in this area is fairly low, data show that there has been significant rainfall on occasions.
- The project area lies within evaporation zone 3A, which has a total Mean Annual Evaporation (MAE) of 180 mm.
- Average temperature ranges between 12.1℃ (June / July) and 24℃ (December).

2.4 SITE LAYOUT

Figure 2-2 presents the site layout and presents the locations of the site infrastructure.

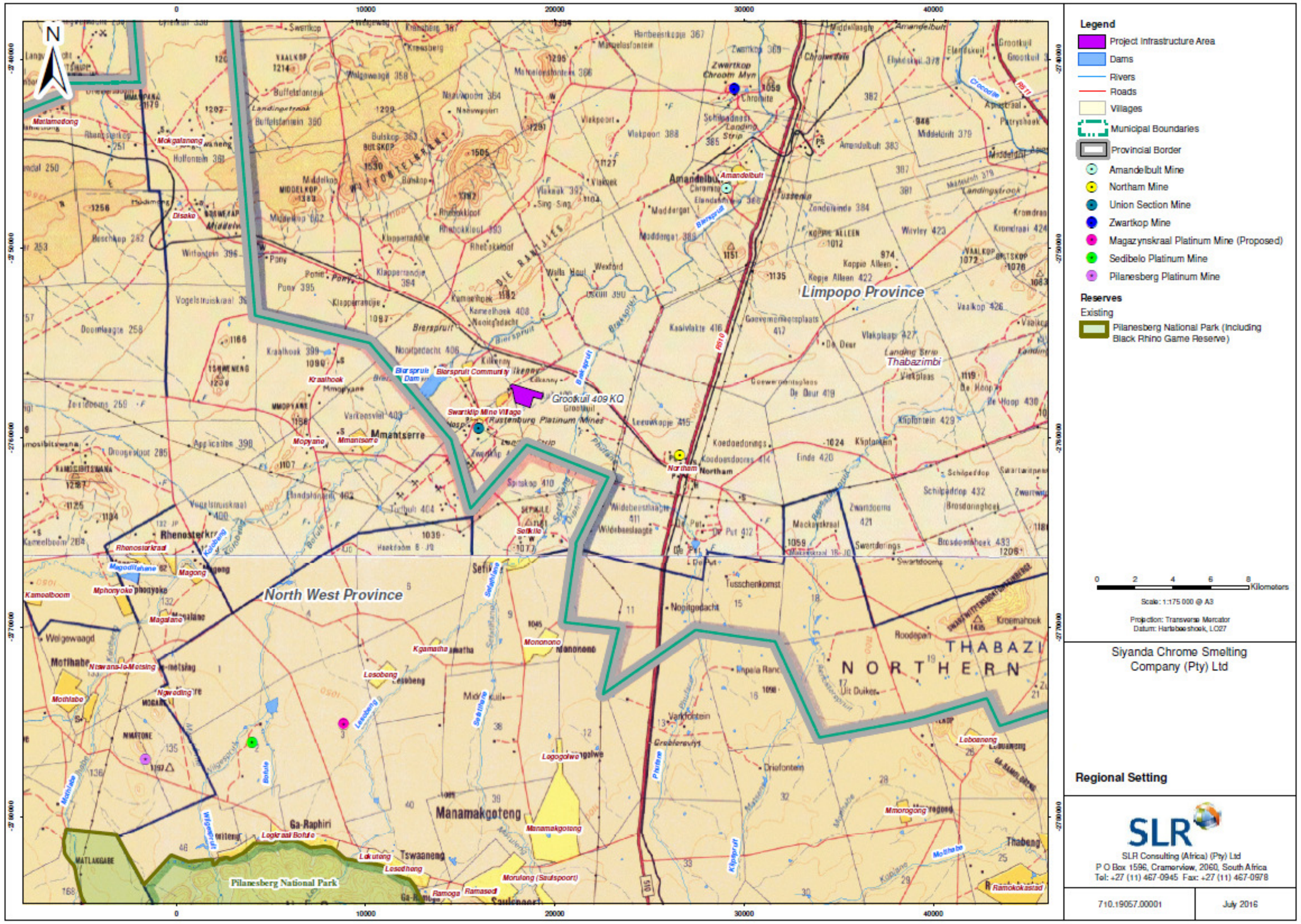


FIGURE 2-1: SITE LOCATION PLAN

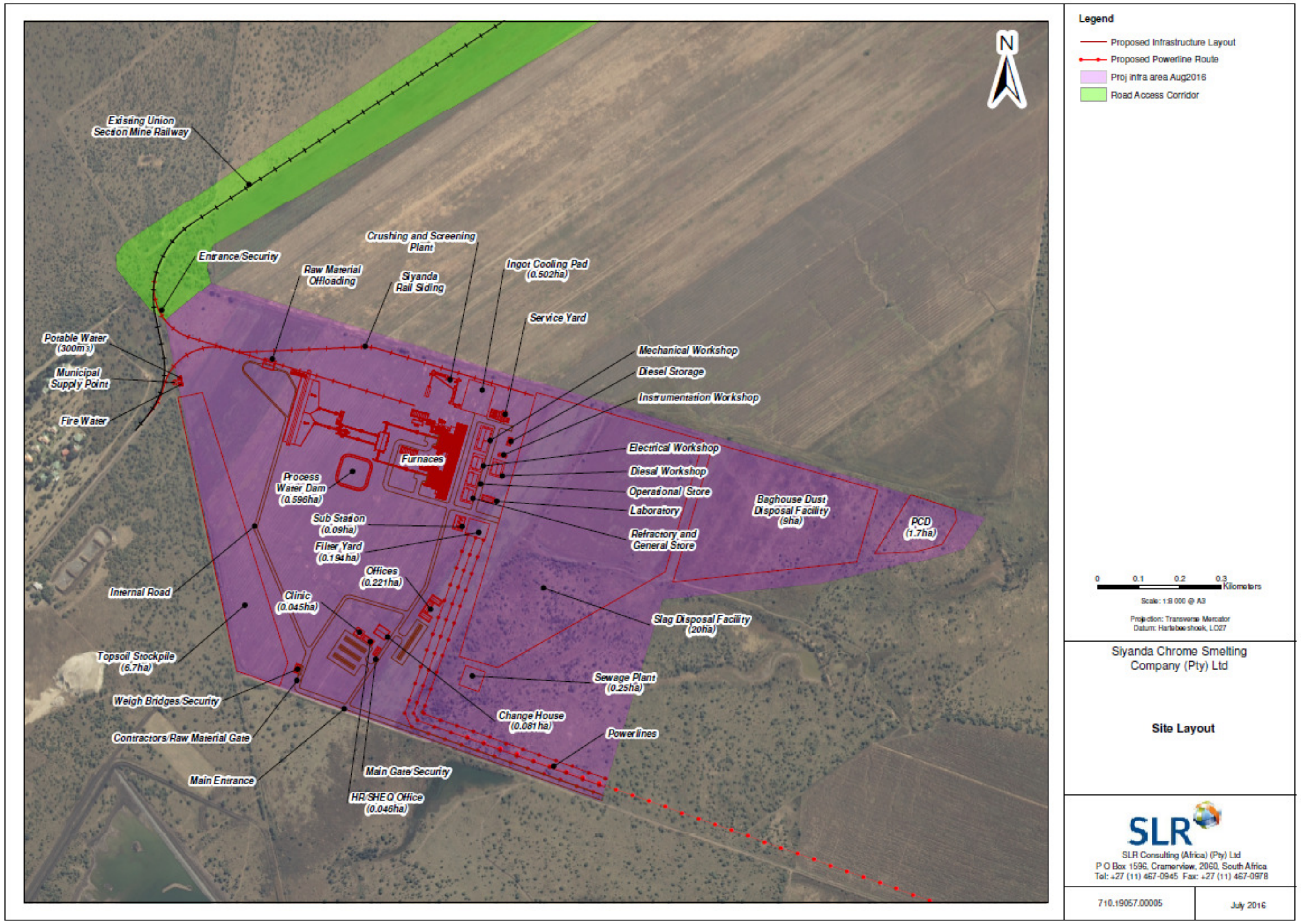


FIGURE 2-2: SITE LAYOUT

3 CONSULTATION PROCESS

As part of the scoping process, regulatory authorities and interested and affected parties (IAPs) were consulted. Table 3-1 presents issued raised in relation to groundwater and indicates in which section of this report, the issues have been addressed.

TABLE 3-1: SUMMARY OF ISSUES RAISED RELATED TO GROUNDWATER

Issue Raised	By Whom and When	Response by Project Team	Section of Groundwater Report where addressed
What happens if they extract water from a borehole before they get a water use license?	Comment by Marietjie Schoeman at focused meeting, on Johan Young's property (Kameelhoek ptn 9), 26 May 2016	The boreholes drilled on site to date have been drilled under the supervision of the environmental impact assessment team for groundwater quality and quantity monitoring purposes and this monitoring will continue if and when the project becomes operational. Should Siyanda wish to use borehole water at any stage this will require authorisation in terms of the National Water Act (NWA) through a Water Use Licensing (WUL) process.	Drilling Campaign: Section 5.8.2 Water Supply: Section 7.3.2 Authorisation in terms of NWA – addressed within EIA Report
How has Siyanda already managed to drill boreholes without a water use license			
For the purposes of the WULA, SLR should identify all relevant water uses on the proposed site and surrounding the proposed site	Comment raised by Makahane Rudzani (DWS) at the authority site visit-meeting, Swartklip Rec Centre, 23 July 2015	All relevant water uses will be identified and applied for.	Addressed in EIA Report
How much water will this operation utilise, since I realise it is a large plant	Comment raised by Hannes Olckers at scoping meeting, Northam Town Hall, 23 July 2015	The operational phase water requirements are expected to be 86m^3/day (potable water) and 133m^3/day (process water).	Water Supply: Section 7.3.2
Where is additional water going to come from for the purposes of the project? There is already a shortage of water in the town of Northam.	Comment raised by Hannes Olckers at scoping meeting, Northam Town Hall, 23 July 2015	It is not expected that the proposed project will be water intensive. It is expected that Siyanda will reuse water in its circuit and source make up water from the municipal supply scheme. Siyanda is also considering using water from one on-site borehole however this will be for emergency backup purposes only (in the event that municipal water is not available),.	Water Supply: Section 7.3.2
Where does Siyanda plan to source water from?	Comment by Vernon Koekemoer at focused meeting, on Johan Young's property (Kameelhoek ptn 9), 26 May 2016		
Will groundwater be tested for the purposes of the project? I no longer have any drinking water available in my borehole	Comments raised by Johan Young at scoping meeting, Northam Town Hall, 23	SLR has undertaken the hydrocensus which has been used to inform the groundwater specialist study. Impacts on water supply and quality have been assessed in the groundwater report.	Hydrocensus: Section 5.7 Monitoring Programme: Section 9 Impact Assessment: Section 7.3.2
I am concerned about the groundwater impacts as a result of the slag dump.			
We are concerned about the water related impacts.	Comment by Philip Schoeman and Pier De Vries during focused scoping meeting with Union Mine, 13 May 2015		
It is common knowledge that a Ferrochrome Smelter is	Comment raised by Ernst Burger (on behalf of the		

Issue Raised	By Whom and When	Response by Project Team	Section of Groundwater Report where addressed
associated with, amongst others: water pollution.	Schoeman family, the beneficiaries of a Testamentary Trust) – draft scoping report comments, received on the 04 May 2016		
Pivots on our farm cannot be used anymore due to the lack of water.	Comments raised by Sandy McGill, Mr and Mrs Schoeman at the scoping meeting, Swartklip Rec Centre, 21 July 2015		
Water levels in our boreholes have dropped significantly from 24m to 60m.			
Water is very scarce in the area. I do not know any borehole in the area that still has water.			
The issue with regards to the lack of water is a cumulative issue as no mine will take responsibility for the lack of water.			
Water is being drawn down into the pits. Therefore Siyanda should seek alternative means of sourcing water because the groundwater is very scarce for all farmers.		It is expected that Siyanda will reuse water in its circuit and source make-up water from the municipal supply scheme. Siyanda is also considering using water from one on-site borehole however this will be for emergency backup purposes only (in the event that municipal water is not available),	Water Supply: Section 7.3.2
What are the chances that they can include neighbouring farms in the groundwater study	Comment raised by Johan Young at scoping meeting, Northam Town Hall, 23 July 2015	SLR included Mr Johan Young's borehole in the hydrocensus. Groundwater quality and quantity information will be made available in the EIA report.	Hydrocensus: Section 5.7 Monitoring Programme: Section 9
What is meant by a weathered aquifer?	Comment raised by Hannes Olckers at scoping meeting, Northam Town Hall, 23 July 2015	A weathered aquifer is usually shallow and is called the weathered aquifer due to the weathering (or erosion) of the shallow geology through mechanical and chemical processes.	Hydrogeological Setting: Section 5.1
What happens if the water table drops?	Comment by Vernon Koekemoer at focused meeting, on Johan Young's property (Kameelhoek ptn 9), 26 May 2016	Since it is not expected that Siyanda will use material quantities of groundwater (borehole water) for the project, it is not anticipated that there should be material impacts on groundwater levels.	Impact Assessment (includes Mitigations): Section 8

4 GEOLOGICAL SETTING

The following section presents the geological setting of the Siyanda Project.

4.1 REGIONAL GEOLOGY

The Siyanda Project Area lies within the western limb of the Bushveld Igneous Complex (BIC), a large, pear-shaped, layered intrusion, located within the Limpopo Province.

The BIC includes the Rustenburg Layered Suite (RLS); a sequence of layered mafic intrusions, comprising gabbros, norites, anorthosites and pyroxenites.

The RLS is rich in reserves of platinum group metals (PGM), chromium and vanadium, which are exploited in the region. The orebodies within the BIC include the chromite rich Upper Group 2 (UG2) reef and the platinum-bearing Merensky Reef.

A generalised stratigraphic column for the RLS, showing the key sub-divisions, as accepted by the South African Committee for Stratigraphy (SACS, 1980), as cited in (Johnson *et al*, 2006) is presented in Table 4-1.

TABLE 4-1: GENERALISED STRATIGRAPHIC COLUMN (JOHNSON *ET AL* (2006)

Suite	Standard Zonal Subdivision		Western Limb Nomenclature as be SACS (1980)	
Rustenburg Layered Suite	Upper Zone (Ferro-gabbroic)	Subzone C: Olivine - Apatite diorite		Bierkraal Magnetite Gabbro
		Subzone B: Olivine - Magnetite Gabbro-norite		
		Subzone A: Magnetite gabbro-norite		
	Main Zone (Gabbro-nortitic)	Upper \ subzone: gabbro-norite		Pyramid Gabbronorite
		Lower Subzone: Gabbro-norite		
	Critical Zone (ultramafic to mafic)	Upper Subzone: norite, anorthosite, pyroxenite	Schilpadnesy Sub-suite	Mathlagame Norite Anorthosite
		Lower subzone: pyroxenite		Ruighoek Bronzite
	Lower Zone (ultramafic)	Upper Pyroxenite Subzone	Vlakfontein Sub-suite	Tweelaagte Bronzite
		Harzburgite Subzone		Groenfontein Harzburgite
		Lower Pyroxenite Subzone		Makgope Bronzite
				Eerlyk Bronzite
	Marginal Zone (noritic)	Norites		Kroondal Norite
				Kolobeng Norite

4.2 LOCAL GEOLOGY

An extract of the 1:250,000 geological map of the Siyanda Project Area (2426 – Thabazimbi) is presented as Figure 4-1. The key formations / lithologies identified in the figure are:

- Bierkraal Magnetite Gabbro.

- Pyramid Gabbro-norite.
- Mathlagame Norite-anorthosite.

Characteristics of the three formations / lithologies are presented in Table 4-2.

TABLE 4-2: CHARACTERISTICS OF THE MAIN ROCK TYPES FOUND AT SIYANDA

Rock Type	Characteristics
Gabbro	• Basic rock • Coarse grained • Dark in colour • Pyroxene, plagioclase, minor amphibole and olivine • Pyroxene tends to be clinopyroxene
Norite	• Basic rock • Coarse grained • Dark in colour • Pyroxene plagioclase, minor amphibole and olivine • Pyroxene tends to be orthopyroxene (high Mg and Fe)
Anorthosite	• Basic rock • Coarse grained • Light in colour • Plagioclase feldspar (>90%)

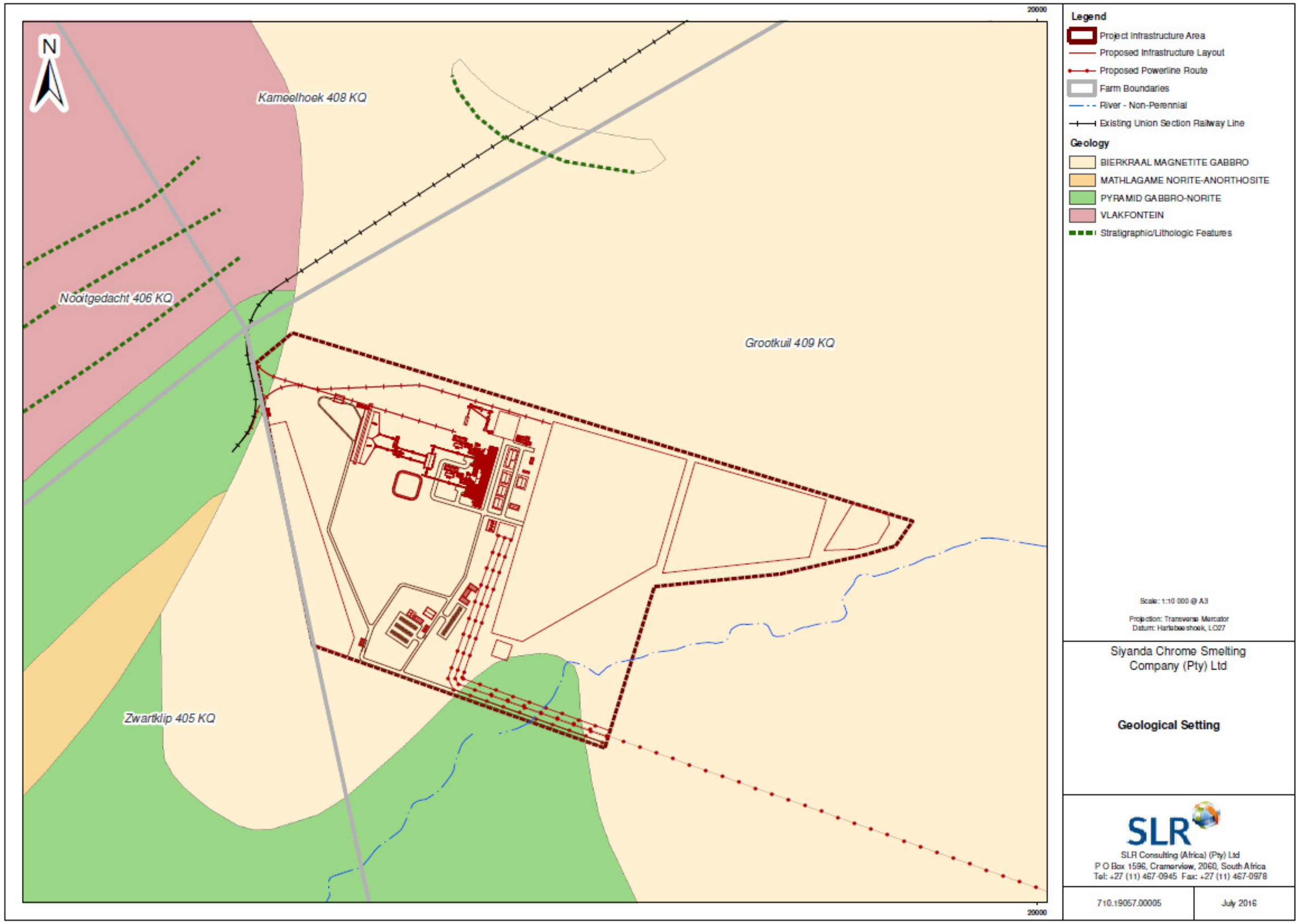


FIGURE 4-1: GEOLOGICAL SETTING OF SIYANDA

5 HYDROGEOLOGICAL SETTING

This section presents the hydrogeological setting of the project area.

5.1 AQUIFER SYSTEMS

The Bushveld Igneous Complex (BIC) typically comprises:

- A shallow weathered aquifer system formed as a result of intensive, in-situ chemical weathering processes of the underlying bedrock. Groundwater flow is typically intergranular and may be laterally connected to alluvial aquifers associated with river systems.
- A deep un-weathered aquifer system with negligible matrix porosity and permeability but contains planes of discontinuity in the rock matrix, including both faults and joint planes (collectively referred to as fractures). The infiltration and flow of groundwater in such systems is controlled by the prevailing complex fracture network and can vary in space and time. Such conditions relate to structurally controlled flow systems.

The shallow weathered aquifer can vary in thickness, typically between 12 to 30m (average 15m). The degree and intensity of weathering, or more specifically the spatial and depth variations control the geometry of the shallow weathered aquifer profile.

The shallow weathered aquifer is considered to have low to moderate transmissivity, but high storativity. It is recharged by rainfall or by leakage from perennial and non-perennial surface water drainages and dams, although direct recharge from rainfall is limited, as the mafic rocks of the BIC tend to weather to a swelling clay rich soil, referred to turf or black cotton soil, which demonstrated low permeability and can reduce infiltration unless preferential flow paths are opened by vertical desiccation cracks.

The deeper un-weathered aquifer that underlies the shallow weathered aquifer typically has a very low hydraulic conductivity where the bedrock matrix is intact. The effective hydraulic conductivity is determined by the presence of fractures, however fractures may be poorly connected resulting in significant local variations in yield.

The infiltration of water from the shallow weathered to the deeper fractured bedrock aquifer system (vertical leakage) is strongly heterogeneous and requires permeable soils and interconnected fracture systems which act as conduits.

Lateral groundwater flow in the shallow aquifer, is typically driven by topographic gradients.

5.2 AQUIFER TYPE

An extract of the Hydrogeological Map for the Area is presented in Figure 5-2. Table 5-1 presents the details of the principal groundwater occurrence in the project area as presented on the figure.

TABLE 5-1: ESTIMATED YIELDS BASED ON HYDROGEOLOGICAL MAP FOR THE PROJECT AREA

Farm	Lithology	Matrix	Yield (L/s)
Grootkuil	**Mafic / ultra mafic intrusive rocks:** dolerite, diabase, diorite, gabbro, dunite, pyroxenite, norite, anorthosite, hornblendite, carbonatite	Intergranular and Fractured	0.5 – 2.0

5.3 AQUIFER CLASSIFICATION

In terms of the Aquifer Classification Map of South Africa (Conrad *et al*, 1999), the Siyanda project area is classified as a **minor aquifer region,** which implies a moderately-yielding aquifer system of variable water quality.

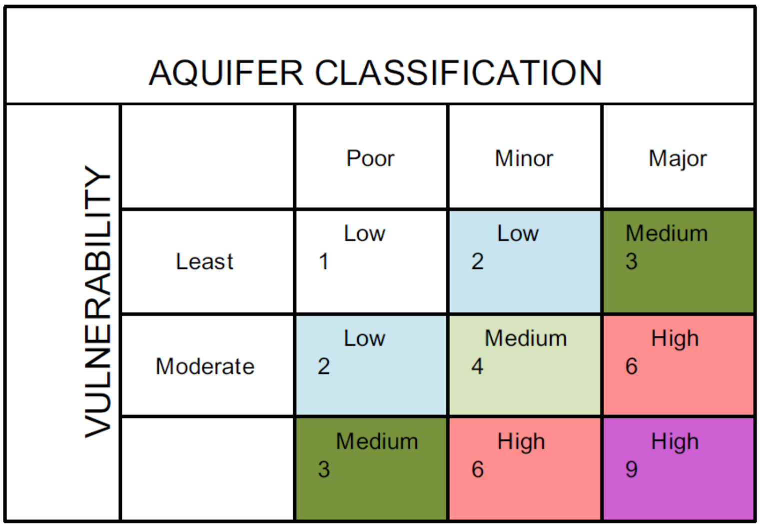
Although borehole yields in the deeper aquifer are generally considered low, structural features such as faults and fractures can produce higher yielding boreholes.

5.4 AQUIFER VULNERABILITY

The Aquifer Vulnerability Map of South Africa (Conrad et al. 1999c) indicates the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer. Based on the map, the Siyanda project area is a ‘least vulnerable area’ that is only vulnerable to conservative pollutants in the long term when continuously discharged or leached.

5.5 AQUIFER SUSCEPTIBILITY

The Aquifer Susceptibility Map of South Africa (Conrad *et al*, 1999b), indicates the qualitative measure of the relative ease with which a groundwater body can be potentially contaminated by anthropogenic activities and includes both aquifer vulnerability and the relative importance of the aquifer in terms of its classification. The map indicates that the Siyanda project area (minor aquifer with least vulnerability) has ‘low’ susceptibility as presented in Figure 5-1 below.



AQUIFER CLASSIFICATION				
VULNERABILITY		Poor	Minor	Major
	Least	Low 1	Low 2	Medium 3
	Moderate	Low 2	Medium 4	High 6
		Medium 3	High 6	High 9

FIGURE 5-1: AQUIFER SUSCEPTIBILITY MATRIX

5.6 GROUNDWATER QUALITY

The Groundwater Quality Map of South Africa (Conrad et al, 1999c), indicates that the groundwater within the project area is likely to have a slightly salty taste, with electrical conductivity concentrations of between 70 and 150 mS/m.

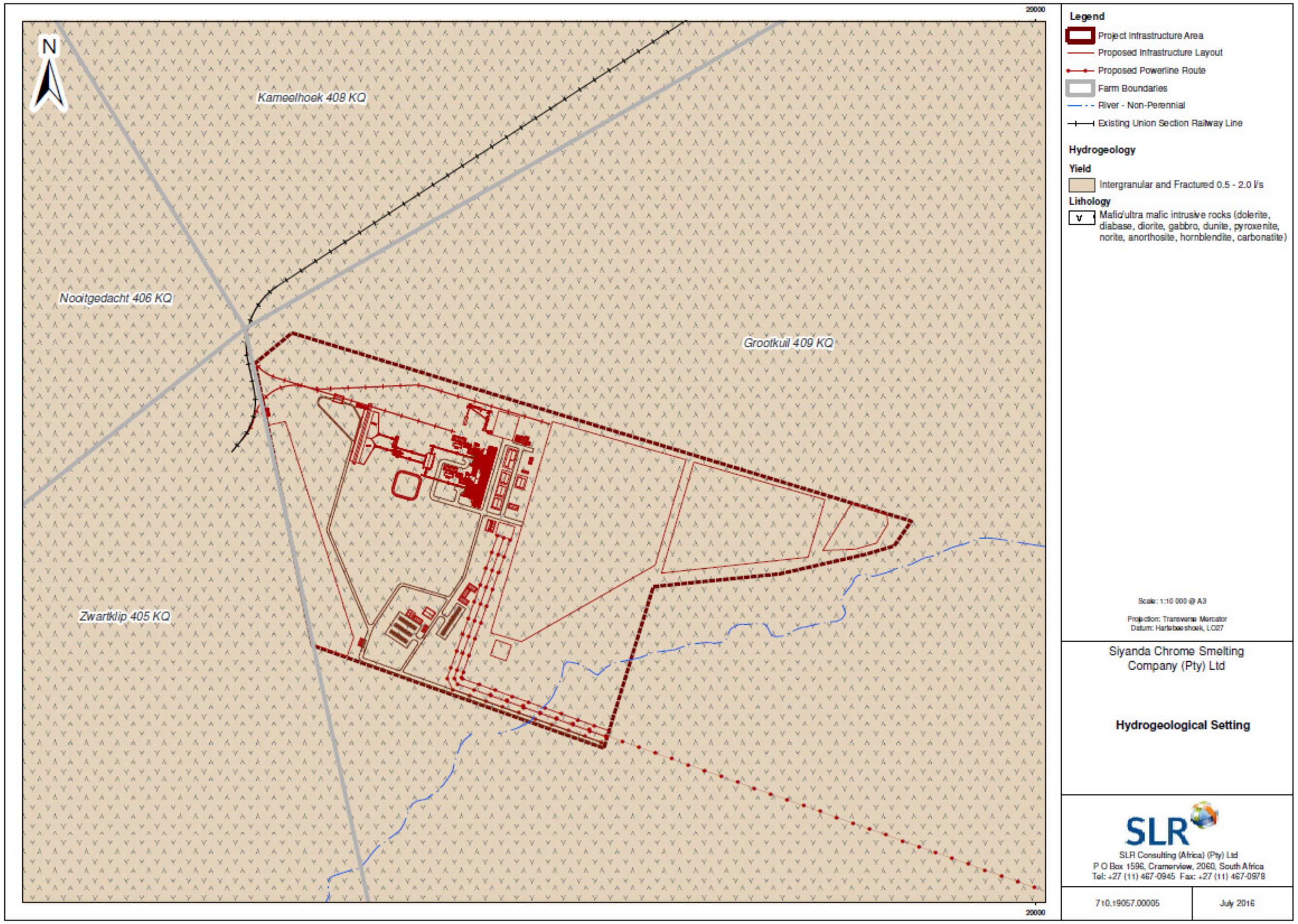


FIGURE 5-2: EXTRACT OF THE HYDROGEOLOGICAL MAP OF THE AREA

5.7 WATER USERS AND CURRENT WATER CONDITIONS

A hydrocensus was conducted by SLR Africa between 14th July 2015 and 6th August 2015. The time of the site work has negligible implications on the outcome of the assessment, although groundwater levels are likely to be at the lower end of the seasonal range given that the work was done mid-winter.

The objective of the hydrocensus was to identify groundwater and surface water users within a 5 km radius of the project area. Details such as depth of boreholes, water use and owners were recorded.

Groundwater levels were measured and groundwater samples collected for water quality purposes from selected locations.

Full details are provided in the Hydrocensus report (SLR, 2016b). Hydrocensus data are presented in Appendix B.

5.7.1 MONITORING POINTS

In total, sixteen (16) sites were visited; thirteen (13) groundwater monitoring points and three (3) surface water monitoring points. Details of the locations are presented in Table 5-2 (groundwater) and Table 5-3 (Surface Water).

Locations of all monitoring points visited during the hydrocensus are presented on Figure 5-3.

Key observations include:

- The depth of boreholes ranged from 10 m to over 100 m. Due to the geology of the area, boreholes and their yield are associated with fractures.
- Primary groundwater and surface water uses at identified sites include domestic use, drinking water for livestock (cattle / game).
- Surface watercourses and dams were dry during the hydrocensus. Surface watercourses in the area are ephemeral and flow only during times of rainfall.

TABLE 5-2: SUMMARY OF THE GROUNDWATER MONITORING POINTS FOR THE 2015 HYDROCENSUS

Borehole ID	Farm Name	Borehole Coordinates (WGS84)		Borehole Depth (m)	Borehole Status	Site Purpose	Water Application	Water Level Recorded	Water Sample Collected	Method
		Latitude	Longitude							
BH1	Grootkuil 3	-24.9357222	27.2147222	Obstruction at 10m	Not in use	Game farm	None	No	No	-
BH3	Grootkuil 3	-24.9336667	27.2125000	19	Not in use	Game farm	None	Yes	Yes	Pump
BH4	Grootkuil 3	-24.9306667	27.2036944	51	In use	Game farm	Livestock watering	Yes	Yes	Bailer
BH5	Grootkuil 3	-24.9329167	27.2180833	37	Not in use	Game farm	None	Yes	Yes	Bailer
BH6	Grootkuil 0	-24.9117222	27.2203888	130	Not in use	Farm	None	Yes	Yes	Bailer
BH7	Grootkuil 0	-24.9155278	27.2237500	>100	Not in use	Farm	None	Yes	Yes	Bailer
BH10	Grootkuil 4 (Union Section Mine)	-24.9315833	27.1821944	10	Not in use	Game farm	None	No	No	-
BH11	Nooitgedacht	-24.8923333	27.1516944	50	In use	Farm/guesthouse	Domestic	No	Yes	Tap – Jo-Jo
BH12	Wildebeestlagte	-24.9598333	27.2357222	60	In use	Game farm	Domestic	No	Yes	Tap
Johan Young BH1	Kameelhoek 3	-24.9071180	27.1720370	60	In use	Farm	Domestic, Livestock Watering	Yes	Yes	Tap in House
Johan Young BH2	Kameelhoek 3	-24.9068800	27.1687860	60	In use	Farm	Domestic, Livestock Watering	Yes	Yes	Tap in House
WM11	Union Section (Union Section Mine	-24.9402500	27.1785000	25	Not in use	Down-gradient of TSF on Union Section Mine	Monitoring only	Yes	Yes	Bailer
WM6	Union Section (Union Section Mine)	-24.9451111	27.1792777	27	Not in use	Down-gradient of TSF on Union Section Mine	Monitoring only	Yes	Yes	Bailer

TABLE 5-3: SUMMARY OF THE SURFACE WATER MONITORING POINTS FOR THE 2015 HYDROCENSUS

Monitoring Point ID	Farm Name	Borehole Coordinates (WGS84)		Source	Water Application	Flow Velocity	Water Sample Collected During Hydrocensus
		Latitude	Longitude				
SW1	Grootkuil 4	-24.9342500	27.17766666	Ephemeral stream / Weir	Weir from Union Section Mine	Dry	No
SW2	Grootkuil 0	-24.9237500	27.21511111	Small dam	Livestock Watering	Dry	No
SW3	Grootkuil 3	-24.9335556	27.21533333	Ephemeral stream	None	Dry	No

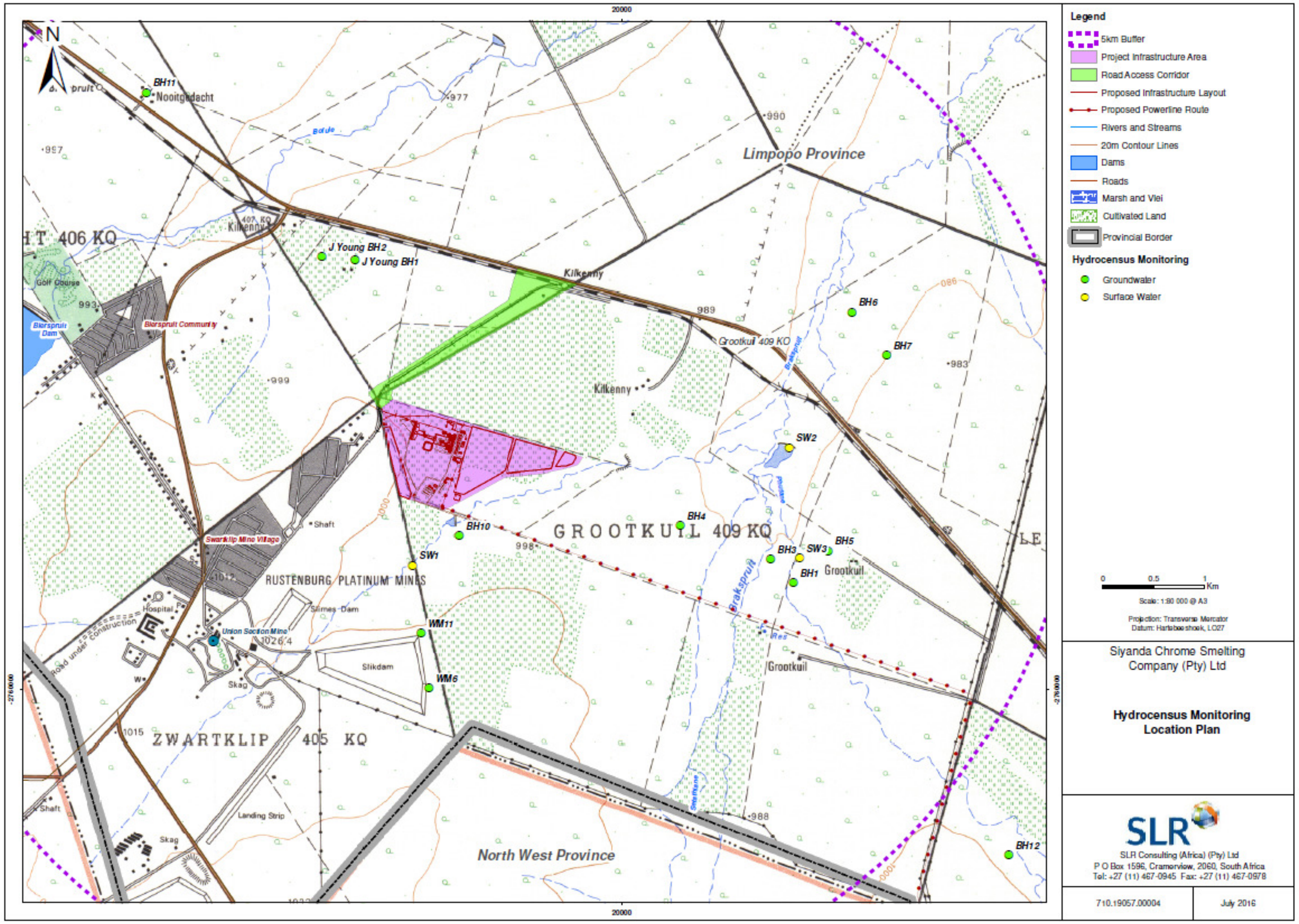


FIGURE 5-3: LOCATION OF HYDROCENSUS MONITORING LOCATIONS

5.7.2 GROUNDWATER LEVELS

A total of nine (9) water levels were recorded in boreholes, while the remaining water levels were unable to be measured due to the presence of installed pumps or other obstructions within the boreholes. Recorded groundwater levels ranged between 7.3 mbgl (WM11) and 19.4 mbgl (Johan Young BH1). Groundwater levels are presented in Table 5-4.

TABLE 5-4: GROUNDWATER LEVELS RECORDED DURING THE HYDROCENSUS

Borehole ID	Borehole Depth (m)	Water Level (mbgl)	Groundwater Elevation (mamsl)
BH1	10.00*	Borehole obstructed at 10.00m	
BH3	19.00	13.31	978.19
BH4	51.00	13.65	979.38
BH5	37.00	18.70	971.94
BH6	>100	12.87	967.12
BH7	>100	18.41	963.26
BH10	10.00	DRY	
BH11	~50.00	Inaccessible for water level measurements	
BH12	~60.00	Inaccessible for water level measurements	
WM11	25.00	7.31	996.73
WM6	27.00	11.78	995.80
J Young BH1	60.00	19.40	967.46
J Young BH2	60.00	13.80	972.64

Note: *blocked at 10m. True depth of borehole unknown

5.7.3 GROUNDWATER QUALITY

Groundwater sampling was performed at eleven (11) of the boreholes visited by SLR. Sampled boreholes were selected based on location, in order to gather a spread of data across the area.

Sampling was undertaken in accordance with the Water Research Commission's (WRC) Groundwater Sampling Report (Weaver, et al, 2007).

Samples were submitted to an accredited laboratory for analysis of general and inorganic parameters. The hydrocensus results suggest that groundwater and surface water in the area is predominantly used for domestic purposes (including drinking) and livestock watering. Therefore the water quality results were compared against the following guidelines:

- South African National Standards (SANS: 241 (2015)) Water Quality Standards.
- Department of Water Affairs (DWAF) (now Department of Water and Sanitation [DWS]) Target Water Quality Range (TWQR) for Livestock Watering (2009).

The SANS 241: 2015 specifies limits in terms of four categories:

- Acute Health – poses an immediate unacceptable health risk if present at concentrations exceeding the numerical limits specified.
- Aesthetics – does not pose an unacceptable health risk if present at concentrations exceeding the numerical limits specified, but will taint water with respect to taste, odour and colour.
- Chronic Health – poses an unacceptable health risk if ingested over an extended period if present at concentrations exceeding the numerical limits specified.
- Operational – is essential for assessing the efficient operation of treatment systems and risks to infrastructure.

The DWAF TWQR for Livestock Watering refers to a 'No Effect Range'. This is the range of concentrations at which the presence of each constituent would have no known or anticipated adverse effects on the suitability of water for livestock watering. These ranges were determined by assuming long-term continuous use (lifelong exposure) and incorporate a margin of safety.

Significant findings with regards to water quality include:

- Concentrations of the majority of elements were low and recorded at concentrations below relevant water quality standards.
- Concentrations of arsenic (As), iron (Fe), manganese (Mn), sodium (Na), nickel (Ni), electrical conductivity (EC), total dissolved solids (TDS), chloride (Cl), sulphate (SO_4) and ammonia (NH_4-N) were reported at concentrations in excess of one of the stipulated water quality standards in at least one sample and considered chemicals of concern (CoCs).
- Concentrations of EC, TDS, Cl and SO_4 are all elevated in three (3) boreholes; MW6 and WM11, located adjacent to the Union Section Mine and Johan Young BH1. The elevated concentrations in MW6 and WM11, could at first be considered to be a result of the seepage from the TSF, however similar concentration, albeit lower for all the aforementioned parameters, are recorded in Johan Young BH1 which is used for domestic purposes without any treatment of filtering which indicates that for some boreholes, groundwater is naturally enriched, and is most likely to be due to the geology.
- Through discussions with Johan Young, the taste of the water from his two boreholes are very different. The two boreholes are located approximately 300m away from each other and drilled to approximately the same depth of 60 m. The water quality results show a difference for key parameters as presented in Table 5-5.
- A piper diagram showing the different water facies for each ample is presented in Figure 5-4.

TABLE 5-5: COMPARISON OF KEY PARAMETERS IN WATER FROM JOHAN YOUNG'S BH1 AND BH2

Parameter	Johan Young BH1	Johan Young BH2
pH	8	8.5
Calcium (mg/L)	43	3
Potassium (mg/L)	2.8	1.1
Magnesium (mg/L)	327	146
Sodium (mg/L)	177	31
Electrical Conductivity (mS/m)	323	104
Total Dissolved Solids (mg/L)	2116	628
Total Alkalinity as $CaCO_3$ (mg/L)	464	600
Chloride (mg/L)	681	34
Sulphate (mg/L)	382	15

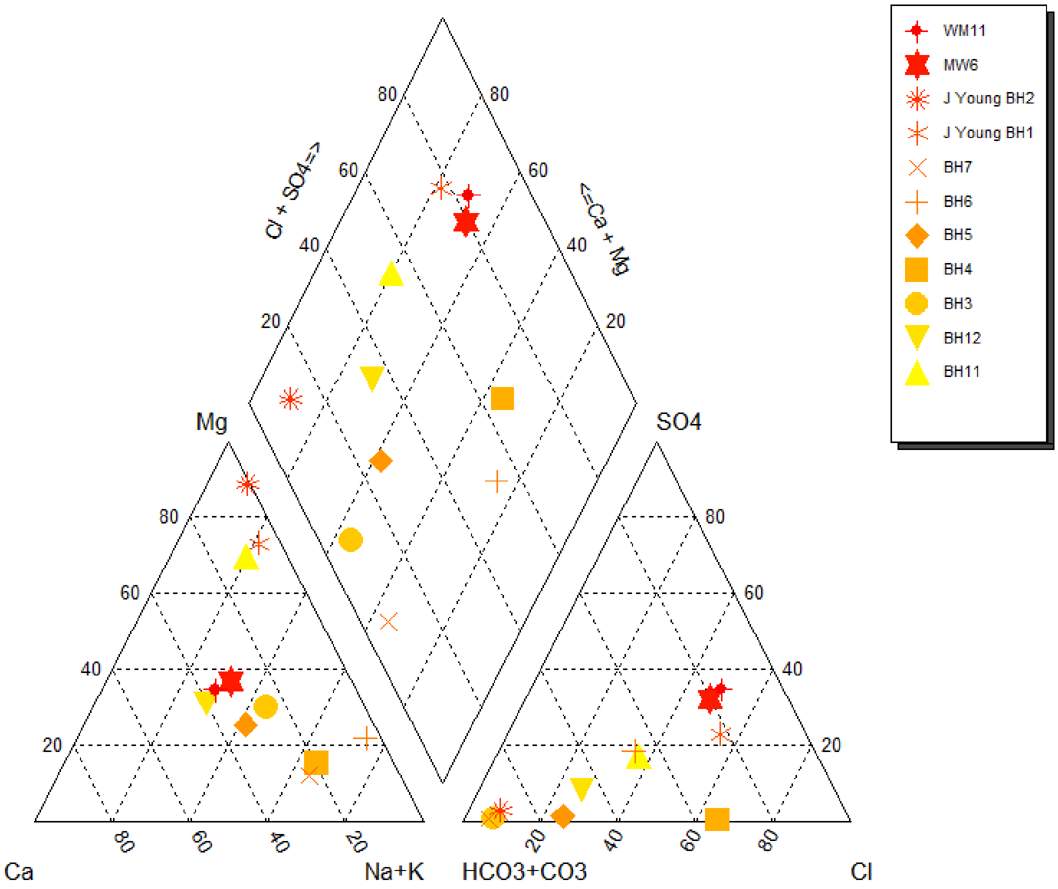


FIGURE 5-4: PIPER DIAGRAM FOR THE SIYANDA HYDROCENSUS GROUNDWATER SAMPLES

5.8 DRILLING CAMPAIGN

It was proposed that boreholes would be drilled within the Siyanda Project Area; to penetrate the shallow weathered zone and the deeper fractured bedrock aquifer.

5.8.1 BOREHOLE SITING

A geophysical survey was undertaken by VSA Leboa Consulting (Pty) Limited (VSA) on 8th and 9th July 2015.

The objectives of the geophysics was to determine geological features of hydraulic significance such as fracture zones, igneous dykes or areas of particularly deep weathering and to assist in final determination of drilling locations.

VSA undertook six (6) traverses over the project area. Resistivity (EM-34) and magnetic techniques were used. Geophysical traverse graphs are presented in Appendix C.

Based on the geophysical survey results and the site layout, three (3) proposed drilling locations were selected.

5.8.2 DRILLING CAMPAIGN

Drilling was undertaken by Water Worx Consulting (Pty) Limited (Water Worx), subcontracted through VSA over the period 28th July 2015 to 31st July 2015. Work was supervised by an SLR hydrogeologist.

The site work was undertaken at this time due to dry winter conditions. The soil type in the area (black turf) restricts access with vehicles when the ground is wet. The time of the site investigation has no implications on the outcome of the overall assessment, although groundwater levels are likely to be at their lowest.

A total of five (5) boreholes were drilled using rotary air percussion with foam. Details of the boreholes are provided in Table 5-6 and their locations are presented in Figure 5-5. Borehole logs and penetration rates are presented in Appendix D.

The boreholes were typically drilled to six inch (165 mm) diameter to total depth. In the case of unstable upper-formation, the hole was drilled at eight inch (203 mm) diameter until stable formation was encountered and steel casing installed to this depth.

Slotted casing was installed at targeted intervals in the casing string depending on the nature and location of water strikes. Gravel pack consisting of clean rounded silica gravel (3-5 mm size), was installed in the annulus along the length of, and extending above, the screened interval. Bentonite and grout mix was installed on top of the gravel pack, to surface.

Following completion of the borehole, airlifting was carried out to develop the boreholes and remove sediment remaining from the drilling process.

A cement block was cast around the top of the casing. A cap was fitted to the top of casing to prevent the ingress of foreign material into the boreholes. The caps were marked clearly with the borehole identification (ID).

TABLE 5-6: SUMMARY OF BOREHOLES DRILLED FOR SIYANDA PROJECT

Borehole ID	**SIY-BH01S**	**SIY-BH01D**	**SIY-BH02S**	**SIY-BH02D**	**SIY-BH03**
Latitude	-24.926063	-24.92609	-24.92745	-24.927444	-24.9204
Longitude	27.187590	27.18756	27.18443	27.18434	27.17774
Drilled Date	31st July 2015	28th July 2015	31st July 2015	28th July 2015	30th July 2015
Borehole Depth (mbgl)	12	60	18	50	60
General Geology	Weathered Magnetite Gabbro	Magnetite Gabbro	Weathered Gabbro Norite	Gabbro Norite	Gabbro Norite
Water Strike (mbgl)	None	None	12 (fracture) 15 (fracture)	11 (fracture) 14 (fracture) 16 (fracture)	34 (fracture)
Static Water Level (mbgl)	Dry	32	6	6	18
Blow Yield (L/s)	-	None	0.9 1.9	0.7 0.4 1.1	0.3
Plain Casing (mbgl)	0-6	0-12	0-6	0-24	0-30
Slotted Casing (mbgl)	6-12	-	6-18	-	30-36
Open Hole (mbgl)	-	12-60	-	24-50	36-60

Key information obtained through drilling:

- Weathered unit extends from surface to between 9m and 13m.
- Borehole SIY-BH01 (shallow and deep) was the only borehole to extend through magnetite rich gabbro.
- Boreholes SIY-BH02 (shallow and deep) and BH03 extended only through Gabbro Norite. It is noted that the geological map suggested that both of these borehole are on magnetite rich gabbro. It is likely that boreholes are on the contact of the two lithologies.
- Even though the water strike in boreholes SIY-BH02 were shallow, water strikes are typically associated with fractures.

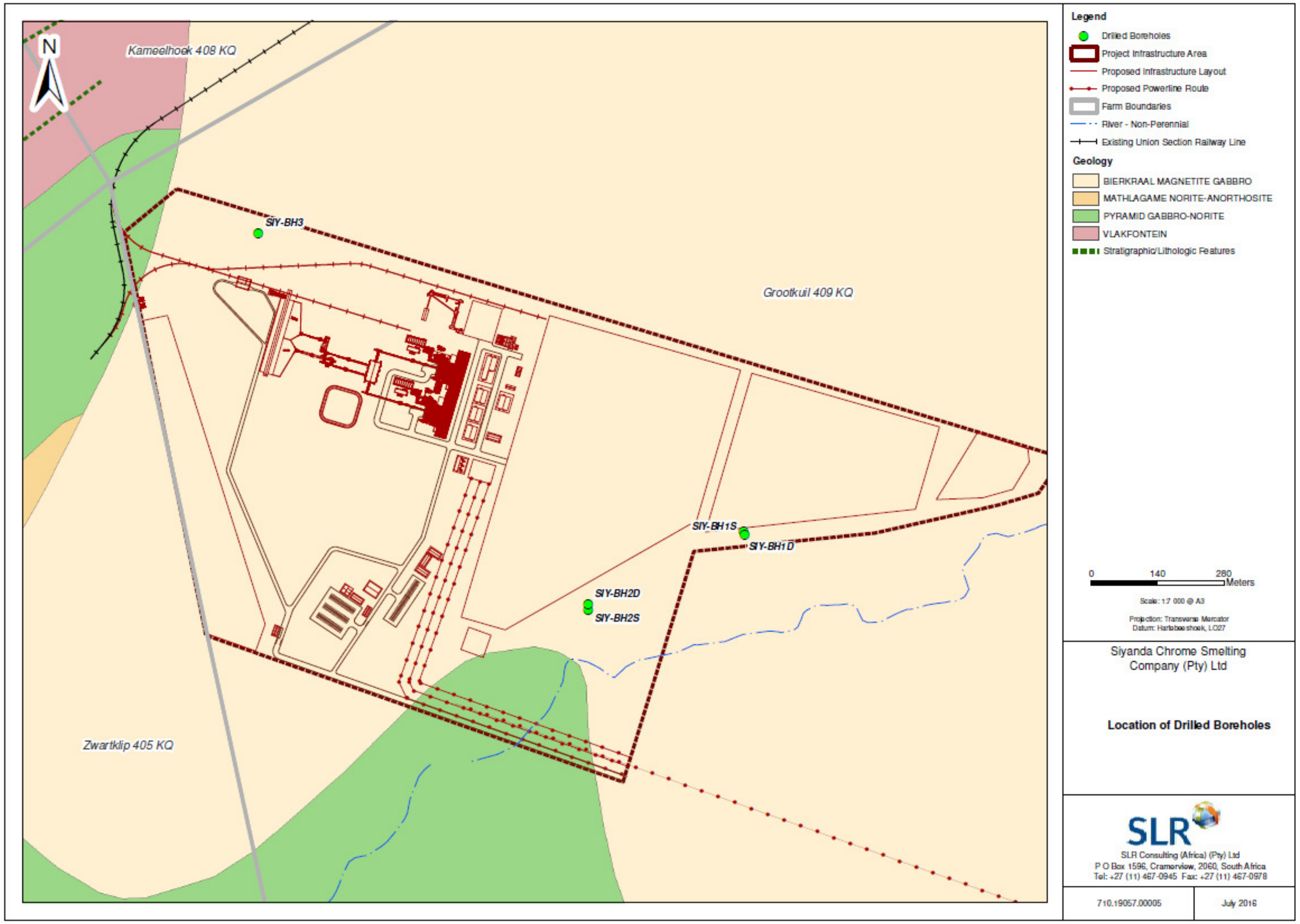


FIGURE 5-5: LOCATION OF THE FIVE BOREHOLES DRILLED AT SIYANDA

5.9 HYDRAULIC TESTING

The hydraulic testing was undertaken by VSA Leboa Consulting (Pty) Limited (“VSA”) on 5th and 6th of August 2015. The testing was partially supervised by an SLR Hydrogeologist.

Hydraulic testing was performed in borehole SIY-BH02-S. Borehole SIY-BH02-D was used as an observation borehole, although due to the construction of the borehole, drawdown in this borehole was not expected.

5.9.1 STEP DRAWDOWN TEST

A step drawdown test (SDT) was initially performed to determine a suitable pumping rate for the constant discharge rate. In accordance with SANS 10299-4:2003 - Test Pumping of Water Wells, four steps were performed, each of an hour length and progressively higher discharge rates. The pumping rate for each step was based on the blow yield determined during the drilling and the performance of the previous step. Details are provided in Table 5-7.

Water levels in the pumped borehole and observation borehole were monitored using both a pressure transducer and manually using an electrical dip tape at predetermined times. The discharge rate was measured at regular intervals using the drum-and-stopwatch method.

At the end of the last step, the pump was shut down and the recovery of the groundwater levels monitored until the initial water level had been reached.

The resulting drawdown in the pumped borehole is presented in Table 5-7. Pumping test data is presented in Appendix E.

TABLE 5-7: SUMMARY OF STEP DRAWDOWN PUMPING TEST DETAILS

Borehole ID	Depth of Borehole (mbgl)	Groundwater Strike (mbgl)	Static Water Level (mbgl)	Depth of Pump (mbgl)	Step Test No.	Test Duration (min)	Average Pump Rate (L/s)	Drawdown (m)
SIY-BH2S	18.00	9.00	5.31	15.00	1	60	0.45	0.16
					2	60	1.50	0.42
					3	60	3.00	0.58
					4	60	6.50	2.22

5.9.2 CONSTANT DISCHARGE TEST

A 24 hour constant discharge test (CDT) was undertaken in borehole SIY-BH-02S following the SDT. The pumping rate for the CDT was determined from the SDT.

Water levels in the pumped borehole and observation borehole were monitored using both a pressure transducer and manually using an electrical dip tape at regular intervals. The discharge rate was measured at regular intervals using the drum-and-stopwatch method.

At the end of the CDT, the pump was shut down and the recovery of the groundwater levels monitored until of the initial water level had been reached.

5.9.3 PUMP TEST RESULTS

The pump test data were analysed a using Aqtesolve (Figure 5-6), specific software for determining hydraulic parameters of an aquifer.

The data was solved using Cooper Jacob method and suggests a confined double porosity aquifer, which is characterised by both linear flow in the beginning of the test followed by bilinear flow at a later stage of the test.

The transmissivity of the aquifer was calculated to be 80 m^2/day.

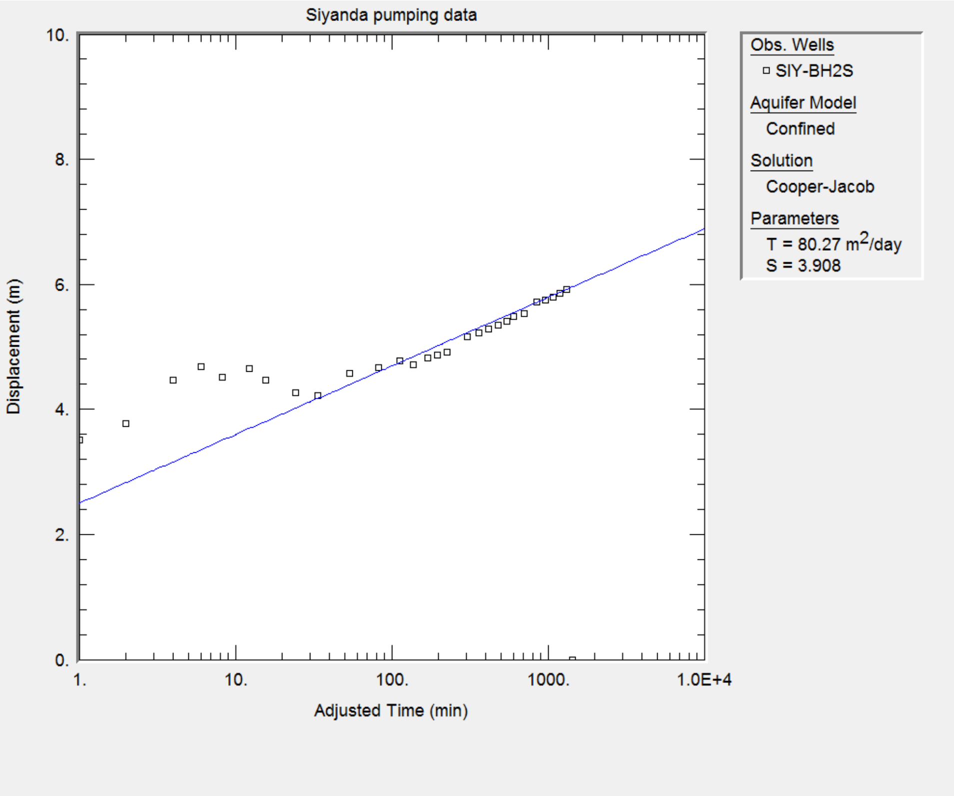


FIGURE 5-6: SIYANDA PUMPING TEST DATA RESULTS

5.9.4 GROUNDWATER SAMPLING

Towards the end of the constant discharge test a water sample was taken for quality purposes.

Sampling was undertaken in accordance with the WRC Groundwater Sampling Report (Weaver, et al, 2007). Full results are provided in Appendix F.

Samples were submitted to an accredited laboratory for analysis of general and inorganic parameters. The water quality results were compared against the SANS: 241 (2015) Water Quality Standards and the DWAF Target Water Quality Range (TWQR) for Livestock Watering (2009).

Significant findings include:

- Concentrations of the majority of elements were low and recorded at concentrations below relevant water quality standards.
- Concentrations of sodium (Na), electrical conductivity (EC), total dissolved solids (TDS), chloride (Cl) and sulphate (SO_4) were reported at concentrations in excess of one of the stipulated water quality standards in at least one sample and considered chemicals of concern (CoCs).
- The results are consistent with samples collected during the hydrocensus.

6 CONCEPTUAL SITE MODEL

A conceptual site model (CSM) can be defined as a "representation of a real system" (Fetter, 2001). It can be used as a tool to assist with the assessment of impacts and the management of potential sources of pollution and is used as a base for the groundwater numerical model.

The hydrogeological CSM developed for Siyanda, based on the available information, is presented in Figure 6-1.

Key aspects are:

- A weathered unit exists from surface to approximately 13 m irrespective of geology (magnetite gabbro and pyramid gabbro norite.
- Shallow groundwater can occur in the weathered unit (groundwater was encountered at shallow depths within borehole SIY-BH02), but predominantly associated with fractures and geological contacts.
- Yields are in the range of 0.2 L/s to 5 L/s.

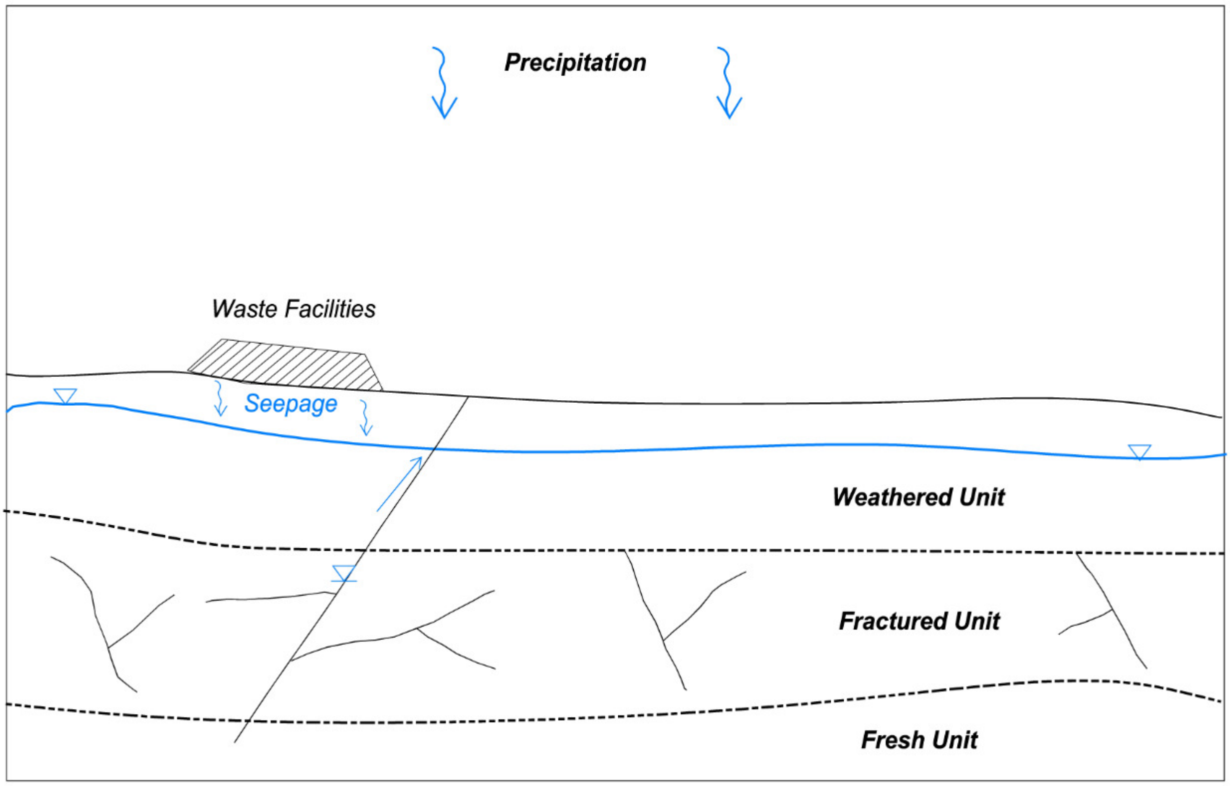


FIGURE 6-1: SIYANDA HYDROGEOLOGICAL CONCEPTUAL SITE MODEL (CSM)

7 GROUNDWATER NUMERICAL MODEL

To assess the potential impact of the Siyanda waste disposal facilities on the local groundwater system, SLR developed a numerical groundwater flow model to simulate the possible contaminant transport.

7.1 MODELLING CODE SELECTION

The groundwater flow model constructed for this investigation utilised the numerical code *FEFLOW* developed by DHI-WASY, that solves three-dimensional ground-water flow problems using the finite-element method.

FEFLOW is a widely used, commercially available groundwater numerical code and is fully suitable for the Siyanda numerical simulations of the hydrogeology.

The numerical code selection has been made in terms of suitability to provide the answers required from the groundwater model:

- Determine the distribution of hydraulic heads during and post-operation, and in response to groundwater abstraction for water supply.
- Predict the extent and magnitude of a possible contaminant plume from the slag and baghouse dust facility during and post-operation.

The model domain is split into 3-dimensional triangular prisms, constituting the 3D finite elements containing the material (hydraulic) properties. The elements are connected to each other at corners – constituting nodes, where the hydraulic heads are assigned and flow equations are calculated for each node during the model run.

7.2 MODELLING DOMAIN AND BOUNDARY CONDITIONS

The selection of a groundwater model domain is usually done based on the larger catchment areas, presence of hydrographic features and known geological features and their hydraulic behaviour.

In the case of Siyanda Project, the model domain was selected purely on catchment areas and divides between the catchments, and in such a way that the boundaries are sufficiently far to avoid any boundary condition interference with the groundwater flow in the project area, considered in the groundwater model as a stress component. The model domain is shown in Figure 7-1, together with the main elements incorporated into the groundwater model.

The boundary conditions of the Siyanda Groundwater Model are set as following (Figure 7-1):

1) No-flow boundaries:

a. A **no-flow boundary** considers that no fluid exchange (in- or out- the groundwater system) takes place along this section of the model boundaries. The no-flow boundary was selected at the southern, eastern and northern sides of the model domain, along the lines of high elevations representing watershed lines;
b. **Specified head boundaries** consider that fluid exchange occurs along in- and out- the model domain, in such a way that the hydraulic head boundaries are maintained at their initial values.
    1. External boundaries: along the low elevation river on the western side of the model domain boundaries.
    2. Internal boundaries included in the groundwater domain are set along the rivers included in the model domain.

7.3 MODEL SET-UP AND DISCRETIZATION

The development of the model consisted of discretising the model domain into individual elements for which changes would be computed during simulations, setting of boundary conditions, and calibration. These are described in the following sections.

7.3.1 HYDROGEOLOGICAL UNITS

The framework for the 3D numerical simulations consists of the geology present in the Siyanda Project. Figure 7-2 shows the simplified geological units incorporated.

The main hydrogeological units derived from the simplified geology map are:

- Weathered zone (upper aquifer).
- Fresh intact basement rocks (lower aquifer).

These will be discussed later in the model construction section.

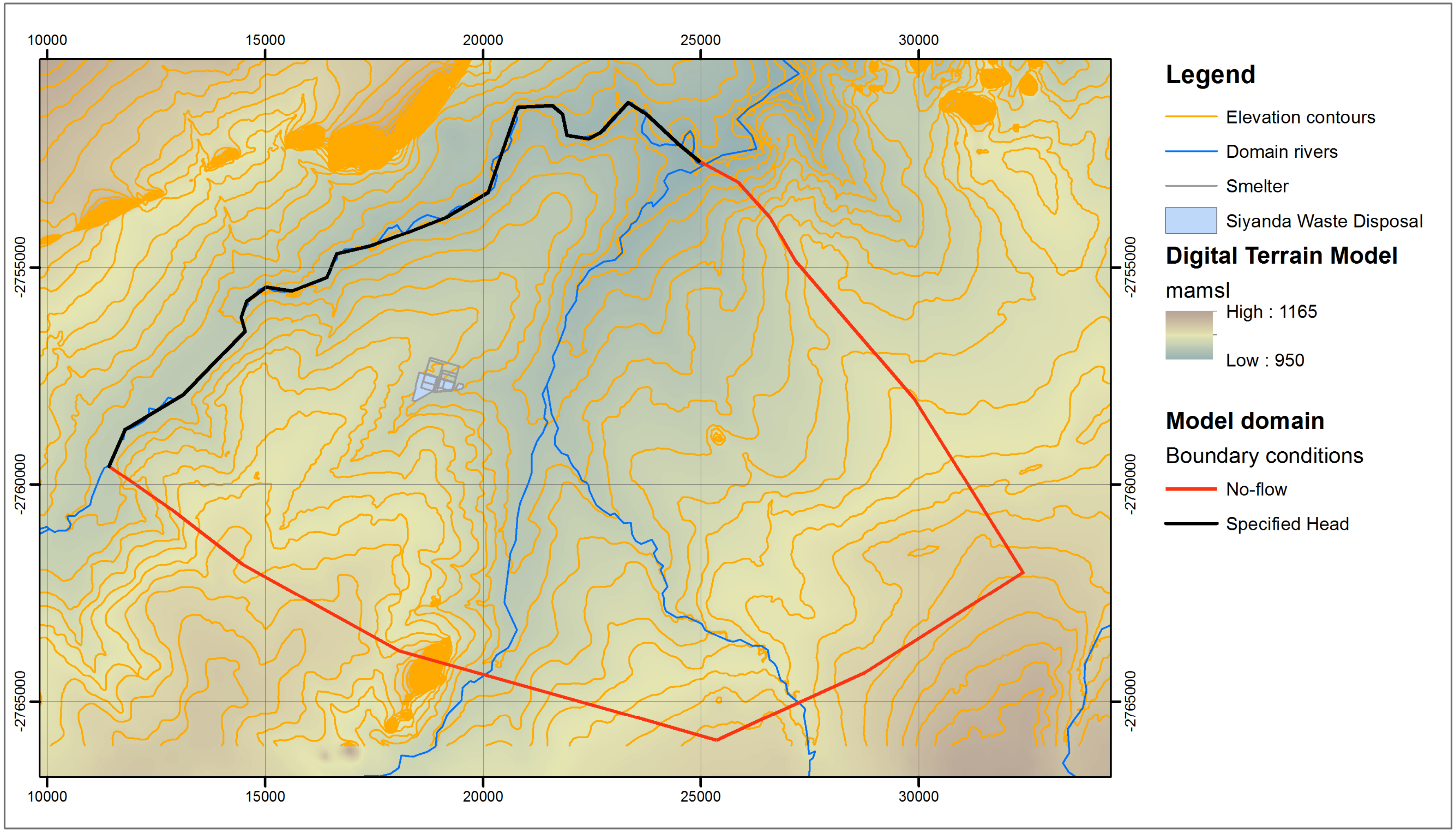


FIGURE 7-1: SIYANDA MODEL DOMAIN

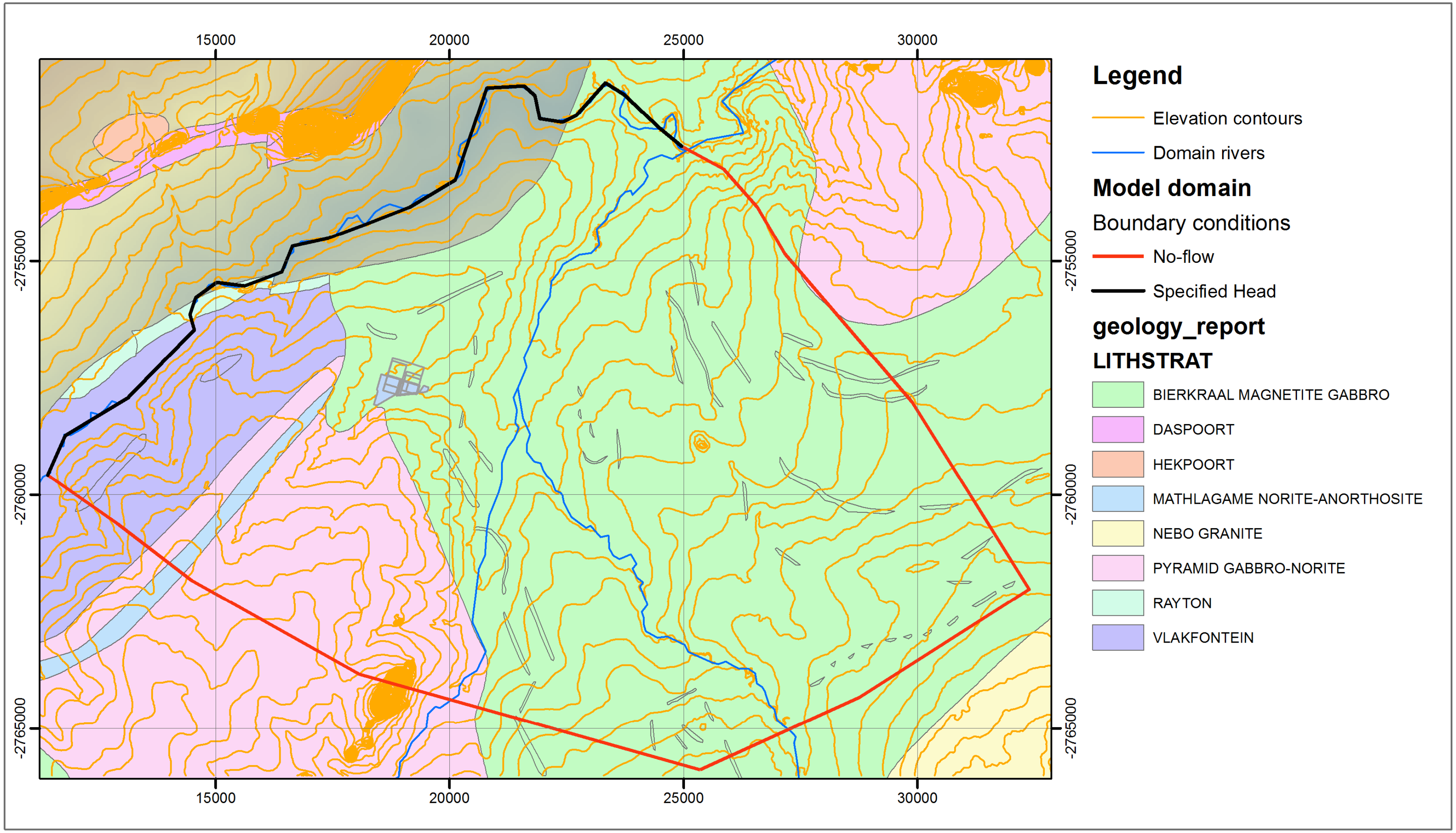


FIGURE 7-2: GEOLOGY OF SIYANDA PROJECT

7.3.2 HORIZONTAL DISCRETIZATION

The horizontal discretization was achieved taking into consideration the following elements:

- The stratigraphy within the model domain (hydrogeological units).
- The footprint of the disposal facilities.
- The positions of groundwater and hydrocensus boreholes.

The horizontal discretization is achieved by a mesh definition to contour the boundaries of the required mining elements.

All surface facilities are critical components for the groundwater impact assessment, and therefore the model will have to account for these. Although these elements will be simulated during the predictive simulation stage of the model, provisions must be made for these during the model setup phase, for both horizontal and vertical dimensions.

Figure 7-3 shows the horizontal discretization of the Siyanda model domain. The elements sizes within the Siyanda model vary from 200m at the edge (boundaries) of the model to 10m elements in the focus areas where better hydraulic resolution is required. The model is finely refined in waste disposal areas (areas of hydraulic and geochemical stresses), and less refined outside the stress areas.

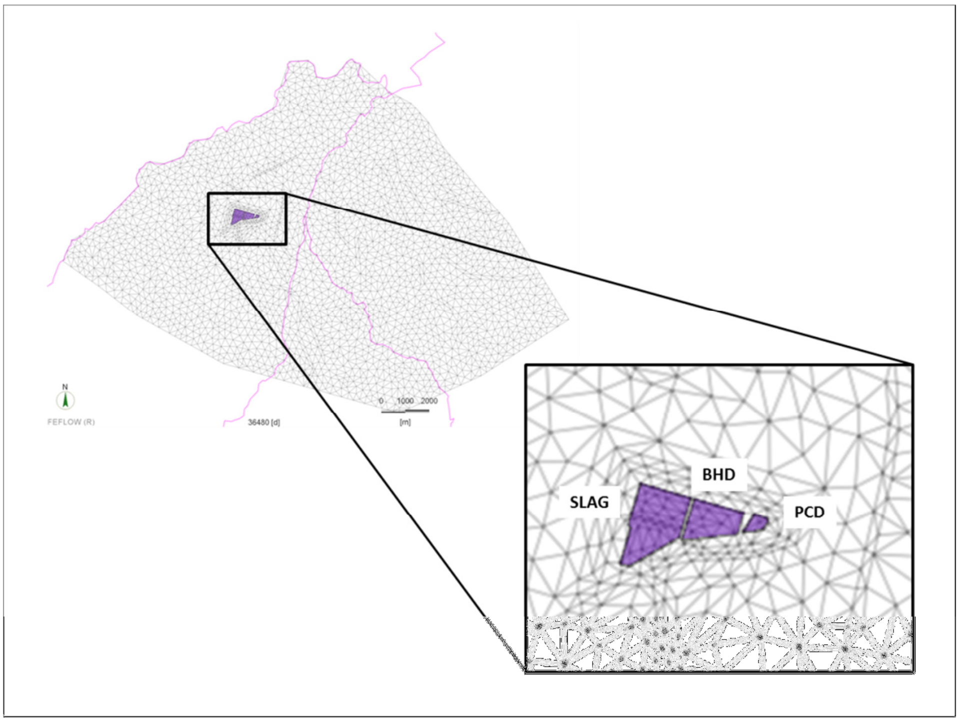


FIGURE 7-3: SIYANDA MODEL - HORIZONTAL DISCRETIZATION

7.3.3 VERTICAL DISCRETIZATION

The stratigraphy and hydrogeological units constitute the two major components which determine the vertical discretization for the Siyanda groundwater model.

The stratigraphy will be represented as zones of different hydraulic properties on the various layers inside the model domain, in such a way that it represents best the local geology and hydro-stratigraphic units.

The vertical layering of the model was achieved by splitting the 3D model into five vertical layers to represent the geology, weathering and additional layers to avoid errors related to the no-flow boundary condition at the bottom of the 3D numerical model, as shown in Figure 7-4.

Table 7-1 details the model layers considered for the Siyanda groundwater model.

TABLE 7-1: SIYANDA MODEL - VERTICAL LAYERS

Surface	Layer Name	Thickness (m)
1	Top soil	0.5 – 1
2	Weathered	20 - 25
3	Fresh1	50
4	Fresh2	100
5	Fresh3 (bottom)	200

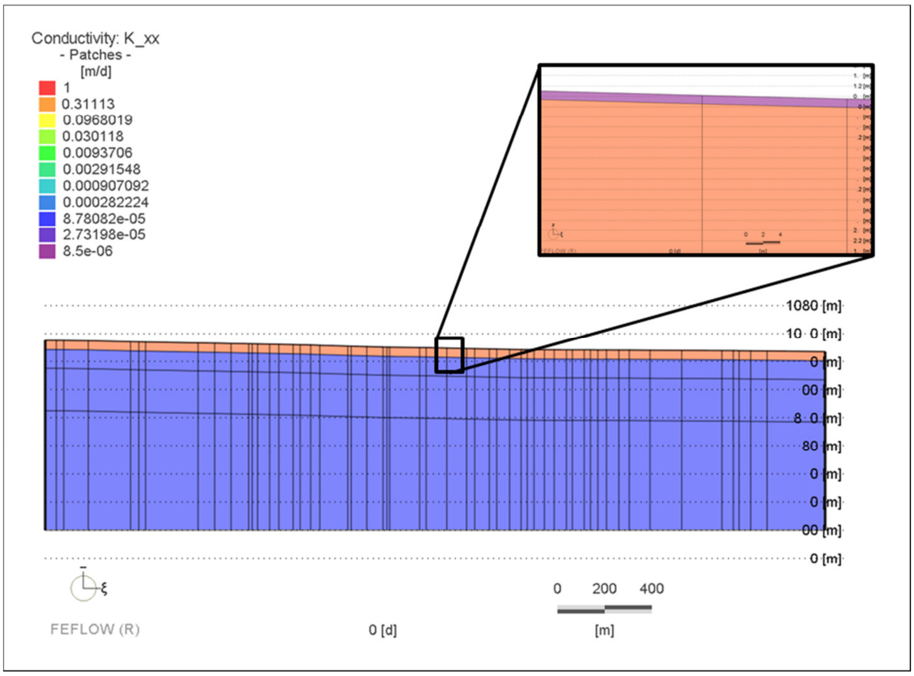


FIGURE 7-4: SIYANDA MODEL - VERTICAL DISCRETIZATION

The resulting 3-dimensional finite element grid for the Siyanda 3D numerical groundwater model contains:

- 25,320 elements, and
- 15,666 nodes.

7.3.4 TIME DISCRETIZATION – TIME SERIES

The Siyanda groundwater model is susceptible to changes occurring in time. These have an influence on groundwater quality.

To realize a reasonable time discretization, the model was setup to run as transient flow and transport at constant time steps.

The simulation period was selected to include both waste deposition for a period of 20 years, and post-waste deposition for a further period of 80 years.

The time step was defined to 1 month; this is considered in the model code as a constant 30.4 days per month.

7.4 GROUNDWATER MODEL INITIALS

7.4.1 GROUNDWATER RECHARGE

The groundwater recharge represents a percentage of the rainfall which will reach and contribute to the fluid mass balance within the model domain. The average annual rainfall value is 571 mm/yr.

The initial groundwater recharge values for the Siyanda steady-state calibration run was assigned at 1% of MAP which equals to the value of 1.6 x 10^{-5} m/d.

Transient values for recharge at monthly time-steps will be determined after the steady-state calibration.

7.4.2 HYDRAULIC HEAD

The initial hydraulic head distribution over the whole groundwater model domain was computed based on a combination of several measurements during the hydrocensus, water levels measurements from the drilled boreholes and the general difference between the measured water levels and the topography.

The initial groundwater levels (pre-calibration) are shown in Figure 7-5.

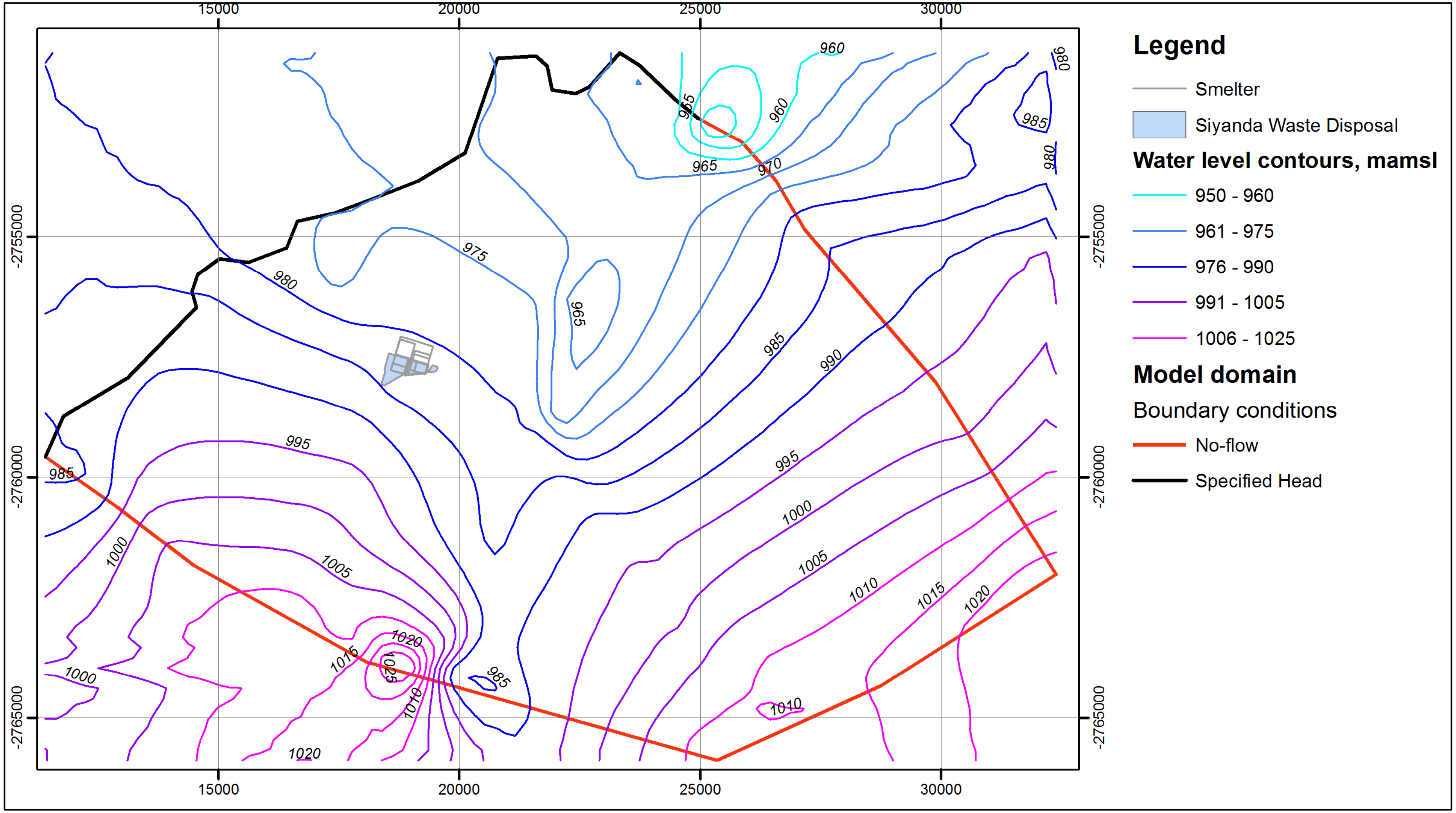


FIGURE 7-5: SIYANDA - INITIAL GROUNDWATER LEVELS

7.4.3 HYDRAULIC PROPERTIES

The initial hydraulic properties for the Siyanda groundwater numerical model are shown in Table 7-2.

TABLE 7-2: SIYANDA - INITIAL HYDRAULIC PROPERTIES

Surface	Layer	Layer Name	K_h [m/d]	K_v [m/d]
1	Top soil	0.5 – 1	Variable	Variable
2	Weathered	20 - 25	0.01	0.005
3	Fresh1	50	0.001	0.001
4	Fresh2	100	0.0003	0.0003
5	Fresh3 (bottom)	200	0.0005	0.0005

The initial hydraulic properties for the model, together with the initial hydraulic heads represent the start of the calibration process.

7.5 MODEL CALIBRATION

The calibration of a groundwater model consists in comparing the measured water levels and the water levels computed during the calibration run. The initial steady-state calibration of the Siyanda groundwater model was run using the initial hydraulic properties assigned together with the hydraulic head values and average groundwater recharge values computed from the average rainfall data throughout the model domain.

The first step in the calibration process was the run of the *PEST* (parameter estimation) routine on the Siyanda model.

The second step was to run the PEST model in steady-state model, until suitable calibration is obtained. Table 7-3 shows the comparison between the steady-state computed hydraulic head vs. the measured hydraulic head for the observation boreholes considered.

The differences between the measured hydraulic head and computed hydraulic head are very small, and the calibration was considered satisfactory. The Residual Mean Square Error (RMSE) and Normalized Residual Mean Square Error (NRMSE), which represent the quantitative measure of the model calibration are within the prescribe groundwater modelling guidelines (ASTM).

TABLE 7-3: SIYANDA - STEADY-STATE CALIBRATION FOR HYDRAULIC HEAD

Obs. Point	Observed Value	Predicted Value	Difference
Johan Young BH2	975.00	975.05	-0.05
Johan Young BH1	971.00	974.66	-3.66
SIY-BH03	983.00	982.75	0.25
WM11	994.00	993.02	0.98

Obs. Point	Observed Value	Predicted Value	Difference
WM6	995.00	994.92	0.08
SIY-BH02D	983.00	984.12	-1.12
BH3	967.00	970.50	-3.50
BH6	961.00	964.30	-3.30
BH7	960.00	963.56	-3.56
RMSE			2.39
NRMSE			6.84%

7.6 TRANSIENT SIMULATION

The objective of the transient simulation was to identify and determine the extent of any possible contaminant which could migrate from the 3 identified waste disposal areas at Siyanda: slag deposition facility (Slag), bag house dust deposition facility (BHD) and also from the pollution control dam (PCD).

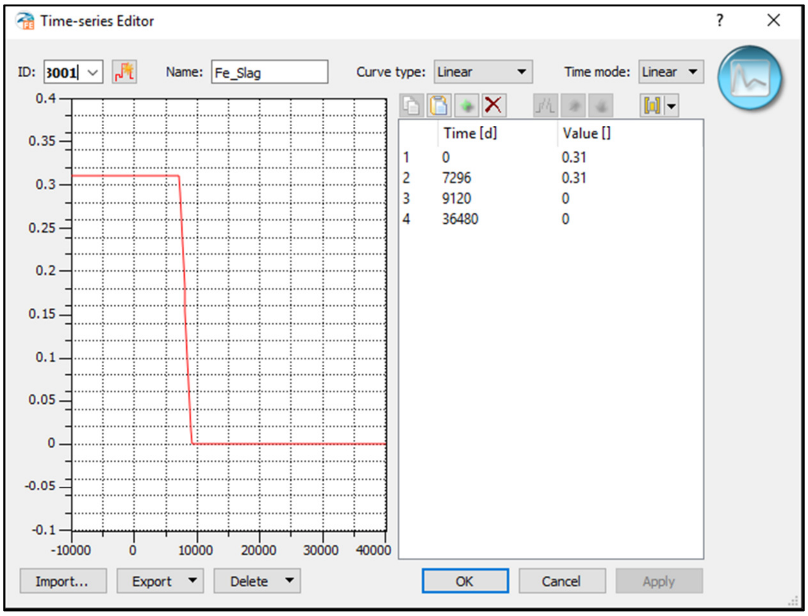
7.6.1 SOURCE TERM

The source term is characterised by seepage quality and seepage rates which may or may not reach the groundwater in the source term areas.

The source term concentration considered for the Siyanda Project was determined through a geochemical assessment (SLR, 2016c). As informed by the geochemical assessment, the main contaminant exceeding the prescribed groundwater quality limits and identified as per the water contact quality statement was iron (Fe).

This was used in the mass transport simulation as a mass concentration boundary condition at following concentrations:

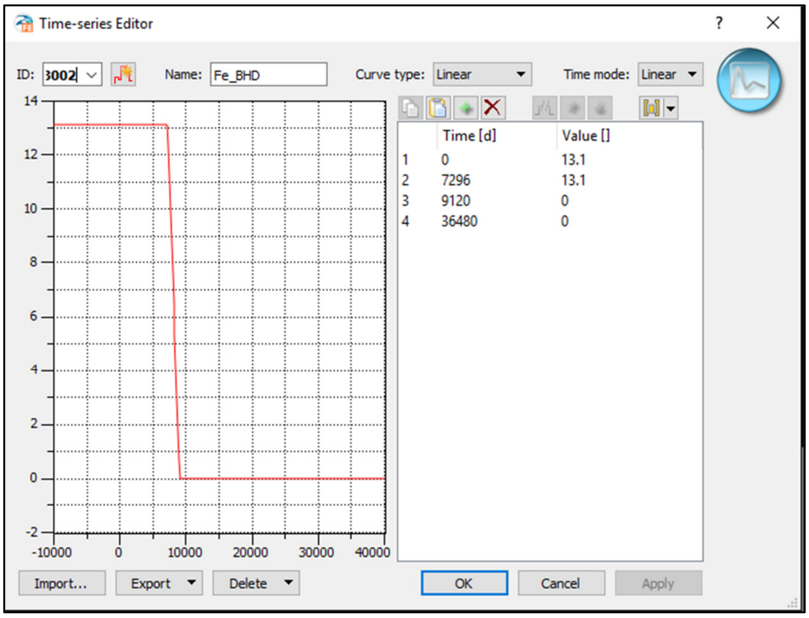
- Slag: 0.31mg/l (Figure 7-6).
- BHD: 13.1 mg/l (Figure 7-7).
- PCD: 13.1 mg/l – maximum concentration derived from the Slag and BHD source term (Figure 7-7).



ID: 3001 Name: Fe_Slag Curve type: Linear Time mode: Linear

	Time [d]	Value []
1	0	0.31
2	7296	0.31
3	9120	0
4	36480	0

FIGURE 7-6: FE CONCENTRATION APPLIED TO SLAG



ID: 3002 Name: Fe_BHD Curve type: Linear Time mode: Linear

	Time [d]	Value []
1	0	13.1
2	7296	13.1
3	9120	0
4	36480	0

FIGURE 7-7: FE CONCENTRATION APPLIED TO BHD (AND PCD)

Other contaminants were negligible and/or within the prescribed limits.

The main assumption is that the three facilities will be associated with the following liner permeability. It should be noted that this is a conservative approach given that the slag disposal facility will have a Class C liner system and the BHD and PCD facilities will have Class A liner systems:

- Slag: permeability of 10^{-9} m/s.

- BHD: permeability of 10^{-9} m/s.
- PCD: permeability of $10\ x^{-9}$ m/s.

The groundwater model incorporates this as concentration boundary condition on the Slag, BHD and PCD for a period of 20 years. After that, until the end of the simulation, the concentration boundary condition is removed, allowing the contaminant transport model to determine the evolution of the contaminant plume with the residual Fe present at year 20.

The recharge applied for the storage facilities area was $10\ x^{-10}$ m/s.

7.6.2 SIMULATIONS RESULTS

The following figures (Figure 7-8 to 7-12) illustrate the extent of the Fe contaminant plume at same time steps used to illustrate the hydraulic heads and cone of drawdown:

- Year 1: Figure 7-8.
- Year 10: Figure 7-9.
- Year 20: Figure 7-10.
- Year 50: Figure 7-11.
- Year 100: Figure 7-12.

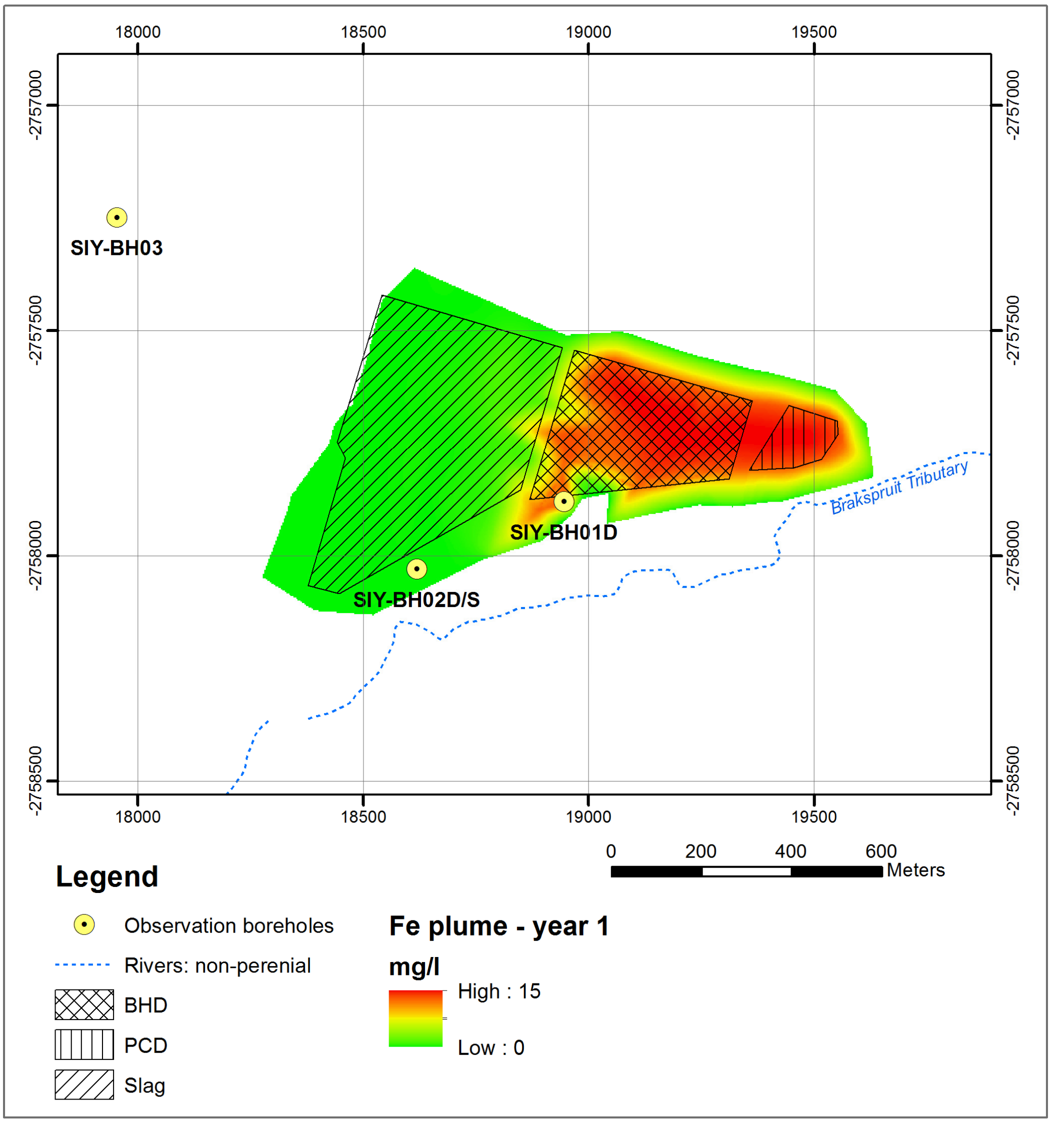


FIGURE 7-8: SIYANDA - FE PLUME: YEAR 1

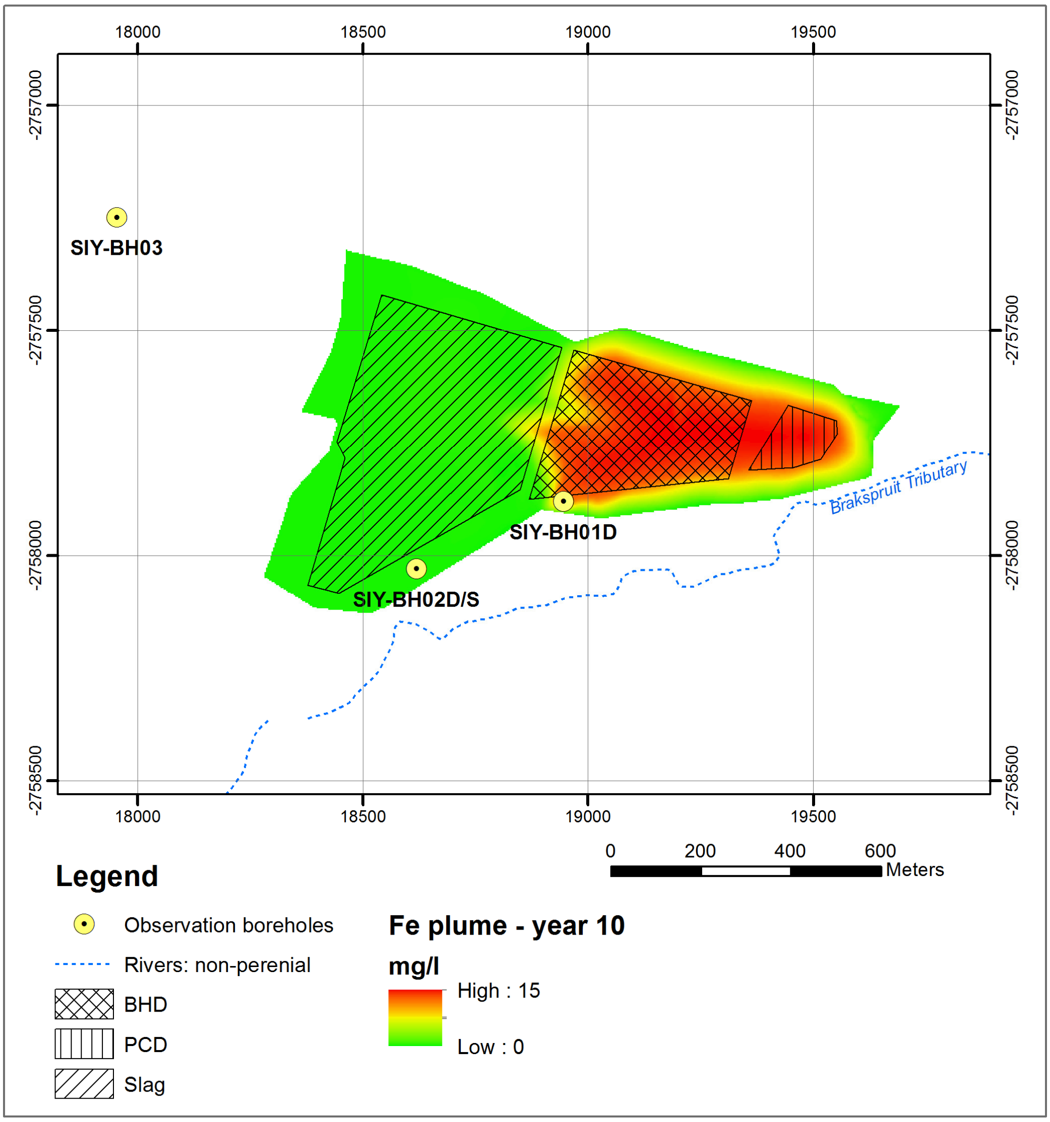


FIGURE 7-9: SIYANDA - FE PLUME: YEAR 10

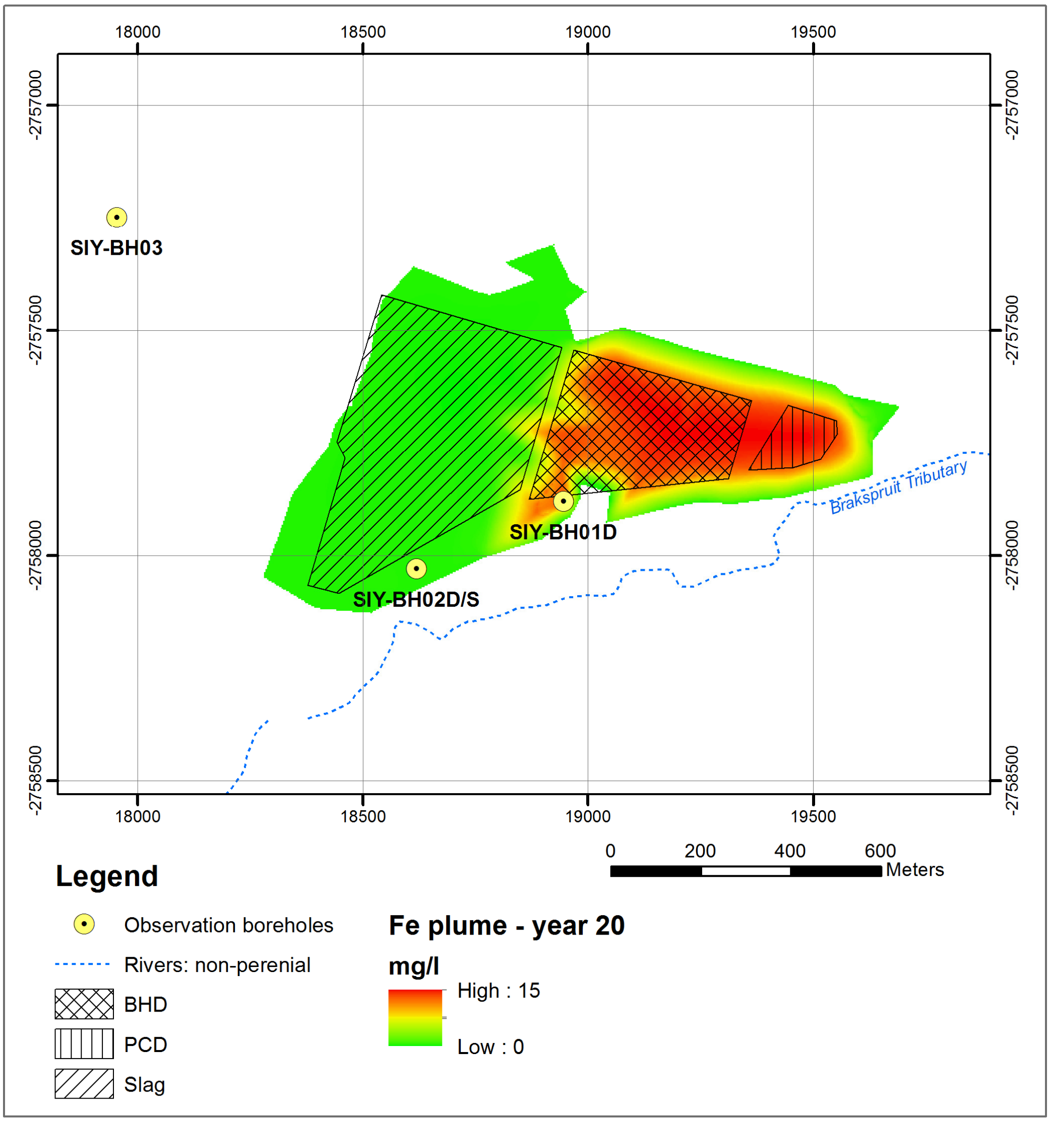


FIGURE 7-10: SIYANDA - FE PLUME: YEAR 20

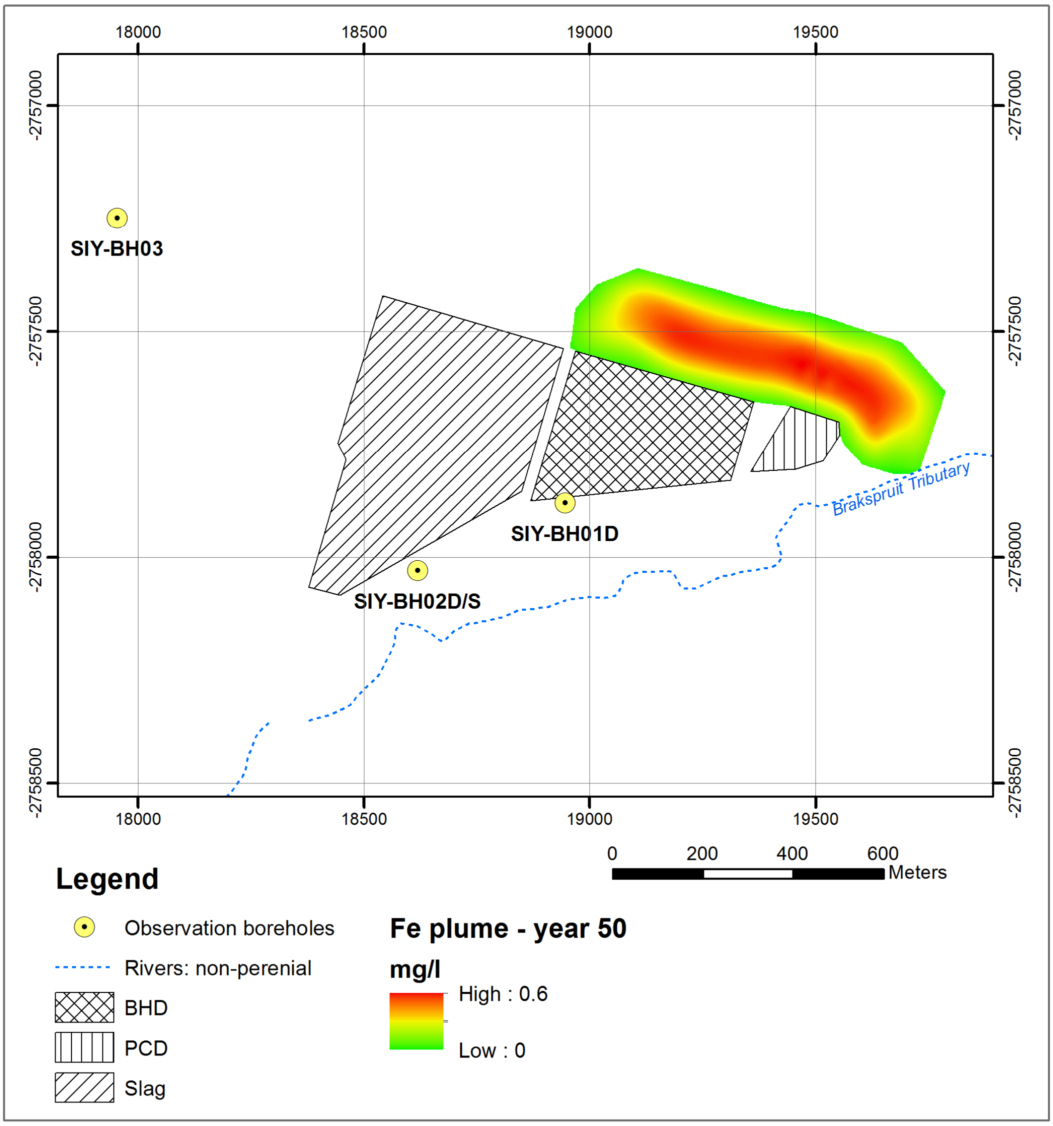


FIGURE 7-11: SIYANDA - FE PLUME: YEAR 50

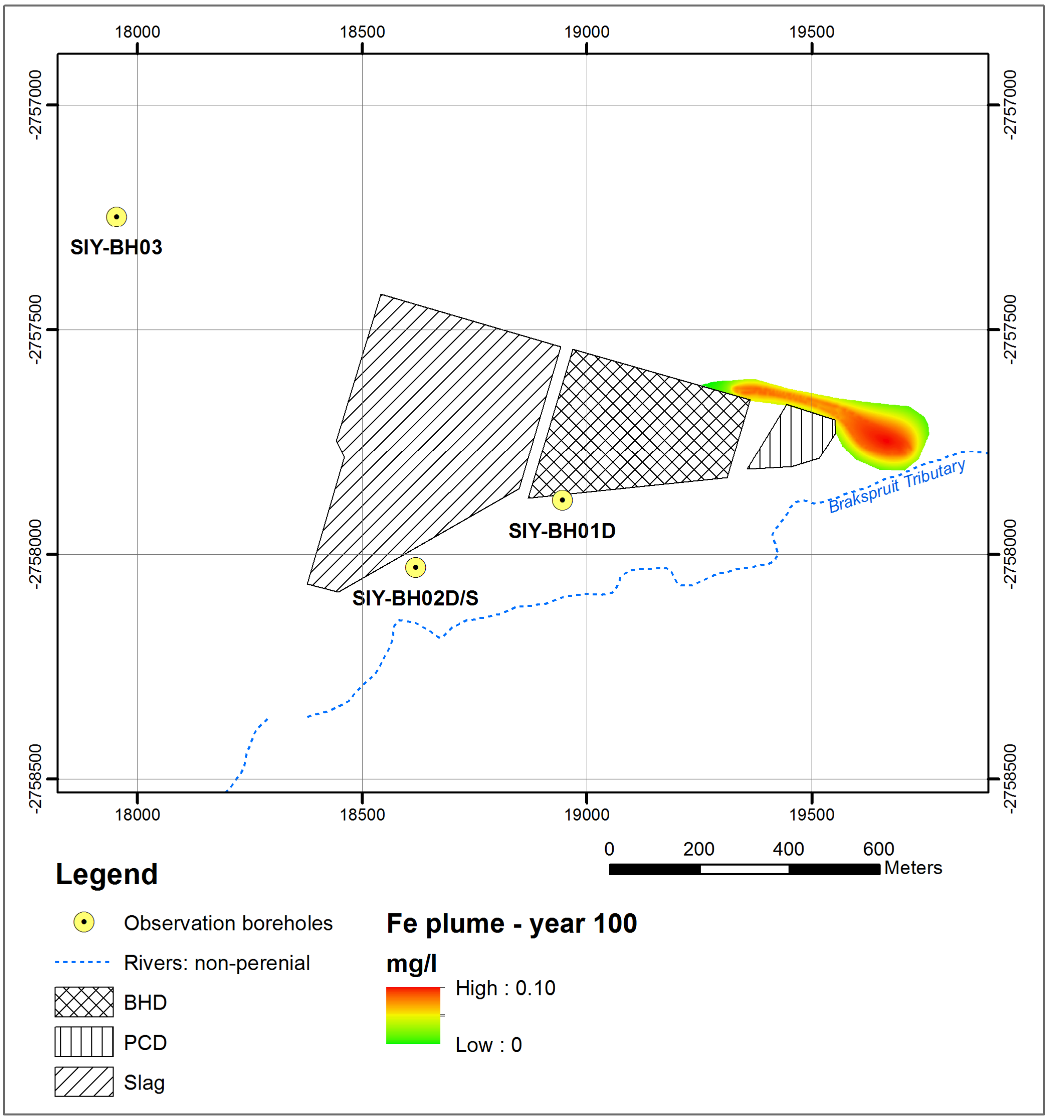


FIGURE 7-12: SIYANDA - FE PLUME: YEAR 100

7.6.3 GROUNDWATER SUPPLY

Water will be required for both potable and process requirements. The operational phase water requirements are expected to be 86m^3/day (potable water) and 133m^3/day (process water).

It is not expected that the proposed project will be water intensive. It is expected that SCSC will reuse water in its circuit and source make up water from the municipal supply scheme. SCSC is also considering using water from one on-site borehole however this will be for emergency backup purposes only.

At this stage of the groundwater model, the water supply from groundwater boreholes was simulated from one borehole only, SIY-BH-02S, with following conditions:

- Pumping rates: 3 L/s.
- Pumping duration: 12 hrs/day.
- Recovery duration: 12 hrs/day.
- Pump depth: 15 mbgl.
- Simulation period for groundwater abstraction: 20 years.

Simulation of pumping with a pumping rate of 3 L/s, from SIY-BH-02S, for a period of 12 hrs/day followed by a period of recovery for 12 hrs/day, does not have any impact on the groundwater levels. This was expected due to:

- The borehole is pumped at a lower rate than it's potential (5 L/s).
- The water levels are allowed to recover for a period equal with the pumping period.
- These recommendations take into account the safe operation of the borehole in such a way that it preserves the groundwater reserves in the weathered aquifer.

It should however be noted that abstraction from this borehole will be done only in emergency instances where municipal water is not available.

7.7 MODELLING CONCLUSIONS

After the predictive simulations run for Siyanda Project, the following conclusions can be drawn:

1. Groundwater Levels

The project will have negligible impact on the groundwater regime. The only abstraction point (SIY-BH-02S) simulated at a pumping rate of 3 L/s for a period of 12 hrs/day will not impact in any way on the groundwater levels.

If additional boreholes will be drilled and used for groundwater abstraction, then an update of the groundwater model must be run.to include the new boreholes.

2. Contaminant Flow

The Fe contaminant plume migrates towards North-North East following the general groundwater flow direction.

The simulated iron concentrations migrate from the storage facilities as per Table 7-4.

TABLE 7-4: MIGRATION OF FE PLUME

Source concentration, Fe, mg/l	Year	Plume migration (up to 0 mg/l concentration)	Max. plume concentration, Fe, mg/l
Slag: 0.31 BHD: 13.1 PCD: 13.1	1	126m	13.1
Slag: 0.31 BHD: 13.1 PCD: 13.1	10	142m	13.1
Slag: 0.31 BHD: 13.1 PCD: 13.1	20	211m	13.1
-	50	239m	0.6
-	100	216m	0.1

Although the plume shows an increased distance vs. time, it must be noted that the Fe concentrations show a decreasing trend in time, after the termination of the sources (20 years).

One important assumption in the source term estimation was that the PCD facility will have the same seepage concentrations as the highest concentration determined for the Slag and BHD. However, this is an overestimation of the source term in the PCD. The scenario simulated therefore represents a worst case scenario.

Figure 7-13 shows a safety buffer at 0 mg/l limit concentration around the maximum extent for the contaminant plumes developed during time. SLR recommends that no domestic groundwater water supply borehole be drilled within the buffer zone.

Groundwater quality must be monitored regularly within the buffer zone.

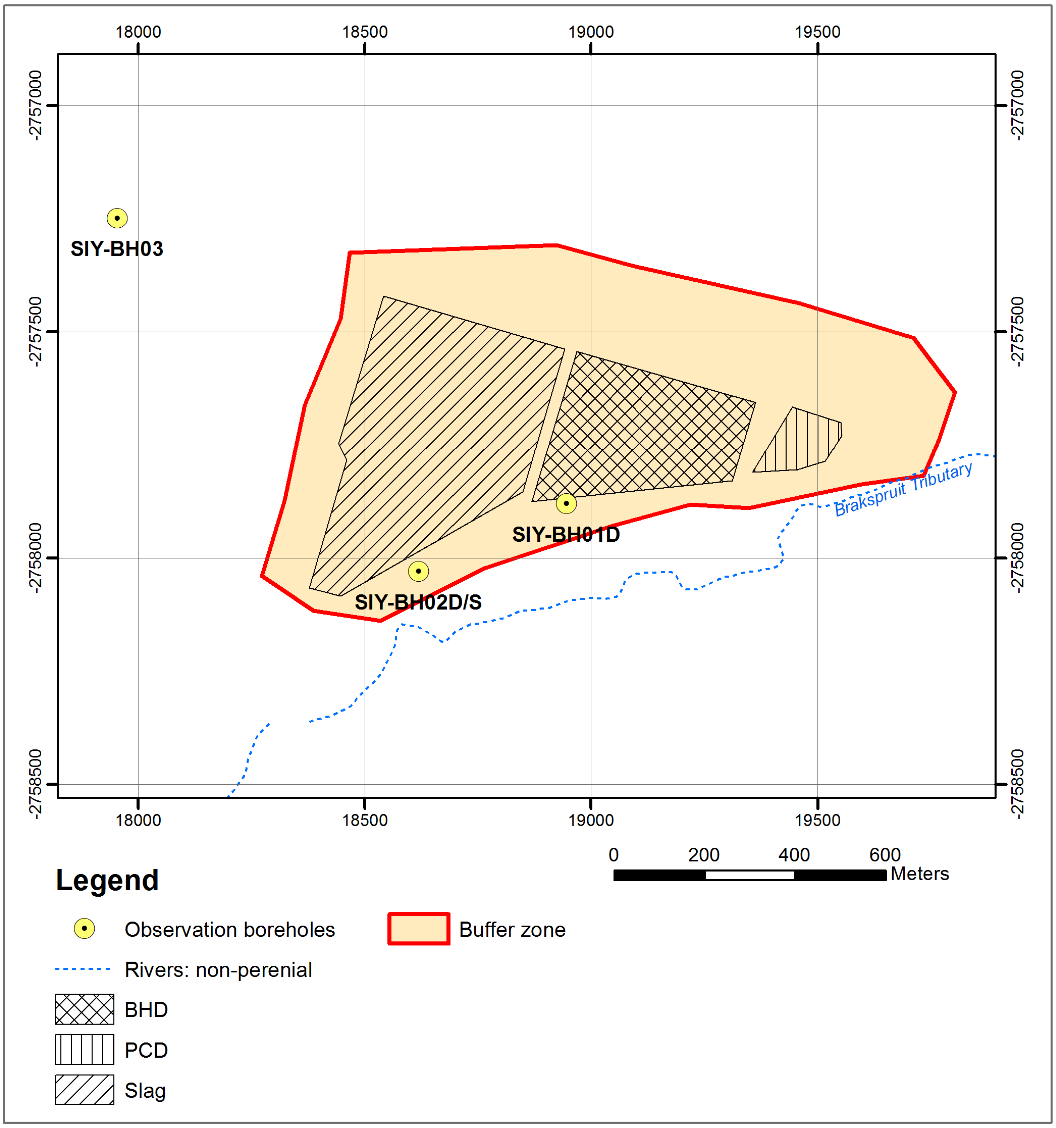


FIGURE 7-13: SIYANDA - PROTECTION ZONE

3. Water Abstraction

Groundwater may be abstracted from SIY-BH-02S for industrial purposes only.

8 GROUNDWATER IMPACT ASSESSMENT

Based on the work undertaken, the proposed development at Siyanda will have the following potential impacts:

- Reduction of groundwater levels and availability through abstraction of groundwater.
- Potential for impairment of groundwater and surface water quality as a result of contamination associated with the two waste facilities (slag and baghouse dust).

Predictive simulations were run using the calibrated numerical groundwater model. The simulation results indicate the potential impact of groundwater abstraction for water supply and contaminant transport scenarios.

The impacts on groundwater have been assessed in terms of possible impacts on groundwater users during three stages of development: construction, operation and closure.

Table 8-1 presents a summary of the possible unmitigated potential impacts, and Table 8-2 presents a summary of the possible mitigated potential impacts, as discussed in detail below.

8.1 REDUCTION OF GROUNDWATER LEVELS AND AVAILABILITY

The possible abstraction of water from an on-site borehole for the use as potable and/or process water has the potential to cause a lowering of groundwater levels in the construction, operation and decommissioning phases. Lowering of groundwater levels through abstraction may cause a loss in water supply to third party borehole users if they are in the impact zone and may impact base flow of the Brakspruit tributary .

It is important to note that potable and process make-up water for the proposed project will be sourced from the municipal supply scheme, and provision for potential abstraction from an on-site borehole has been made only in case of emergencies when municipal supply is not available and the water within the existing circuit is insufficient. The impacts associated with a reduction in groundwater levels have been assessed to cater for such emergency instances.

8.1.1 RATING OF IMPACT

Severity

Based on the results of the groundwater study which simulated abstraction from borehole SIY-BH02S at a sustainable pumping rate of 3 L/s for a period of 12 hrs/day, it is not expected that there be any impact on the groundwater levels. It follows that there is also not expected to be any impact on base flow of the Brakspruit tributary as a result of borehole abstraction. It must be noted that this is not only because of the limited impact of abstraction but also because of the fact that the tributary only runs after periods of rainfall. Without mitigation (i.e. exceeding the pumping plan), no impacts on third party users or the base flow of the Brakspruit tributary is expected albeit that the cone of depression would be marginally greater than in the mitigated scenario.

The severity in the unmitigated scenario is medium, reducing to low with mitigation.

Duration / Reversibility

The duration of the impacts is linked to the duration of the abstraction and the recharge time thereafter. It is expected that the duration of abstraction activities (with mitigation) will recover daily and given that water levels will not be affected (i.e. that aquifer recovery time is not applicable) this is a short duration with mitigation. In the unmitigated scenario, if the recommended pumping plan is not followed, the recovery time would be expected to be longer, thereby implying a medium duration.

Spatial scale / Extent

The spatial scale is medium without mitigation, reducing to low with mitigation.

Consequence

In the unmitigated scenario, the consequence is medium, reducing to low with mitigation.

Probability

Results indicate that the probability of impacting third party water supply and the Brakspruit tributary base flow is low in both the unmitigated and mitigated scenarios.

Significance

In the unmitigated and mitigated scenario the significance is low.

8.1.2 MITIGATION MEASURES

No mitigation measures are required, however it is recommended that monitoring of groundwater levels us undertaken through the construction and operational phases to ensure the project is not causing negative impact.

If an emergency situation arises which requires borehole abstraction, the recommended abstraction plan will be followed. This is limited to pumping at a rate of 3 L/s for a period of 12 hrs/day.

In the unlikely event that any project related loss of water supply is experienced by the surrounding borehole users, SCSC will provide compensation that could include an alternative water supply of equivalent quantity and water quality.

8.2 GROUNDWATER CONTAMINATION

There are a number of sources in all project phases that have the potential to pollute groundwater and impact surrounding groundwater users. In the construction, decommissioning and closure phases some of these potential pollution sources are temporary and diffuse in nature. Even though the sources are temporary in nature, related potential pollution can be long term. The operational phase will present more long term potential sources.

For the purpose of this assessment, the unmitigated scenario assumes an impaired Class C liner for all three of the main potential pollution sources (the slag disposal facility, baghouse slurry facility as well as the PCD). With mitigation, the baghouse dust slurry facility and PCD will have a higher specification of liner (i.e. Class A) and less impairments are expected with successful implementation of the liner system during construction and operation. The unmitigated aspect of the impact assessment which follows below is therefore considered to be conservative.

8.2.1 RATING OF IMPACT

<u>Severity</u>

Possible sources of groundwater contamination include seepage from various stockpiles, accidental spills and leaks, seepage from the dirty water circuit and mineralised waste facilities (slag disposal facility, baghouse dust slurry facility and PCD). Groundwater modelling focussed on the most significant potential sources including the slag disposal facility, baghouse dust slurry facility and PCD.

The groundwater model (which conservatively assumed a Class C liner for the slag disposal facility, baghouse dust slurry facility and PCD) predicts that an iron (Fe) plume could migrate 216 m from these sources over a period of 100 years. Although the plume shows an increased distance vs. time, it must be noted that the Fe concentrations show a decreasing trend in time, after the termination of the sources (20 years). This plume is not predicted to reach third party boreholes in either the unmitigated or mitigated scenario. In the unmitigated scenario, albeit that the groundwater model shows the maximum plume extent situated marginally before the tributary, there is a possibility that the plume could extend under the Brakspruit tributary which is unlikely to have any implications in the dry season. In the wet season (albeit that there will be a diluting effect) if the unsaturated groundwater zone is contaminated and interacts with the tributary flow there may be limited impacts on the tributary. In the mitigated scenario, given that the baghouse slurry facility and PCD will be lined with Class A liners, no plume is expected to extend in the vicinity of the tributary.

It follows that in the unmitigated scenario the potential groundwater pollution amounts to a <u>medium</u> severity. In the mitigated scenario, the severity can be reduced to <u>low</u>.

Duration / Reversibility

Groundwater contamination is long term in nature, occurring for periods longer than the life of proposed project. This amounts to a high duration in the unmitigated scenario, reducing to medium with mitigation.

Spatial scale / Extent

Given that the potential sources are located immediately adjacent to the property boundary there is a potential for the pollution plume to extend beyond the project area boundary in both the unmitigated and mitigated scenarios even though the actual extent of the plume is limited. With mitigation measures focussed on containing the pollution plume it is expected that the plume can be contained to within the site boundary and the spatial scale can be reduced to low.

Consequence

The consequence is high in the unmitigated scenario reducing to low with mitigation.

Probability

The probability of the impact occurring relies on a causal chain that comprises three main elements:

- Does contamination reach groundwater resources?
- Will people and animals utilise this contaminated water?
- Is the contamination level harmful?

The first element is that contamination reaches the groundwater resources underneath or adjacent to the proposed project area. It is expected that the plume may reach groundwater resources.

The second element is that third parties and/or livestock use this contaminated water for drinking purposes. No third party boreholes are located within the contamination plume zone and it is not expected that the plume should affect the Brakspruit tributary.

The third element is whether contamination is at concentrations which are harmful to users. In the immediate vicinity of the facilities (i.e. the delineated buffer zone) the concentrations could be at levels which are harmful to users, however since there are no users within this zone, it is not expected that there will be associated impacts.

As a combination, the unmitigated and mitigated probability is low in both scenario.

Significance

The unmitigated significance is medium and the mitigated significance is low.

8.2.2 MITIGATION MEASURES

The objective of the mitigation measures is to prevent pollution of groundwater resources and related harm to water users (people, animals and biodiversity).

SCSC will comply with both the National Water Act (36 of 1998) and Regulation 704 (4 June 1999) or any future amendments thereto, and the terms and conditions of water authorisations/licenses.

In the construction, operation and decommissioning phases SCSC will ensure that all hazardous chemicals (new and used), incoming raw materials, product, dirty water, mineralised wastes and non-mineralised wastes are handled in a manner that they do not pollute groundwater. This will be implemented through a procedure(s) covering the following:

- Pollution prevention through basic infrastructure design.
- Pollution prevention through maintenance of equipment.
- Pollution prevention through education and training of workers (permanent and temporary).
- Pollution prevention through appropriate management of hazardous chemicals, materials and non-mineralised waste.
- The required steps to enable containment and remediation of pollution incidents.
- Specifications for post rehabilitation audit criteria to ascertain whether the remediation has been successful and if not, to recommend and implement further measures.

Infrastructure that has the potential to cause groundwater contamination will be identified and included in a groundwater pollution management plan which will be implemented as part of the operational phase. This plan has the following principles:

- Map potential pollution sources.
- Track (through groundwater modelling updates every 3 years) the extent of the existing or potential contamination plume.
- Design and implement intervention measures to prevent, eliminate and/or control the pollution plume;
- Monitor all existing and potential impact zones to track pollution and mitigation impacts.
- Where monitoring results indicates that third party water supply has been polluted by SCSC, SCSC will ensure that an alternative equivalent water supply will be provided.

TABLE 8-1: SUMMARY OF UNMITIGATED POTENTIAL IMPACTS

Potential Impact	Severity and Nature	Duration	Spatial Scale and Extent	Consequence	Probability	Significance	Mitigation and / or Management Measures
Groundwater abstraction for water supply	Medium	Medium term	Medium	Medium	Low	Low	Yes (Management)
Groundwater Contamination	Medium	Long term	Medium	High	Low	Medium	Yes

TABLE 8-2: SUMMARY OF MITIGATED POTENTIAL IMPACTS

Potential Impact	Severity and Nature	Duration	Spatial Scale and Extent	Consequence	Probability	Significance
Groundwater abstraction for water supply	Low	Short term	Low	Low	Low	Low
Groundwater Contamination	Low	Medium term	Low	Low	Low	Low

8.3 IDENTIFIED AREAS OF SENSITIVITY

The groundwater modelling identified a safety buffer of maximum extent for the contaminant plumes developed during time (based on iron concentrations), as presented in Section 7.7. It has been recommended that no domestic groundwater water supply borehole to be drilled within the buffer zone and that groundwater quality be monitored regularly within this zone.

The area as presented in Figure 8-1 has been identified as 'sensitive', for the Siyanda project

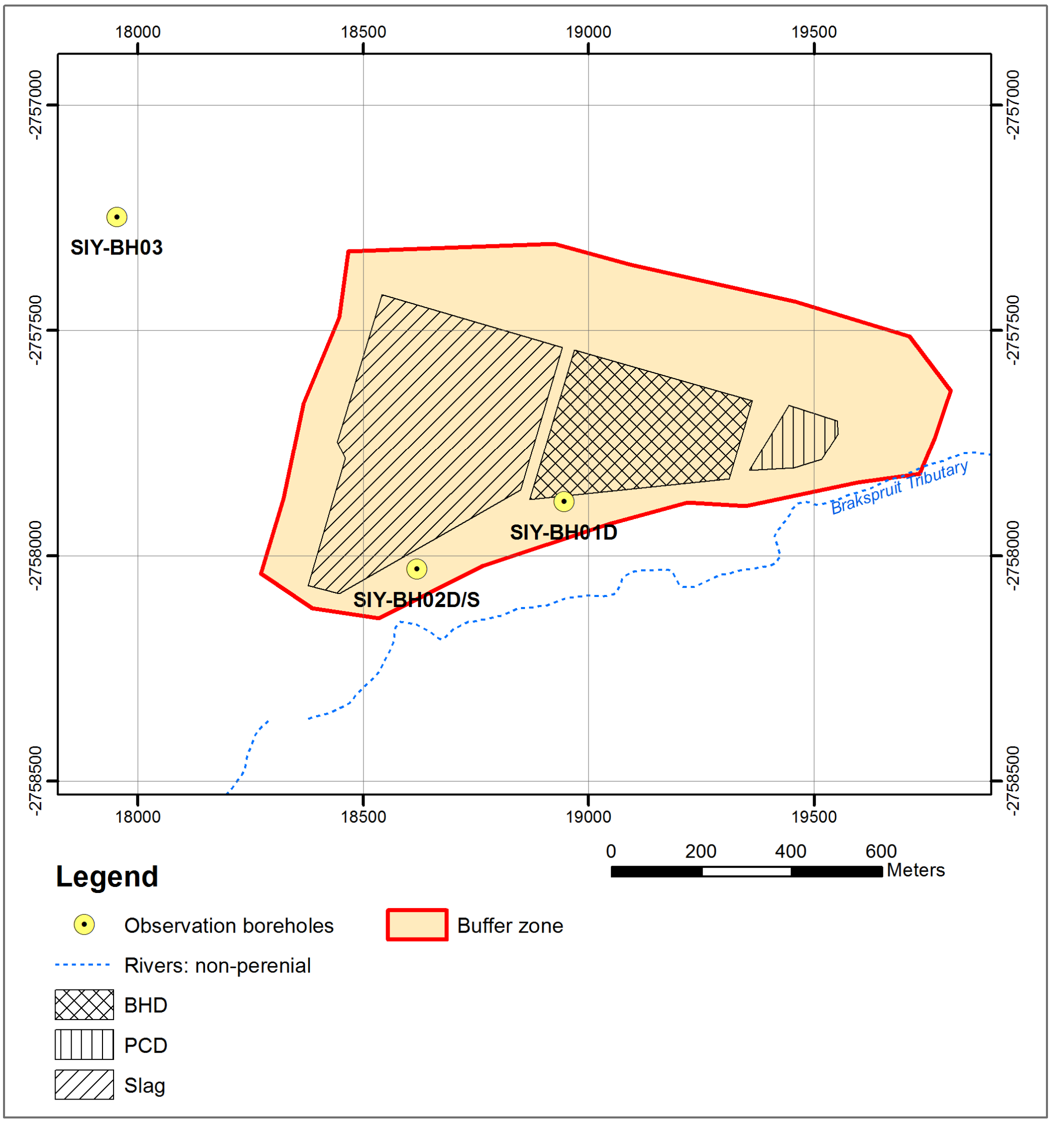


FIGURE 8-1: AREAS OF SENSITIVITY

9 BASELINE MONITORING PROGRAMME

In order to assess potential impacts of the ferrochrome smelter and associated infrastructure on the surrounding water resources, baseline monitoring is required. The measurement of environmental parameters (groundwater levels and ground-, surface water quality) prior to development allows the range of variation of the system to be determined and allows reference points to be established against which changes in the future can be measured.

A baseline monitoring programme was set up for the Siyanda Project following the hydrocensus and commenced in March 2016.

9.1 MONITORING FREQUENCY

Initially, monitoring was undertaken on a monthly basis for groundwater levels and quarterly for ground- and surface water quality. Subsequently, monitoring was reduced to quarterly only. Table 9-1 presents the dates in which monitoring was undertaken / due.

TABLE 9-1: GROUNDWATER MONITORING DATES

Date	Type of Monitoring	Parameters Monitored
2016/03/18	Quarterly Q1	Groundwater levels and ground- surface water quality
2016/05/04	Monthly	Groundwater levels
2016//06/21	Monthly	Groundwater levels
2016/07/29	Quarterly Q2	Groundwater levels and ground- surface water quality
Due September 2016	Quarterly Q3	Groundwater levels and ground- surface water quality
Due December 2016	Quarterly Q4	Groundwater levels and ground- surface water quality

9.2 MONITORING LOCATIONS

Details of the monitoring points are presented in Table 9-2 (groundwater) and Table 9-3 (surface water). Monitoring locations are presented in Figure 9-1.

TABLE 9-2: SUMMARY OF THE GROUNDWATER MONITORING POINTS FOR THE BASELINE MONITORING

Borehole ID	Farm Name	Borehole Coordinates		Borehole Depth (m)	General Geology*
		Latitude	Longitude		
SIY-BH01S	Grootkuil 3	-24.926063	27.187590	12	Weathered Magnetite Gabbro
SIY-BH01D	Grootkuil 3	-24.92609	27.18756	60	Magnetite Gabbro
SIY-BH02S	Grootkuil 3	-24.92745	27.18443	18	Weathered Gabbro Norite
SIY-BH02D	Grootkuil 3	-24.927444	27.18434	60 but collapsed to 25 (water levels only)	Gabbro Norite
SIY-BH03	Grootkuil 3	-24.9204	27.17774	60	Gabbro Norite
BH4	Grootkuil 3	-24.930666	27.2036944	51	Magnetite Gabbro
Johan Young BH1	Kameelhoek 3	-24.9071180	27.1720370	60	Vlakfontein
Johan Young BH2	Kameelhoek 3	-24.9068800	27.1687860	60	Vlakfontein

* Based on geological map and borehole logs where available.

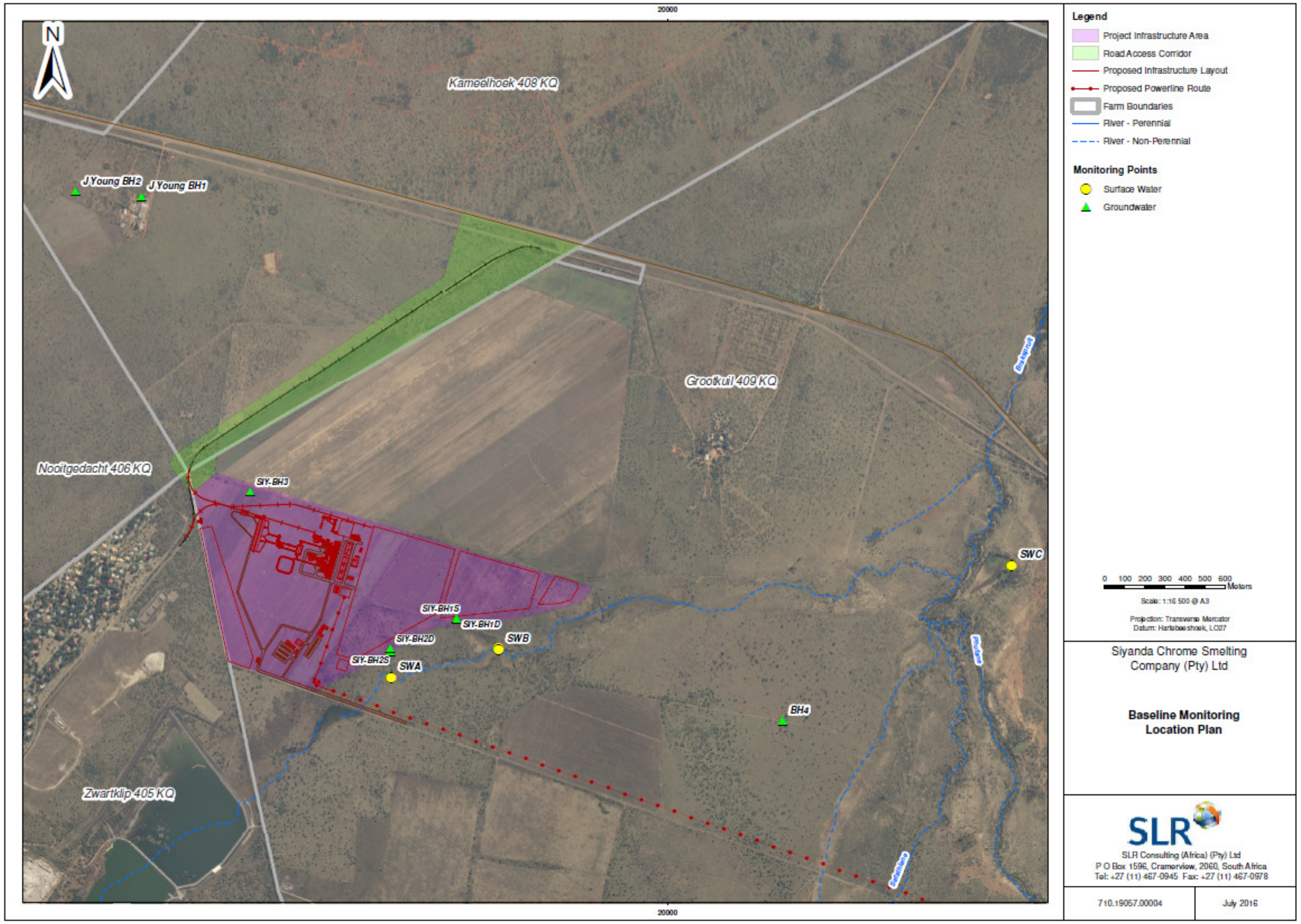


FIGURE 9-1: MONITORING LOCATION PLAN

TABLE 9-3: SUMMARY OF THE SURFACE WATER MONITORING POINTS FOR THE BASELINE MONITORING

SW ID	Farm Name	Borehole Coordinates		Description
		Latitude	Longitude	
SWA	Grootkuil 3	-24.928750	27.184394	Spruit – up stream of site, near to SIY-BH02
SWB	Grootkuil 3	-24.927459	27.189690	Kidney shaped dam on Grootkuil 3
SWC	Grootkuil 3	-24.923643	27.214967	Dam on Schoeman's property – down-stream of site

9.3 ANALYTICAL SUITE

The analytical suite for groundwater and surface water samples is presented in Table 9-4.

TABLE 9-4: ANALYTICAL SUITE

Analytical Suite		
pH	Total Dissolved Solids	Nitrate as N
Electrical Conductivity	Bicarbonate as HCO_3	Magnesium
Alkalinity	Carbonate as CO_3	Manganese
Chloride	Sodium	ICP-OES scan - dissolved metals (groundwater)
Fluoride	Potassium	ICP-OES scan - total metals (surface water)
Sulphate	Calcium	

9.4 LEGAL COMPLIANCE

The predominant water supply source in the area is for domestic uses (including drinking) and livestock watering. Therefore the groundwater and surface water quality results were compared against the following guidelines:

- South African National Standards (SANS: 241 (2015)) Water Quality Standards.
- Department of Water Affairs (DWAF) (now Department of Water and Sanitation [DWS]) Target Water Quality Range (TWQR) for Livestock Watering (2009).

The SANS 241: 2015 specifies limits in terms of four categories:

- Acute Health – poses an immediate unacceptable health risk if present at concentrations exceeding the numerical limits specified.
- Aesthetics – does not pose an unacceptable health risk if present at concentrations exceeding the numerical limits specified, but will taint water with respect to taste, odour and colour.
- Chronic Health – poses an unacceptable health risk if ingested over an extended period if present at concentrations exceeding the numerical limits specified.
- Operational – is essential for assessing the efficient operation of treatment systems and risks to infrastructure.

The DWAF TWQR for Livestock Watering refers to a 'No Effect Range'. This is the range of concentrations at which the presence of each constituent would have no known or anticipated adverse effects on the suitability of water for livestock watering. These ranges were determined by assuming long-term continuous use (lifelong exposure) and incorporate a margin of safety.

9.5 RESULTS

The results of the baseline monitoring will be reported separately once the 12 months of monitoring has been completed. A summary of the results collected so far is presented in the following section.

9.5.1 GROUNDWATER LEVELS

To date, groundwater levels have been recorded on four (4) occasions between 18th March 2016 and 29th July 2016. A summary of the water levels are presented in Table 9-5. A hydrograph is presented in Figure 9-2.

TABLE 9-5: SUMMARY OF GROUNDWATER LEVELS

BH ID	Count	Groundwater Level (mbgl)			Groundwater Elevation (mamsl)			Range (m)
		Min.	Ave.	Max.	Min.	Ave.	Max.	
SIY-BH01S	4	DRY			DRY			-
SIY-BH01D	4	31.72	31.81	31.87	963.13	963.19	963.28	0.15
SIY-BH02S	4	5.65	5.94	6.13	989.87	990.06	990.35	0.48
SIY-BH02D	4	5.95	6.10	6.26	989.74	989.90	990.05	0.31
SIY-BH03	4	17.56	17.83	18.04	988.96	989.17	989.44	0.48
BH4	3	16.38	16.42	16.47	971.53	971.58	971.62	0.09
J Young BH1	4	19.70	19.93	20.43	975.57	976.07	976.30	0.73
J Young BH2	4	14.08	14.21	14.31	979.69	979.79	979.92	0.23

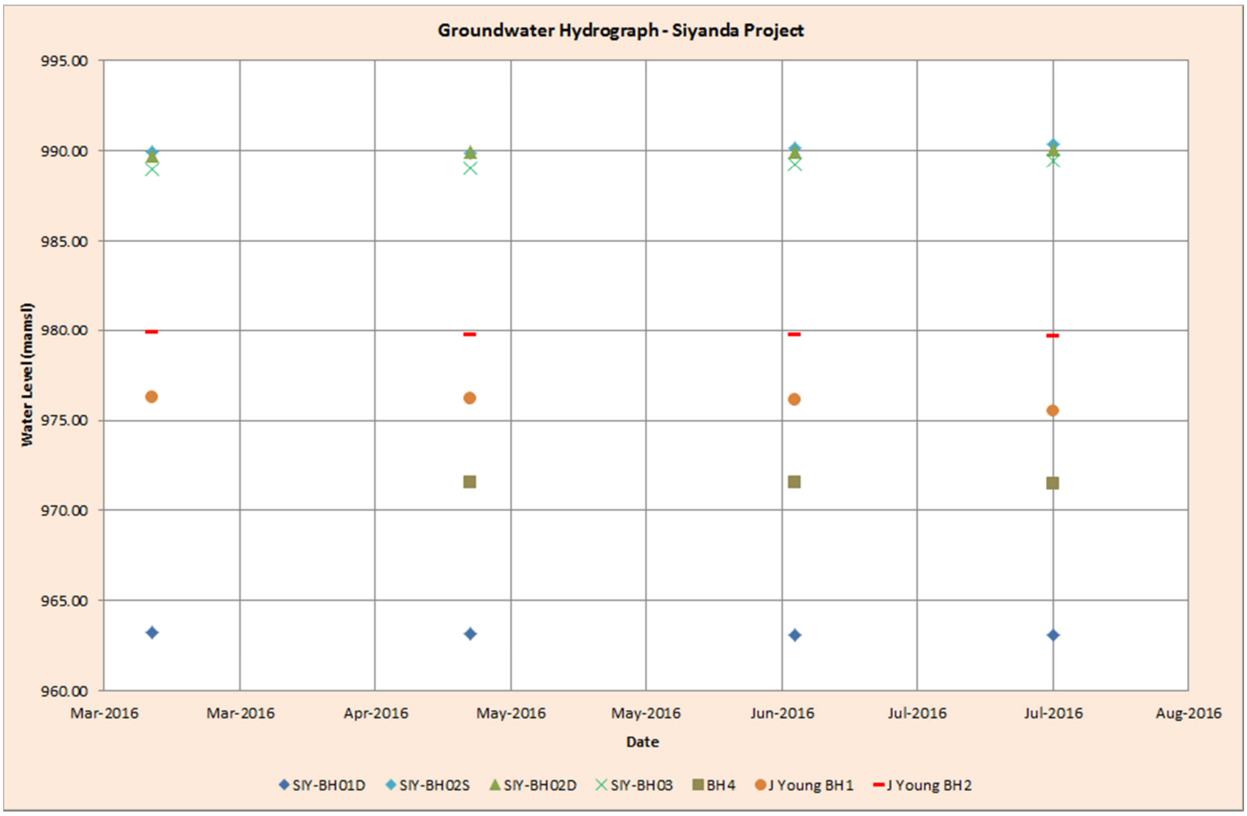


FIGURE 9-2: GROUNDWATER HYDROGRAPH

9.5.2 GROUNDWATER QUALITY

To date, groundwater quality has been recorded on two (2) occasions; 18th March 2016 and 29th July 2016.

When compared to relevant water quality standards, the following chemicals of concern were identified:

- Iron (Fe)
- Manganese (Mn)
- Sodium (Na)
- Electrical conductivity (EC)
- Total dissolved solids (TDS)
- Chloride (Cl)
- Sulphate (SO_4)

The data for each borehole for both monitoring events for the chemicals of concern is presented in Table 9-6. Laboratory Certificates are presented in Appendix G.

TABLE 9-6: WATER QUALITY DATA FOR CHEMICALS OF CONCERN

Sample ID/	Date of Sampling	Concentration (mg/L)						
		Fe	Mn	Na	EC	TDS	Cl	SO4
DWAF TWQR - Livestock Watering		**10**	**10**	**2000**	**N/A**	**N/A**	**1500**	**1000**
SANS 241 (2015) Operational		**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
SANS 241 (2015) Aesthetic		**0.3**	**0.1**	**200**	**170**	**1200**	**300**	**250**
SANS 241 (2015) Acute Heath		**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**500**
SANS 241 (2015) Chronic Health		**2**	**0.4**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
SIY-BH01D	2016/03/18	0.014	<0.01	247	161	872	289	151
	2016/07/29	0.013	<0.025	242	154	1030	369	181
SIY-BH2S	2016/03/18	3.40	0.295	247	296	1898	817	345
	2016/07/29	9.03	0.519	234	333	2710	811	450
SIY-BH03	2016/03/18	4.32	0.239	219	282	1688	691	369
	2016/07/29	3.93	0.210	213	292	1898	728	383
BH4	2016/03/18	-	-	-	-	-	-	-
	2016/07/29	7.40	0.127	218	148	824	345	1.00
J Young BH1	2016/03/18	0.025	<0.01	201	330	2046	747	402
	2016/07/29	0.029	<0.025	186	325	2554	747	417
J Young BH2	2016/03/18	0.012	<0.01	33.07	107	626	37.00	16.00
	2016/07/29	0.013	<0.025	32.94	107	640	41.00	14.00

Note: highlighted cells indicate which water quality standard has been exceeded.

9.5.3 SURFACE WATER OBSERVATIONS

To date, surface water monitoring has occurred on two (2) occasions; 18th March 2016 and 29th July 2016. Observations made for each monitoring point are presented in Table 9-7.

TABLE 9-7: SURFACE WATER OBSERVATIONS

SW Point	Description	Observation 2016/03/18	Observation 2016/07/29
SWA	Spruit – near to SIY-BH02	No access	Dry
SWB	Kidney shaped dam on Grootkuil portion 3	Full and flooding	Low water Level
SWC	Dam on Schoeman’s property (portion 0 of Grootkuil)	Full	No access

9.5.4 SURFACE WATER QUALITY

To date, surface water quality has been recorded on two (2) occasions; 18th March 2016 and 29th July 2016.

When compared to relevant water quality standards, the following chemicals of concern were identified:

- Aluminium (Al)
- Iron (Fe)
- Manganese (Mn)

The data for each surface water monitoring point for both monitoring events for the chemicals of concern are presented in Table 9-8. Laboratory Certificates are presented in Appendix G.

TABLE 9-8: WATER QUALITY DATA FOR CHEMICALS OF CONCERN

Sample ID/	**Date of Sampling**	**Concentration (mg/L)**		
		Al	**Fe**	**Mn**
DWAF TWQR - Livestock Watering		**5**	**10**	**10**
SANS 241 (2015) Operational		**0.3**	**N/A**	**N/A**
SANS 241 (2015) Aesthetic		**N/A**	**0.3**	**0.1**
SANS 241 (2015) Acute Heath		**N/A**	**N/A**	**N/A**
SANS 241 (2015) Chronic Health		**N/A**	**2**	**0.4**
SWB	2016/03/18	<0.1	0.051	<0.01
	2016/07/29	2.86	2.66	0.324
SWC	2016/03/18	2.10	1.95	0.278
	2016/07/29	-	-	-

Note: highlighted cells indicate which water quality standard has been exceeded.

10 CONCLUSION AND RECOMMENDATIONS

SLR was commissioned by SCSC to undertake a groundwater impact assessment for the Siyanda Ferrochrome Project, near Northam in the Limpopo Province of South Africa.

The following work has been undertaken to assess groundwater:

- Desk review – reviewing published data for the area, including geological and hydrogeological maps.
- Consultation with authorities and Interested Affected Parties (IAPs).
- Site investigations – including geophysical survey, drilling of boreholes and pumping tests.
- Development of groundwater numerical model.
- Groundwater Impact Assessment which includes proposed mitigation measures.

Based on the results of the assessment, the following can be concluded:

Groundwater Levels

Based on the results of the groundwater study which simulated abstraction from borehole SIY-BH02S at a sustainable pumping rate of 3 L/s for a period of 12 hrs/day, it is not expected that there be any impact on the groundwater levels, no impacts on third party users and no impact on base flow of the Brakspruit tributary as a result of borehole abstraction.

Notwithstanding, it is highly recommended that monitoring of groundwater levels be undertaken to ensure that changes in water depths can be identified. In the unlikely event that groundwater abstraction is causing noticeable impact on the groundwater levels and possibly causing a loss of water supply to third parties, appropriate compensation will be provided by SCSC until such time as the groundwater abstraction ceases.

Contaminant Flow

There are a number of sources in all project phases that have the potential to pollute groundwater and impact surrounding groundwater users: slag disposal facility, baghouse slurry facility as well as the pollution control dam (PCD) are the key sources.

As informed by the geochemical assessment, the main contaminant exceeding the prescribed groundwater quality limits was iron (Fe).

The groundwater model (which conservatively assumed a Class C liner for the slag disposal facility, baghouse dust slurry facility and PCD) predicts that an iron (Fe) plume could migrate 216 m from these sources over a period of 100 years. Although the plume shows an increased distance vs. time, it must be noted that the Fe concentrations show a decreasing trend in time, after the termination of the sources (20 years). This plume is not predicted to reach third party boreholes in either the unmitigated or mitigated scenario. In the unmitigated scenario, albeit that the groundwater model shows the maximum plume extent situated marginally before the tributary, there is a possibility that the plume could extend under the Brakspruit tributary which is unlikely to have any implications in the dry season. In the wet season (albeit that there will be a diluting effect) if the unsaturated groundwater zone is contaminated and interacts with the tributary flow there may be limited impacts on the tributary.

If mitigation measures are put in place, which include a more stringent liner specification (Class A) for baghouse slurry facility and PCD, no plume is expected to extend in the vicinity of the tributary.

It is highly recommended that monitoring of water quality is undertaken to ensure that changes in water quality from baseline conditions can be identified. In the unlikely event that the project is causing noticeable impact on the groundwater / surface water quality and possibly causing a negative impact on third parties, appropriate compensation will be provided by SCSC.

The results of this assessment are considered acceptable for the purpose of this level of assessment and there is no reason not to proceed with the project provided that the waste facility design and any impact mitigation measures, as recommended, are implemented.

11 ASSUMPTIONS AND LIMITATIONS

- The groundwater model suggested that water abstraction from borehole SIY-BH02S will not have impact on the groundwater regime, however If additional boreholes are to be drilled and used for groundwater abstraction, then an update of the groundwater model must be run to include the new boreholes.
- All facilities were considered as being lined with a Class C liner; this presents a worst case scenario and the actual impacts are associated to be even less significant than what has been assessed given that the liner will be designed according to a higher/more stringent design specifications.
- The life of facilities is assumed to be 20 years. If through waste minimisation efforts the life of the facilities are extended the groundwater model should be updated at that point.
- The source concentration estimation for the PCD facility is an overestimation. The scenario simulated therefore represents a worst case scenario.

12 REFERENCES

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SLR Consulting (Africa) (Pty) Limited (2016b) Siyanda Chrome Smelter Hydrocensus Report. SLR Project No.: 710.19057.00004

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13 DECLARATION OF INDEPENDENCE

I, *Jenny Ellerton* hereby declare that *SLR Consulting (Africa) (Pty) Limited*, an independent consulting firm, has no interest or personal gains in this project whatsoever, except receiving fair payment for rendering an independent professional service.

Consultant name: Jenny Ellerton

Jenny Ellerton

Signature:
Date: September 2016

Jenny Ellerton

Jenny Ellerton and Mihai Muresan
(Report Author)

Caitlin Hird
(Project Manager)

Mihai Muresan
(Project Reviewer)

APPENDIX A: CURRICULUM VITAE OF PROJECT TEAM

Jenny Ellerton
Senior Hydrogeologist / Geochemist

Curriculum Vitae

Qualifications

MSc	2005	Hydrogeology – University of Birmingham
BSc (Hons)	2002	Geology and Physical Geography Dual Honours - Keele University (Upper Second)
FGS	Since 2006	Fellow of the Geological Society

Key Areas of Expertise

Jenny has **10 years** of professional experience gained in both the UK and South Africa. Key areas of Jenny's expertise are summarised below

Groundwater Assessments	Groundwater Assessments – to support environmental impact assessments, water use licence applications and engineering design.
Hydrogeological Site Investigation	Supervising drilling contractors for numerous types of site investigations and undertaking aquifer tests.
Environmental Monitoring	Groundwater, surface water, leachate & gas monitoring.
Development of Conceptual Site Models	Analysis & interpretation of geological and hydrogeological information.
Acid Rock Drainage Assessments	Geochemical assessment and remediation of mine related water pollution.
Project Management	Experience in management of field based hydrogeological studies and desk based projects.

Summary of Experience and Capability

Jenny is a Senior Hydrogeologist within SLR with 10 years of geological and hydrogeological experience gained through a master's degree and environmental consultancy both in the UK and South Africa.

Jenny has undertaken projects covering all aspects of hydrogeology and specialises in the following:

- Site investigation, including the installation of groundwater and gas monitoring boreholes and the detailed logging of soil and rock samples.
- Undertaking monitoring and sampling of surface water, groundwater, landfill gas and leachate and undertaking field permeability tests and data analysis.
- Qualitative and quantitative Hydrogeological Risk Assessments.
- Groundwater assessments for Environmental Statements in support of planning applications for mineral extraction operations, landfill developments, and other industrial and commercial developments.

- Geochemical and Acid Rock Drainage (ARD) assessments to characterise the expected waste rock material associated with the mineral extraction process of various types of mining operations in accordance with best practice.
- Waste classification in terms of the National Norms and Standards for the Assessment of Waste for Landfill Disposal (No. R. 635) and Disposal of Waste to Landfill (No. R 636).
- Soil contamination assessment to determine the level of soil contamination in terms of soil screening values as presented in National Norms and Standards for the Remediation of Contaminated land and Soil Quality.

Recent Project Experience

Key aspects of Jenny's recent project experience are summarised below.

Project	Date	Jenny's Role
Siyanda Chrome Smelter Project (South Africa)	Current	Responsible for managing and co-ordinating the groundwater and geochemical studies. Work includes geophysical investigations, drilling and pump testing, collection of samples, development of a conceptual site model and source term and a numerical groundwater model to assess the potential impact of the site on surrounding water resources.
Kudumane Manganese Project (South Africa)	Current	Responsible for co-ordinated drilling to drill boreholes within the riverbed of the Ga-mogara River and to undertake an study to understand the groundwater / surface water interaction at the site in support of the Water Use License Application.
Manica Gold Project (Mozambique)	Current	Involved in both the groundwater and geochemical assessments for the project in support of the Environmental Impact Assessment for the Project.
Lofdal REE Project (Namibia)	Current	Responsible for the selection of representative waste samples for geochemical characterisation and undertaking an assessment of the potential for acid mine drainage (AMD) and metal leaching in support of an Environmental and Social Impact Assessment (ESIA).
Panda Hill Gold Project (Tanzania)	Current	Geochemical assessment to support engineering design work and assess potential impact on groundwater. Work included geochemical modelling and development of a salt balance.
Mokala Manganese Project (South Africa)	September 2015	Waste assessment in terms of the National Norms and Standards to determine the waste type and the class of landfill (liner specification) required to dispose of mining waste.
Alfred Knight Due Diligence Project (South Africa)	August 2014	Responsible for the selection of samples, sample analysis and interpretation of results in terms of the National Norms Standards for the Remediation of Contaminated land and Soil Quality to determine 'baseline' condition of the soil.
Hinda Phosphate Project (Congo)	September 2013	Responsible for co-ordination and undertaking the supervision of the drilling of boreholes and pumping tests. Interpretation of field data and reporting.

Publications

None to date

Mihai Muresan
Team Lead Water (South Africa)

Curriculum Vitae

Qualifications

PrSciNat	Since 2010	Member of the South African Council for Natural Scientific Professions
MSc	1988	Hydrogeology and Engineering Geology, Univ. of Bucharest, Romania

Key Areas of Expertise

Key areas of Mihai's expertise are summarised below.

Hydrogeology	Drilling and testing design, hydrogeological parameters interpretation, monitoring, sampling, numerical modelling
Mining Hydrogeology	Design of dewatering works, predictive simulations of (residual) passive inflows and pore pressures distribution for slope optimization
Groundwater Numerical Modelling	Feflow (DHI-Wasy), MineDW (Itasca)
Unconventional Gas (UCG, CBM, Shale Gas)	Majuba (Eskom), Theunissen (African Carbon Energy), Zonderwater (Exxaro), TOPS (Imperial College, European Commission for Technology), San Juan (San Juan), Prediction of fractures development (Golder Research)

Summary of Experience and Capability

Mihai is a Team Leader (Water) with SLR South Africa and is responsible for SLR's Hydrology and Hydrogeology in South Africa. Mihai has over 25 years of experience within Hydrogeology, Oil and Gas Exploration and Unconventional Gas.

Mihai has managed a wide range of major projects and Mine Dewatering and Environmental Impact Assessment (Groundwater Specialist Studies) projects for major minerals developments throughout Africa for many of the major operators within the minerals industry.

In addition to this he advises clients on a wide range of operational mine dewatering and water supply aspects and hydrogeological operational conditions for development of unconventional gas.

Prior to joining SLR in 2015, he held the position of Mining Hydrogeology Team Leader at Golder Associates Africa, responsible for the dewatering and monitoring network designs and groundwater numerical modelling for mining operations, together with responsibility for the environmental team.

Recent Project Experience

Key aspects of Mihai's recent project experience are summarised below.

Project	**Date**	**Mihai's Role**
Kamoto Copper, DR Congo	2015	Project managed mine dewatering for KCC – complex conditions: 1 open pit and 2 underground mines)
Tizerghaf, Mauritania	2015	Groundwater reserves estimation for SNIM
Technology Options (TOPS) for UCG and CCS	2014	Hydrogeological conditions for site selection criteria, hydrogeological investigation, groundwater numerical modelling for near-far field of gasifier
Tizerghaf, Mauritania	2014	Groundwater reserves estimation for SNIM
Mayoko Iron Ore, Congo	2013	Project managed mine planning groundwater application and EIA Specialist study (groundwater)
Platreef, South Africa	2013	Groundwater numerical modelling: estimation of inflows and EIA Specialist study (groundwater)
Large Open Pit (LOP)	2009	Groundwater numerical modelling for open pit slopes
Orapa and Letlhakne Mines, Botswana	2007	Groundwater numerical modelling: estimation of inflows and pore pressures distribution for open pit mines

Publications

Technology Options for Coupled Underground Coal Gasification and CO2 Capture and Storage – Energy Procedia 63 (2014) 5827-5835 (co-author)

Hydrogeological Numerical Modelling to Simulate UCG Processes – The 2nd Workshop on Underground Coal Gasification, Banff, Canada, 2012

Importance of Pore Pressure Monitoring in High Walls – The Journal of The South African Institute of Mining and Metallurgy, Vol. 108, November 2008

APPENDIX B: HYDROCENSUS REPORT AND DATA

global environmental solutions

Siyanda Ferrochrome Project

Siyanda Ferrochrome Project
Hydrocensus Report

SLR Project No.: 710.19057.00004
Report No.: 01
Revision No.: 01

August 2016

Siyanda Chrome Smelting Company (Pty) Limited

Siyanda Ferrochrome Project

Siyanda Ferrochrome Project
Hydrocensus Report

SLR Project No.: 710.19057.00004
Report No.: 01
Revision No.: 01

August 2016

Siyanda Chrome Smelting Company (Pty) Limited

DOCUMENT INFORMATION

Title	Siyanda Ferrochrome Project
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Client	Siyanda Chrome Smelting Company (Pty) Limited
Date last printed	2016/09/13 05:28:00 PM
Date last saved	2016/09/09 12:24:00 PM
Comments	
Keywords	Hydrocensus, groundwater, surface water, ferrochrome, smelter, Limpopo
Project Number	710.19057.00004
Report Number	01
Revision Number	Revision No.: 01
Status	FINAL
Issue Date	August 2016

This report has been prepared by an SLR Group company with all reasonable skill, care and diligence, taking into account the manpower and resources devoted to it by agreement with the client. Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

No warranties or guarantees are expressed or should be inferred by any third parties.
This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

SIYANDA FERROCHROME PROJECT

HYDROCENSUS REPORT

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LIST OF TABLES

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ACRONYMS AND ABBREVIATIONS

Below a list of acronyms and abbreviations used in this report.

Acronyms / Abbreviations	**Definition**
CoC	Chemicals of concern.
DC	Direct current
EIA	Environmental Impact Assessment
E.N	Electro neutrality
IAP	Interested and Affected Persons
MW	Megawatt (MW)
TWQR	Target Water Quality range
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
SANAS	South African National Accreditation System
SANS	South African National Standards
Mbgl	Metres below ground level
Mamsl	Metres above mean sea level
QA / QC	Quality Assurance / Quality Control

SIYANDA FERROCHROME PROJECT

HYDROCENSUS REPORT

1 INTRODUCTION

SLR Consulting (Africa) (Pty) Limited ("SLR") has been appointed by Siyanda Chrome Smelting Company (Pty) Limited ("SCSC") to undertake a hydrocensus for the proposed ferrochrome smelter located near Northam in the Limpopo Province.

1.1 BACKGROUND

SCSC is proposing to construct a new ferrochrome smelter on portion 3 of the Farm Grootkuil 409 KQ, located approximately 8 km north-west of Northam in Limpopo Province (Figure 1-1).

At this stage in project planning, it is expected that incoming material will be sourced from Union Section mine and possibly also from other mines in future.

The project will comprise two 70 megawatt (MW) direct current (DC) furnaces, a crushing and screening plant, a slag waste facility and a separate baghouse dust waste facility, pollution control dam, and various support infrastructure and services.

Prior to the commencement of the proposed project, an Environmental Impact Assessment (EIA) is required. As part of the EIA, an assessment of the groundwater, the surrounding groundwater users and the potential impacts on the groundwater resources must be undertaken.

1.2 OBJECTIVES

The results of the hydrocensus will feed into the overall Groundwater Impact Assessment. The objectives are:

- To identified groundwater and surface water users within a 5 km radius of the project area.
- To characterise the baseline water conditions.

1.3 REPORT STRUCTURE

The report has been divided accordingly:

- Section 2 describes the methodology and procedures undertaken.
- Section 3 presents the results of the hydrocensus.

  Section 4 summarises and concludes the report.

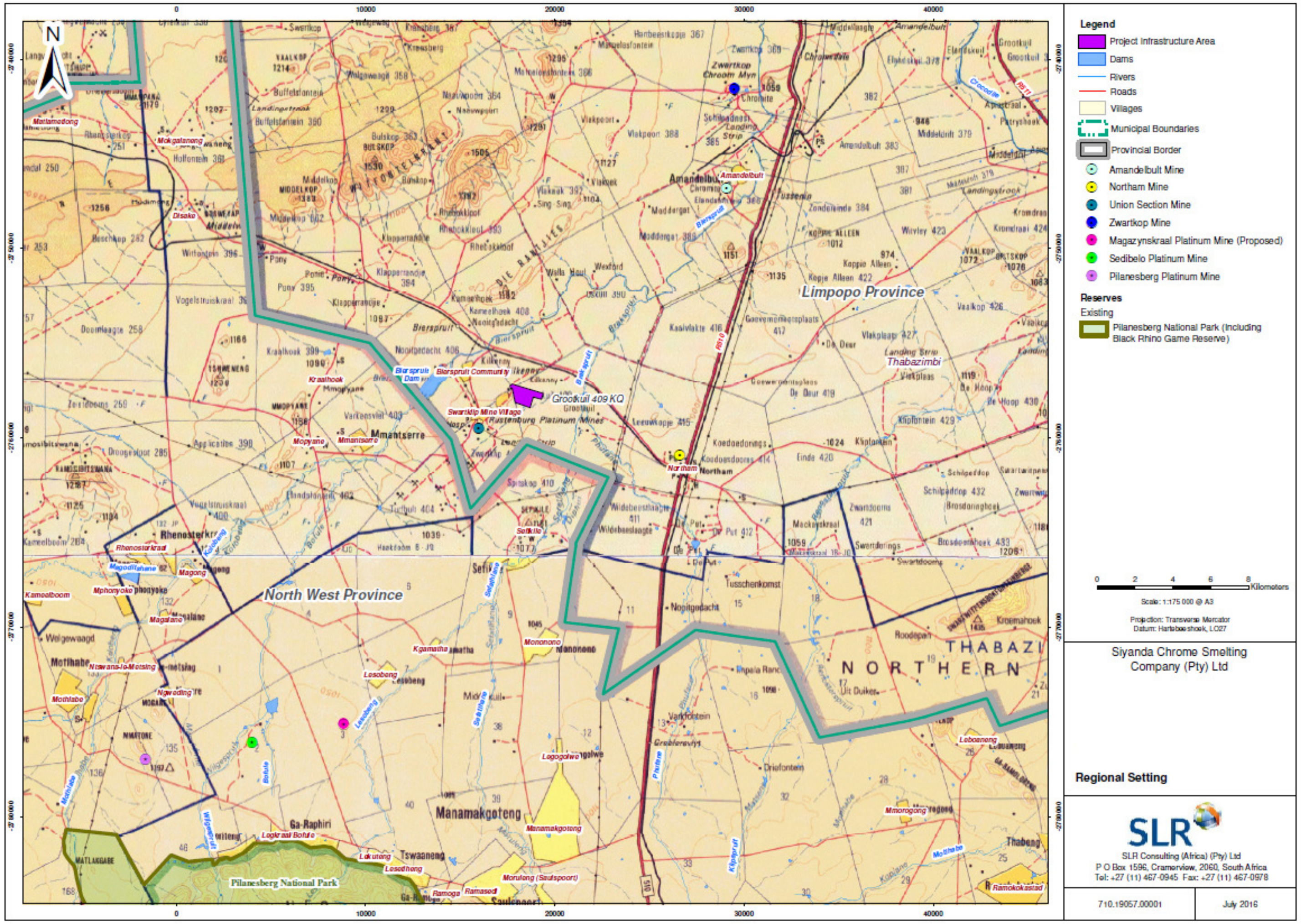

FIGURE 1-1: SITE LOCATION PLAN

2 METHODOLOGY

The following section presents the works undertaken as part of the hydrocensus.

2.1 IAP DATABASE

The hydrocensus team used the project specific public involvement database, referred to as an Interested and Affected Persons (IAP) database. The database was developed from the following sources:

- Deed search information on immediate and adjacent landowners.
- IAP identification through social scans and site visits in the relevant area.
- Registration of IAPs as a result of the background information document distribution, newspaper adverts, site notices and scoping public meetings.
- Registration of the relevant authorities as a result of direct invitation.

Prior to the site visit, IAPs located within a 5 km radius of the site were contacted where possible. IAPs advised whether they had any boreholes, or wells on their land.

2.2 SITE VISIT AND MONITORING LOCATIONS

SLR undertook the hydrocensus between 14th July 2015 and 6th August 2015. The time of the site work has negligible implications on the outcome of the assessment, although groundwater levels are likely to be at the lower end of the seasonal range given that the work was done mid-winter.

In total, sixteen (16) sites were visited; thirteen (13) groundwater monitoring points and three (3) surface water monitoring points. Locations of all monitoring points visited during the hydrocensus are presented on Figure 2-1.

Details such as GPS position, depth of boreholes, water use and owners were recorded. Groundwater levels were measured and water samples collected for water quality purposes from selected locations. Details of the monitoring points are presented in Table 2-1. Photo logs are presented in Appendix A.

2.3 GROUNDWATER LEVELS

Where possible, the depth to groundwater and the depth to the base of each well were measured, using a Solinst® electrical dip meter. Depths were measured against the top of casing and ground level.

Groundwater levels were recorded in a total of nine (9) in boreholes. Water levels in two (2) boreholes, were unable to be measured due to the presence of installed pumps or other obstructions within the boreholes.

2.4 WATER QUALITY

2.4.1 SAMPLE LOCATIONS AND METHODOLOGY

Groundwater sampling was performed at eleven (11) of the boreholes visited by SLR.

Sampled boreholes were selected based on location, in order to gather a spread of data across the area, and also based on operational status. Boreholes with installed and frequently operational pumps were selected as preferred sampling points to ensure water within the boreholes was representative of the intersected aquifer.

Field parameters, including pH, electrical conductivity (EC), total dissolved solids (TDS) and temperature (℃) were measured using a calibrated multi-meter. The locations of sampled boreholes are listed in Table 2-1.

Surface water sampling was not undertaken as surface water monitoring points were dry.

2.4.2 PURGING OF BOREHOLES

Where boreholes were not equipped with a pump, samples were taken using a bailer.

2.4.3 SAMPLE PREPARATION, PRESERVATION AND TRANSPORT

In accordance with the Water Research Commission's (WRC) Groundwater Sampling report (Weaver, et al, 2007), sample filtration for dissolved heavy metals was undertaken in the field using 0.45µm in-line filter to prevent precipitation of metal species. One 250mL plastic bottle, containing nitric acid as a preservative, was filled with filtered water. A second unfiltered, unpreserved sample was collected in a one litre plastic bottle for all other analysis.

Samples were filled to the top of the bottle neck until a meniscus formed. This ensures that all air has been excluded from the samples, which helps to prevent oxidation of the sample. It can also prevent removal of other dissolved gases from solution.

Once collected, samples were labelled appropriately, placed in a cool box with ice blocks and delivered to the selected accredited laboratory with the relevant chain of custody form completed.

TABLE 2-1: SUMMARY OF THE GROUNDWATER MONITORING POINTS FOR THE 2015 HYDROCENSUS

Borehole ID	Farm Name	Borehole Coordinates (WGS84)		Borehole Depth (m)	Borehole Status	Site Purpose	Water Application	Water Level Recorded	Water Sample Collected	Method
		Latitude	Longitude							
BH1	Grootkuil 3	-24.9357222	27.2147222	Obstruction at 10m	Not in use	Game farm	None	No	No	-
BH3	Grootkuil 3	-24.9336667	27.2125000	19	Not in use	Game farm	None	Yes	Yes	Pump
BH4	Grootkuil 3	-24.9306667	27.2036944	51	In use	Game farm	Livestock watering	Yes	Yes	Bailer
BH5	Grootkuil 3	-24.9329167	27.2180833	37	Not in use	Game farm	None	Yes	Yes	Bailer
BH6	Grootkuil 0	-24.9117222	27.2203888	130	Not in use	Farm	None	Yes	Yes	Bailer
BH7	Grootkuil 0	-24.9155278	27.2237500	>100	Not in use	Farm	None	Yes	Yes	Bailer
BH10	Grootkuil 4 (Union Section Mine)	-24.9315833	27.1821944	10	Not in use	Game farm	None	No	No	-
BH11	Nooitgedacht	-24.8923333	27.1516944	50	In use	Farm/guesthouse	Domestic	No	Yes	Tap – Jo-Jo
BH12	Wildebeestlagte	-24.9598333	27.2357222	60	In use	Game farm	Domestic	No	Yes	Tap
Johan Young BH1	Kameelhoek 3	-24.9071180	27.1720370	60	In use	Farm	Domestic, Livestock Watering	Yes	Yes	Tap in House
Johan Young BH2	Kameelhoek 3	-24.9068800	27.1687860	60	In use	Farm	Domestic, Livestock Watering	Yes	Yes	Tap in House
WM11	Union Section Mine	-24.9402500	27.1785000	25	Not in use	Down-gradient of Union Section's TSF	Monitoring only	Yes	Yes	Bailer
WM6	Union Section Mine	-24.9451111	27.1792777	27	Not in use	Down-gradient of Union Section's TSF	Monitoring only	Yes	Yes	Bailer

TABLE 2-2: SUMMARY OF THE SURFACE WATER MONITORING POINTS FOR THE 2015 HYDROCENSUS

Monitoring Point ID	Farm Name	Borehole Coordinates (WGS84)		Source	Water Application	Flow Velocity	Water Sample Collected During Hydrocensus
		Latitude	Longitude				
SW1	Grootkuil 4	-24.9342500	27.17766666	Ephemeral stream / Weir	Weir from Union Section Mine	Dry	No
SW2	Grootkuil 0	-24.9237500	27.21511111	Small dam	Livestock Watering	Dry	No
SW3	Grootkuil 3	-24.9335556	27.21533333	Ephemeral stream	None	Dry	No

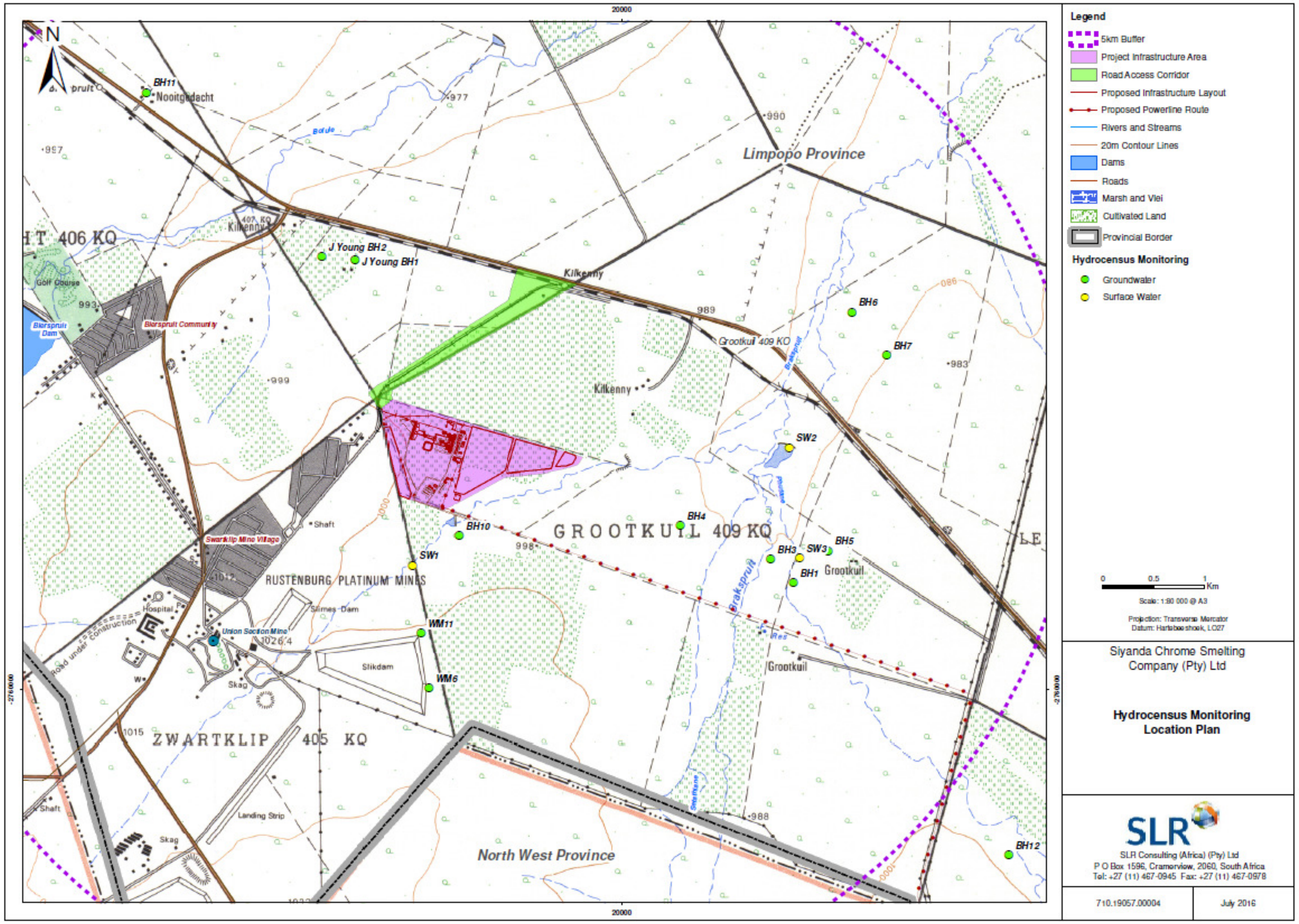

FIGURE 2-1: HYDROCENSUS MONITORING LOCATION PLAN

2.4.4 ANALYTICAL SUITE

All samples were sent to UIS Analytical Laboratory, in Centurion, South Africa. UIS is a SANAS (South African National Accreditation System) accredited laboratory according to ISO/IEC 17025:2005 standards. Table 2-3 presents the analytical suite the samples were submitted for.

TABLE 2-3: ANALYTICAL SUITE

Analytical Suite		
pH	Total Dissolved Solids	Nitrate as N
Electrical Conductivity	Bicarbonate as HCO_3	Magnesium
Alkalinity	Carbonate as CO_3	Manganese
Chloride	Sodium	33 metals (ICP- OES scan)
Fluoride	Potassium	
Sulphate	Calcium	

2.4.5 QUALITY ASSURANCE AND QUALITY CONTROL (QA / QC)

The accuracy of the chemical analysis can be assessed through calculating the electro neutrality for each sample. The electro neutrality (E.N) is calculated using the following equation:

$$E.N.[\%] = \frac{\sum cations\left(\frac{meq}{l}\right) - \sum anions\,(\frac{meq}{l})}{\sum cations\left(\frac{meq}{l}\right) + \sum anions\,(\frac{meq}{l})} * 100\%$$

Samples with a calculated E.N of less than 10% are considered to show an acceptable level of accuracy. Where samples have an E.N. above 10%, results / interpretation of results should be considered with caution.

2.4.6 LEGAL COMPLIANCE

The hydrocensus results suggest that groundwater and surface water in the area is predominantly used for domestic purposes (including drinking) and livestock watering. Therefore the groundwater and surface water quality results were compared against the following guidelines:

- South African National Standards (SANS: 241 (2015)) Water Quality Standards.
- Department of Water Affairs (DWAF) (now Department of Water and Sanitation [DWS]) Target Water Quality Range (TWQR) for Livestock Watering (2009).

The SANS 241: 2015 specifies limits in terms of four categories:

- Acute Health – poses an immediate unacceptable health risk if present at concentrations exceeding the numerical limits specified.
- Aesthetics – does not pose an unacceptable health risk if present at concentrations exceeding the numerical limits specified, but will taint water with respect to taste, odour and colour.
- Chronic Health – poses an unacceptable health risk if ingested over an extended period if present at concentrations exceeding the numerical limits specified.
- Operational – is essential for assessing the efficient operation of treatment systems and risks to infrastructure.

The DWAF TWQR for Livestock Watering refers to a ‘No Effect Range’. This is the range of concentrations at which the presence of each constituent would have no known or anticipated adverse effects on the suitability of water for livestock watering. These ranges were determined by assuming long-term continuous use (lifelong exposure) and incorporate a margin of safety.

3 RESULTS

The following section presents the results of the hydrocensus.

3.1 GENERAL OBSERVATIONS

SLR identified thirteen (13) boreholes during the hydrocensus and visited three (3) surface water monitoring points. Full details of all monitoring points, including photo logs are presented in Appendix A.

Observations were made regarding borehole construction, current status, and water application and usage estimates.

Key findings include:

- The depth of boreholes ranged from 10 m to over 100 m. Due to the geology of the area, boreholes and their yield are primarily associated with fractures.
- Primary groundwater uses at identified sites include domestic use, drinking water for livestock (cattle / game).
- Through discussions with one landowner (Johan Young), the water from the two boreholes located on his property (BH1 and BH2) taste differently. Water is pumped directly from the boreholes into either a jo-jo tank or into the house. No filtering or treatment is undertaken.
- Surface water courses and dams were dry during the hydrocensus. Surface water courses in the area are ephemeral and flow only during times of rainfall.

3.2 GROUNDWATER LEVELS AND FLOW

A total of nine (9) water levels were recorded in boreholes. Recorded groundwater levels ranged between 7.3 mbgl (WM11) and 19.4 mbgl (Johan Young BH1).

Ground surface levels at the borehole locations were extracted from geographic information systems (GIS) and used to convert the groundwater observations to metres above mean sea level (mamsl) datum. The data indicate that the overall inferred groundwater flow direction is towards the north-east and follows topography. Data are presented in Table 3-1.

TABLE 3-1: GROUNDWATER LEVELS RECORDED DURING THE HYDROCENSUS

Borehole ID	Borehole Depth (m)	Water Level (mbgl)	Groundwater Elevation (mamsl)
BH1	10.00*	Borehole obstructed at 10.00m	
BH3	19.00	13.31	978.19
BH4	51.00	13.65	979.38
BH5	37.00	18.70	971.94
BH6	>100	12.87	967.12

Borehole ID	Borehole Depth (m)	Water Level (mbgl)	Groundwater Elevation (mamsl)
BH7	>100	18.41	963.26
BH10	10.00	DRY	
BH11	~50.00	Inaccessible for water level measurements	
BH12	~60.00	Inaccessible for water level measurements	
WM11	25.00	7.31	996.73
WM6	27.00	11.78	995.80
J Young BH1	60.00	19.40	967.46
J Young BH2	60.00	13.80	972.64

Note: *blocked at 10m. True depth of borehole unknown

3.3 GROUNDWATER QUALITY

3.3.1 DATA VALIDATION

The E.N. calculation was applied to the groundwater samples. All but one sample showed an acceptable level of accuracy. The sample collected from BH3 showed an unacceptable error which is likely to be due to elevated ammonia recorded in the sample. Notwithstanding, the laboratory results are considered acceptable for the purposes of this assessment.

3.3.2 DATA REVIEW

The results of the eleven (11) groundwater water samples are presented in Table 3-2. Laboratory Analytical reports are included in Appendix B.

Significant findings include:

- Concentrations of the majority of elements were low and recorded at concentrations below relevant water quality standards.
- Concentrations of arsenic (As), iron (Fe), manganese (Mn), sodium (Na), nickel (Ni), electrical conductivity (EC), total dissolved solids (TDS), chloride (Cl), sulphate (SO_4) and ammonia (NH_4-N) were reported at concentrations in excess of one of the stipulated water quality standards (Section 2.4.6) in at least one sample and considered chemicals of concern (CoCs).
- **Arsenic (As)** concentrations ranged from below the laboratory detection limit of <0.01 mg/L and 0.037 mg/L (WM11). Concentrations were recorded above the SANS 241: 2015 water standard for chronic health (0.01 mg/L) in three (3) boreholes (BH3, MW6 and WM11), two (2) of which are located adjacent to the Union Section Mine Tailings storage facility (TSF).
- **Iron (Fe)** concentrations ranged from below the laboratory detection limit of <0.025 mg/L and 10.64 mg/L (BH3). Concentrations were recorded above the relevant water quality standards in seven (7) boreholes:
  - Concentrations recorded in three (3) boreholes (BH12, MW6 and WM11) were elevated above the SANS 241: 2015 limit for aesthetics (0.3 mg/L).

  - Concentrations recorded in (2) two boreholes (BH4 and BH5) were also elevated above the SANS 241: 2015 limit for chronic health (2 mg/L).
  - Concentrations recorded in two (2) boreholes (BH3 and BH7) were also elevated above the DWAF TWQR for livestock watering (10 mg/L).
- **Manganese (Mn)** concentrations ranged from below the laboratory detection limit of <0.025 mg/L and 1.22 mg/L (BH5). Concentrations were recorded above the relevant water quality standards in four (4) boreholes:
  - The concentration recorded in BH4 was above the SANS 241: 2015 limit for aesthetics (0.1 mg/L).
  - Concentrations recorded in three (3) boreholes (BH3, BH5 and BH7) were elevated above the SANS 241: 2015 limit for chronic health (0.4 mg/L).
- **Sodium (Na)** concentrations ranged between 31 mg/L in Johan Young BH2 and 368 mg/L in WM11. Concentrations recorded in the two (2) boreholes located adjacent to the Union Section Mine TSF (MW6 and WM11) were elevated above the SANS 241: 2015 limit for aesthetics (200 mg/L).
- **Nickel (Ni)** concentrations ranged from below the laboratory detection limit of <0.01 mg/L and 0.071 mg/L in BH3 which exceeded the SANS 241: 2015 DWS for chronic health (0.07 mg/L).
- **Electrical conductivity (EC)** ranged between 70.4 mS/m in BH7 and 484 mS/m in WM11. Concentrations in three (3) boreholes (MW6, WM11 and J Young BH1) exceeded the SANS 241: 2015 DWS for aesthetics (170 mS/m).
- **Total Dissolved Solids (TDS)** ranged between 458 mg/L in BH6 and 3646 mg/L in WM11. Concentrations in three (3) boreholes (MW6, WM11 and J Young BH1) exceeded the SANS 241: 2015 DWS for aesthetics (1200 mg/L).
- **Chloride (Cl)** concentrations ranged between 18 mg/L in BH7 to 1041 mg/L in WM11. Concentrations in four (4) boreholes (BH4, MW6, WM11 and J Young BH1) exceeded the SANS 241: 2015 DWS for aesthetics (300 mg/L).
- **Sulphate (SO_4)** concentrations ranged from below the laboratory detection limit of <5 mg/L to 991 mg/L in WM11. Concentrations were recorded above the relevant water quality standards in three (3) boreholes
  - The concentration in J Young BH1 exceeded the SANS 241: 2015 DWS for aesthetics (250 mg/L).
  - Concentrations recorded in boreholes MW6 and WM11 exceeded the SANS 241: 2015 DWS for acute health (500 mg/L). Boreholes are located adjacent to the Union Section Mine TSF.
- **Ammonia (NH_4-N)** concentrations ranged from below the laboratory detection limit of <0.2 mg/L and 61 mg/L in BH3, although the concentration recorded in BH3 is significantly higher than all other samples. Excluding the concentration of 61 mg/L, the maximum concentration recorded was 13 mg/L in BH7.

TABLE 3-2: GROUNDWATER QUALITY RESULTS FOR THE SIYANDA HYDROCENSUS SAMPLES

BH ID	Al (mg/L)	As (mg/L)	B (mg/L)	Ba (mg/L)	Be (mg/L)	Bi (mg/L)	Ca (mg/L)	Cd (mg/L)	Co (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Hg (mg/L)	K (mg/L)	Li (mg/L)	Mg (mg/L)	Mn (mg/L)	Mo (mg/L)	Na (mg/L)	Ni (mg/L)
DWAF TWQR	**5.00**	**1.00**	**5.00**				**1000**	**0.01**	**1.00**		**0.50**	**10**				**500**	**10**	**0.01**	**2000**	**1.00**
SANS 241: OP	**0.3**																			
SANS 241: AS												**0.3**					**0.1**		**200**	
SANS 241: AH																				
SANS 241: CH		**0.01**	**2.4**	**0.7**				**0.03**	**0.5**	**0.05**	**2**	**2**	**0.006**				**0.4**			**0.07**
BH3	<0.100	0.014	0.060	0.286	<0.010	<0.010	35	<0.010	<0.010	<0.010	<0.010	10.64	<0.010	9.1	<0.010	25	0.568	<0.010	65	0.071
BH4	<0.100	<0.010	0.074	0.179	<0.010	<0.010	54	<0.010	<0.010	<0.010	<0.010	8.46	<0.010	3.1	<0.010	25	0.177	<0.010	200	0.057
BH5	<0.100	<0.010	0.048	0.099	<0.010	<0.010	96	<0.010	<0.010	<0.010	<0.010	3.56	<0.010	3.8	<0.010	45	1.22	<0.010	137	0.026
BH6	<0.100	<0.010	0.041	0.071	<0.010	<0.010	6	<0.010	<0.010	<0.010	<0.010	0.20	<0.010	1.9	<0.010	21	<0.025	<0.010	133	<0.010
BH7	<0.100	<0.010	0.083	0.212	<0.010	<0.010	32	<0.010	<0.010	<0.010	<0.010	10.15	<0.010	5.2	<0.010	10	0.430	<0.010	99	0.066
BH11	<0.100	<0.010	0.018	0.034	<0.010	<0.010	38	<0.010	<0.010	<0.010	<0.010	0.183	<0.010	1.4	<0.010	150	<0.025	<0.010	79	<0.010
BH12	<0.100	<0.010	0.046	0.108	<0.010	<0.010	103	<0.010	<0.010	<0.010	<0.010	0.387	<0.010	2.2	<0.010	48	<0.025	<0.010	83	<0.010
MW6	<0.100	0.021	0.112	0.060	<0.010	<0.010	307	<0.010	<0.010	<0.010	<0.010	1.02	<0.010	1.4	<0.010	221	0.056	<0.010	363	0.019
WM11	<0.100	0.037	0.168	0.071	<0.010	<0.010	397	<0.010	<0.010	<0.010	<0.010	1.41	<0.010	4.3	<0.010	231	<0.025	<0.010	368	0.024
J Young BH1	<0.100	<0.010	0.029	0.051	<0.010	<0.010	43	<0.010	<0.010	<0.010	<0.010	0.072	<0.010	2.8	<0.010	327	<0.025	<0.010	177	<0.010
J Young BH2	<0.100	<0.010	0.013	0.038	<0.010	<0.010	3	<0.010	<0.010	<0.010	0.126	<0.025	<0.010	1.1	<0.010	146	<0.025	<0.010	31	<0.010

BH ID	P (mg/L)	Pb (mg/L)	Sb (mg/L)	Se (mg/L)	Si (mg/L)	Sn (mg/L)	Sr (mg/L)	Ti (mg/L)	U (mg/L)	V (mg/L)	Zn (mg/L)	pH	Electrical Conductivity (mS/m)	Total Dissolved Solids (mg/L)	Total Alkalinity as $CaCO_3$ (mg/L)	Chloride as Cl (mg/L)	Sulphate as SO_4 (mg/L)	Fluoride as F (mg/L)	Nitrate as N (mg/L)	Nitrite as N (mg/L)	Free & Saline Ammonia as N (mg/L)
DWAF TWQR		**0.10**		**50**						**1.00**	**20**					**1500**	**1000**	**2**	**100**		
SANS 241: OP												**5 - 9.7**									
SANS 241: AS											**5**		**170**	**1200**		**300**	**250**				**1.5**
SANS 241: AH																	**500**		**11**	**0.9**	
SANS 241: CH		**0.01**	**0.02**	**0.04**					**0.03**	**0.2**								**1.5**			
BH3	0.266	<0.010	<0.010	0.012	6.3	<0.010	0.368	0.071	<0.010	<0.010	0.111	7.9	123	526	620	38	5	0.5	<0.2	<0.1	61
BH4	0.020	<0.010	<0.010	<0.010	1.3	<0.010	0.590	0.082	<0.010	<0.010	0.033	8.2	144	802	240	341	<5	0.3	0.2	<0.1	1
BH5	0.402	<0.010	<0.010	<0.010	7.0	<0.010	0.561	0.134	<0.010	<0.010	0.011	8.3	124	810	568	140	10	0.5	0.2	<0.1	9
BH6	0.021	<0.010	<0.010	<0.010	0.3	<0.010	0.035	0.010	<0.010	<0.010	<0.010	8.8	83.8	458	196	110	79	1.1	<0.2	<0.1	3.4
BH7	0.391	<0.010	<0.010	<0.010	4.6	<0.010	0.231	0.047	<0.010	<0.010	0.061	7.7	70.4	482	352	18	<5	1.4	<0.2	<0.1	13
BH11	0.024	<0.010	<0.010	<0.010	5.7	<0.010	0.245	0.059	<0.010	<0.010	0.010	8.4	153	940	400	231	147	0.2	1.4	<0.1	0.2
BH12	0.012	<0.010	<0.010	<0.010	7.9	<0.010	0.580	0.158	<0.010	<0.010	2.42	8.1	117	772	432	128	54	0.9	3.8	<0.1	<0.2
MW6	0.024	<0.010	<0.010	<0.010	5.8	<0.010	1.63	0.494	<0.010	0.023	0.034	8.1	423	3094	524	892	816	<0.2	0.6	<0.1	0.2
WM11	0.024	<0.010	<0.010	0.026	5.9	<0.010	1.83	0.647	<0.010	0.011	0.039	8.0	484	3646	464	1041	991	<0.2	0.5	<0.1	0.2
J Young BH1	0.017	<0.010	<0.010	<0.010	29	<0.010	0.362	0.040	<0.010	0.017	0.010	8	323	2116	464	681	382	<0.2	0.2	<0.1	0.2
J Young BH2	<0.010	<0.010	<0.010	<0.010	31	<0.010	0.083	<0.010	<0.010	0.018	0.037	8.5	104	628	600	34	15	<0.2	2.2	0.1	0.3

Note: Highlighted cells indicate the water quality standard that has been exceeded.
DWAF TWQR refers to DWAF Target Water Quality Range for Livestock Watering
SANS 241: OP – Operational. AS – Aesthetics. AH – Acute Heath. CH – Chronic Health. 2015 Standards

3.3.3 HYDROCHEMCIAL FACIES

As water flows through an aquifer it assumes a diagnostic chemical composite as a result of interaction with the lithologic framework. The term hydrochemical facies refers to bodies of groundwater, within an aquifer, that differ in their chemical composition. The facies are a function of the lithology, solution kinetics and flow patterns of the aquifer (Back, 1960 and 1966 as cited in Fetter, 2001) and can assist in determining whether water has been impacted by anthropogenic activities

Hydrochemical facies are classified based on the dominant ions. The hydrochemical facies for the eleven (11) groundwater samples are presented in Table 3-3 and presented graphically as a piper diagram in Figure 3-1.

The data show that the majority of samples are dominated by the bicarbonate anion which indicates relatively young or fresh groundwater.

TABLE 3-3: HYDROCHEMCIAL FACIES OF THE SIYANDA GROUNDWATER SAMPLES

Borehole ID	Hydrochemical Facies	Description
BH3	Na-HCO_3	HCO_3 indicates relatively young or fresh groundwater
BH4	Na-Cl-HCO_3	HCO_3 indicates relatively young or fresh groundwater
BH5	Na-Ca-Mg-HCO_3-Cl	HCO_3 indicates relatively young or fresh groundwater
BH6	Na-Mg-HCO_3-Cl	HCO_3 indicates relatively young or fresh groundwater
BH7	Na-Ca-HCO_3	HCO_3 indicates relatively young or fresh groundwater
BH11	Mg-HCO_3-Cl	HCO_3 indicates relatively young or fresh groundwater
BH12	Ca-Mg-Na-HCO_3-CL	HCO_3 indicates relatively young or fresh groundwater
J Young BH1	Mg-Na-Cl-SO_4-HCO_3	HCO_3 indicates relatively young or fresh groundwater High SO_4, may be due to SO_4 fertiliser (ammonium sulphate), oxidation of sulphide minerals, H_2S oxidation.
J Young BH2	Mg-HCO_3	HCO_3 indicates relatively young or fresh groundwater
WM6	Mg-Na-Ca-Cl-SO_4-HCO_3	HCO_3 indicates relatively young or fresh groundwater High SO_4, may be due to SO_4 fertiliser (ammonium sulphate), oxidation of sulphide minerals, H_2S oxidation. Possible impact from Union Section Mine TSF.
WM11	Ca-Mg-Na-Cl-SO_4	High SO_4, may be due to SO_4 fertiliser (ammonium sulphate), oxidation of sulphide minerals, H_2S oxidation. Possible impact from Union Section Mine TSF.

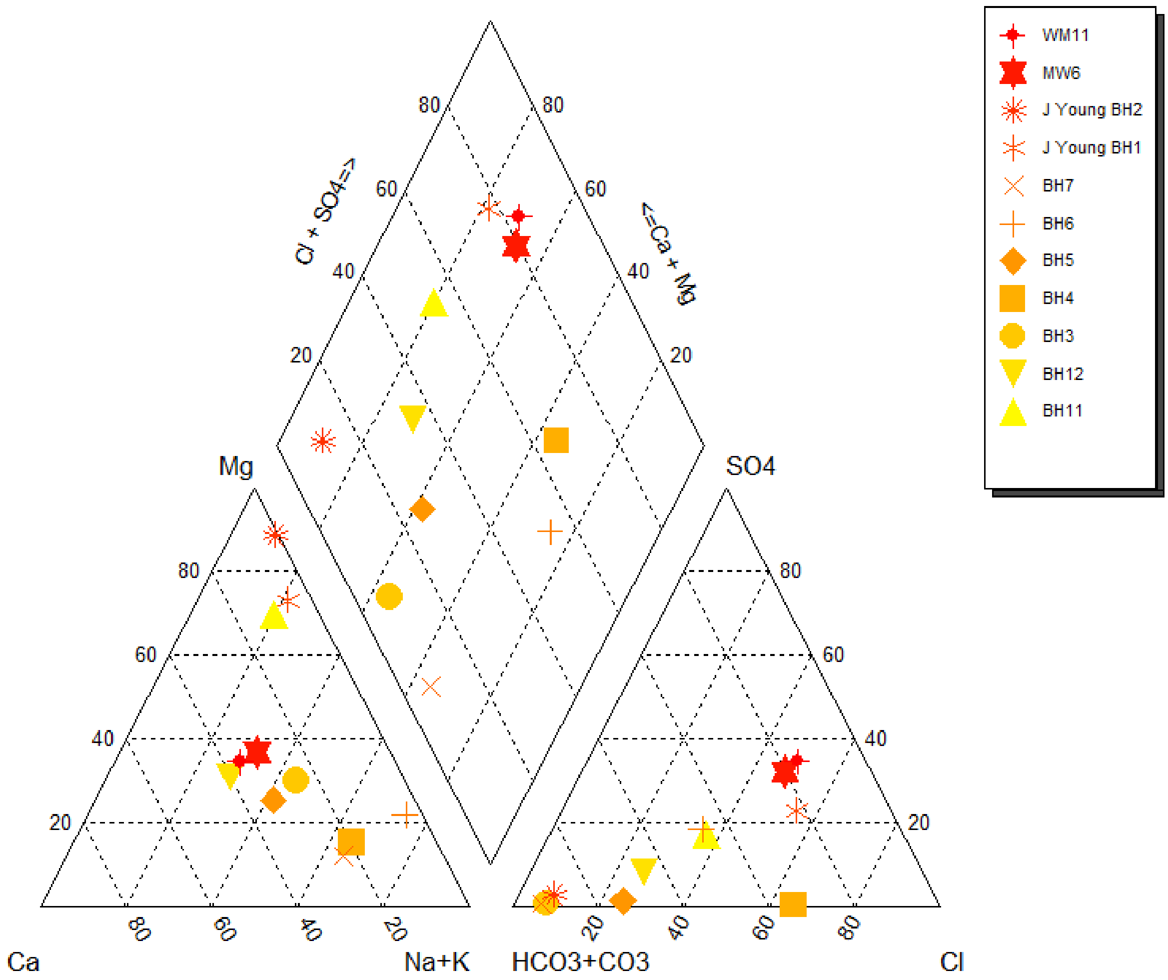

FIGURE 3-1: PIPER DIAGRAM FOR THE SIYANDA HYDROCENSUS GROUNDWATER SAMPLES

3.4 DISCUSSION OF RESULTS

Concentrations of EC, TDS, Cl and SO_4 are all elevated in three (3) boreholes; MW6 and WM11, located adjacent to the Union Section Mine and Johan Young BH1. The elevated concentrations in MW6 and WM11, could at first be considered to be a result of the seepage from the Union Section Mine TSF, however similar concentrations, albeit lower for all the aforementioned parameters, are recorded in Johan Young BH1 which is used for domestic purposes without any treatment of filtering which indicates that for some boreholes, groundwater is naturally enriched in these elements.

Through discussions with Johan Young, the taste of the water from his two boreholes are very different. The two boreholes are located approximately 300m away from each other and drilled to approximately the same depth of 60 m. Based on the geological plan (Figure 3-2) the geology appears to be the same, although BH2 may penetrate, or be on the contact of the magnetite gabbro. The water quality results show a difference for key parameters as presented in Table 3-4.

TABLE 3-4: COMPARISON OF KEY PARAMETERS IN WATER FROM JOHAN YOUNG'S BH1 AND BH2

Parameter	Johan Young BH1	Johan Young BH2
pH	8	8.5
Calcium (mg/L)	43	3
Potassium (mg/L)	2.8	1.1
Magnesium (mg/L)	327	146
Sodium (mg/L)	177	31
Electrical Conductivity (mS/m)	323	104
Total Dissolved Solids (mg/L)	2116	628
Total Alkalinity as $CaCO_3$ (mg/L)	464	600
Chloride (mg/L)	681	34
Sulphate (mg/L)	382	15

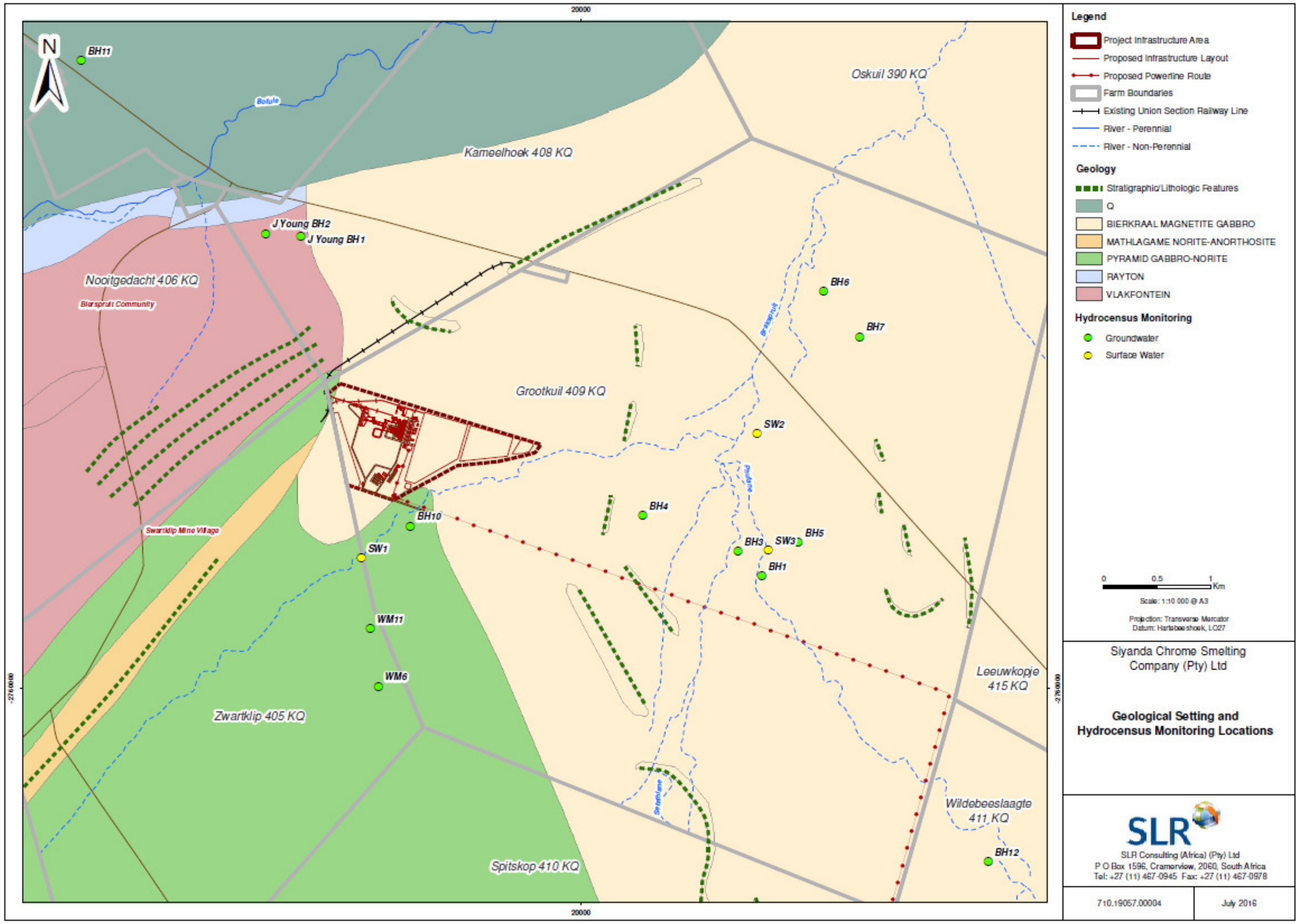

FIGURE 3-2: GEOLOGICAL SETTING AND HYDROCENSUS LOCATIONS

4 SUMMARY AND CONCLUSION

SLR Consulting (Africa)(Pty) Limited was commissioned by SCSC to undertake a hydrocensus in the vicinity of the Siyanda Ferrochrome Project Area, near Northam in the Limpopo Province of South Africa.

This report provides the results and observations recorded for the hydrocensus carried out during July and August 2015.

4.1 GROUNDWATER

SLR visited thirteen (13) boreholes within a 5 km radius of the Siyanda Ferrochrome Project Area. Observations regarding borehole location, construction, water level and status and current usage were recorded.

Of the thirteen (13) boreholes, nine (9) water levels were observed and considered accurate. The remaining water levels were unable to be measured due to the presence of installed pumps or other obstructions within the boreholes. Groundwater levels ranged between 7.3 mbgl (WM11) and 19.4 mbgl (Johan Young BH1).

The data indicate that the overall inferred groundwater flow direction is towards the north-east and follows topography.

Groundwater samples, for quality purposes, were collected from eleven (11) of the boreholes. Samples were analysed at an accredited laboratory.

Groundwater is the predominant water supply source for domestic uses (including drinking) and livestock watering within the project area, therefore, the groundwater quality results were compared against SANS 241: 2015 Drinking Water Quality Standards (DWS) and DWAF Target Water Quality Range (TWQR) for Livestock Watering.

Based on the hydrocensus results, the following is concluded:

- Concentrations of the majority of elements were low and recorded at concentrations below relevant water quality standards.
- Concentrations of arsenic (As), iron (Fe), manganese (Mn), sodium (Na), nickel (Ni), electrical conductivity (EC), total dissolved solids (TDS), chloride (Cl), sulphate (SO_4) and ammonia (NH_4-N) were reported at concentrations in excess of one of the stipulated water quality standards.

Of particular interest:

- Concentrations of EC, TDS, Cl and SO_4 are all elevated in three (3) boreholes; MW6 and WM11, located adjacent to the Union Section Mine and Johan Young BH1. The elevated concentrations in MW6 and WM11, could at first be considered to be a result of the seepage from the Union Section Mine TSF, however similar concentration, albeit lower for all the aforementioned parameters, are recorded in Johan Young BH1 which is used for domestic purposes without any treatment of filtering which indicates that for some boreholes, groundwater is naturally enriched, and is most likely to be due to the geology
- Through discussions with Johan Young, the taste of the water from his two boreholes are very different. The two boreholes are located approximately 300m away from each other and drilled to approximately the same depth of 60 m. The geological map suggests the underlying geology is the same.

4.2 SURFACE WATER

SLR visited three (3) surface water monitoring points which consisted of two (2) surface water course and one (1) dam. All monitoring points were dry during the hydrocensus. Surface water courses in the area are ephemeral and flow only during times of rainfall.

5 RECOMMENDATIONS

Based on the outcome of the hydrocensus report, the following recommendations are made:

- Baseline water monitoring should be undertaken, based on the hydrocensus, to establish the characteristics (levels and quality) of water prior to the smelter becoming operational. Water monitoring should be continued throughout the life of the smelter and results compared to baseline conditions to assess the potential changes in groundwater characteristics over time. It is noted that a monitoring programme has been set out in the Groundwater Assessment Report.

Jenny Ellerton

Jenny Ellerton	**Caitlin Hird**	**Mihai Muresan**
(Report Author)	**(Project Manager)**	**(Project Reviewer)**

REFERENCES

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APPENDIX A: HYDROCENSUS DATA

HYDROCENSUS DATABASE
Project Name: Siyanda Project

Sampling Point	Type	Date	Farm Name	Site Type (BH, stream, dug pit etc.)	Site Status (In Use / Not in use / Destroyed)	Site purpose	Water application (irrigation, animals, domestic etc.	Coordinate Method	Lattitude	Longitude	Coordinate Accuracy	Water Level measured (Yes / No)
BH1	GW	2015/07/14	Grootkuil 3	BH	Not in use	Game farm	None	GPS	-24.93572220	27.21472220	1m	No
BH3	GW	2015/07/14	Grootkuil 3	BH	Not in use	Game farm	None	GPS	-24.93366670	27.21250000	1m	Yes
BH4	GW	2015/07/14	Grootkuil 3	BH	In use	Game farm	None	GPS	-24.93066670	27.20369440	1m	Yes
BH5	GW	2015/07/14	Grootkuil 3	BH	Not in use	Game farm	None	GPS	-24.93291670	27.21808330	1m	Yes
BH6	GW	2015/07/14	Grootkuil RE	BH	Not in use	Farm	None (will be used for animals)	GPS	-24.91172220	27.22038880	1m	Yes
BH7	GW	2015/07/15	Grootkuil RE	BH	Not in use	Farm	None (will be used for animals)	GPS	-24.91552780	27.22375000	1m	Yes
BH10	GW	2015/07/15	Grootkuil (Union mine)	BH	Not in use	Game farm	None	GPS	-24.93158330	27.18219440	1m	No
BH11	GW	2015/07/15	Unknown	BH	In Use	Farm/guesthouse	Domestic	GPS	-24.89233330	27.15169440	1m	No
BH12	GW	2015/07/16	Wildebeestlagte	BH	In use	Game farm	Domestic	GPS	-24.95983330	27.23572220	5m	No
Johan Young BH1	GW	2015/08/06		BH	In USe	Farm	Drinking Water, Irrigation, Animals	GPS	-24.90711800	27.17203700	3m	Yes
Johan Young BH2	GW	2015/08/06		BH	Un Use	Farm	Drinking Water, Irrigation, Animals	GPS	-24.90688000	27.16878600	3m	Yes
WM11	GW	2015/07/15	Union Mine	BH	Not in use	TSF monitoring BH	None	GPS	-24.94025000	27.17850000	3m	Yes
WM6	GW	2015/07/15	Union Mine	BH	Not in use	TSF monitoring BH	None	GPS	-24.94511110	27.17927770	1m	Yes
SW1	SW	2015/07/15	Grootkuil	SW1	Not in use	Ephemeral stream	None	GPS	-24.93425000	27.17766666	1m	N/A
SW2	SW	2015/07/16	Grootkuil	SW2	Not in use	Small dam	Livestock watering	GPS	-24.92375000	27.21511111	1m	N/A
SW3	SW	2015/07/14	Grootkuil 3	Stream bed	Not in use	Ephemeral stream	None	GPS	-24.93355560	27.21533333	1m	N/A

HYDROCENSUS DATABASE
Project Name: Siyanda Project

Sampling Point	Static water Level (m)	Datum (above ground level or top of casing)	Water Level Status (Dry / Flowing / Affected by pumping / Obstructed / Pumping / Recovering / Static)	Were sample taken(Yes / No)	Sample Number	Sampling Method (pump / bailer)	Instrument	pH	EC (uS/cm)	TDS	Temp (°C)
BH1	N/A	N/A	N/A	No	-	-	-	-	-	-	-
BH3	13.31	Below ground level	Static	Yes	BH3	Pump	Exstix	7.3	1444	990	
BH4	13.65	Below ground level	Static	Yes	BH4	Bailer	Exstix	7.33	1632	1144	
BH5	18.7	Below ground level	Static	Yes	BH5	Bailer	Exstix	7.06	1402	981	
BH6	12.87	Below ground level	Static	Yes	BH6	Bailer	Exstix	8.95	851	596	
BH7	18.41	Below ground level	Static	Yes	BH7	Bailer	Exstix	7.35	728	509	
BH10	N/A	N/A	N/A	No	-	-	-	-	-	-	-
BH11	N/A	N/A	N/A	Yes	BH11	Tap	Exstix	7.76	1572	1099	
BH12	N/A	N/A	N/A	Yes	BH12	Tap	Exstix	7.21	1236	864	
Johan Young BH1	19.4	Below Top of Well	Static (had been pumped in AM)	Yes 09:25	J Young BH1	From Tap in House	Exstix	7.41	3480	2380	16.8
Johan Young BH2	13.8	Below Top of Well	Static	Yes 09:45	J Young BH2	From Tap in House	Exstix	7.84	1118	783	16.2
WM11	7.31	Below ground level	Static	Yes	WM11	Bailer	Exstix	6.83	7290	5110	
WM6	11.78	Below ground level	Static	Yes	WM6	Bailer	Exstix	6.81	6480	4510	
SW1	N/A	N/A	N/A	No	-	-	-	-	-		-
SW2	N/A	N/A	N/A	No	-	-	-	-	-		-
SW3	N/A	N/A	N/A	No	-	-	-	-	-		-

HYDROCENSUS DATABASE
Project Name: Siyanda Project

Sampling Point	Water Quality remarks	Date drilled	Borehole Condition	Borehole Depth (m)	Approximate Yield (L/s)	Casing depth (m)	Casing material	Casing inside diameter (mm)	Casing wall thickness (mm)	Pipe diameter (mm)	Pipe material
BH1	-	N/A	Obstructed	-	-	-	steel	170	20	-	-
BH3	Black colour, foul odour (dead rodent)	N/A	Good	19m	N/A	N/A	Steel	170	20	N/A	N/A
BH4	Turbid, brown colour, earthen odour	N/A	Good	51m	N/A	N/A	Steel	170	20	N/A	N/A
BH5	Slightly turbid, light brown, earthen odour	N/A	Good	37m	N/A	N/A	Steel	170	20	N/A	N/A
BH6	Slightly turbid, brownish colour, no odour	Apr-15	Good	130m	Unknown	24	Steel	170	20	N/A	N/A
BH7	Blackish/brown colour, turbid, foul odour (hydrocarbons and remediation fluids)	Apr-15	Good	>100	Unknown	24	Steel	170	20	N/A	N/A
BH10	-	N/A	Good	10m	N/A	N/A	Steel	170	20	N/A	N/A
BH11	Clear, no odour	N/A	Good	50	Unknown	N/A	Steel	170	20	60	Plastic
BH12	Clear, no odour	1998	Good	60	Unknown (good)	N/A	Steel	170	20	60	Plastic
Johan Young BH1	Clean	2003	Good	60	48000L/HR	Unknown	Steel	-	-	-	-
Johan Young BH2	Clean	Pre 1980s	Good	60m	25000L/HR	Unknown	Steel	-	-	-	-
WM11	Bright orange colour, high turbidity, no odour	N/A	Good	25	Unknown	N/A	Steel	170	20	N/A	N/A
WM6	Clear, no odour	N/A	Good	27	Unknown	N/A	Steel	170	20	N/A	N/A
SW1	-	-	-	-	-	-	-	-	-	-	-
SW2	-	-	-	-	-	-	-	-	-	-	-
SW3	-	-	-	-	-	-	-	-	-	-	-

HYDROCENSUS DATABASE
Project Name: Siyanda Project

Sampling Point	Pump type (Submersible / Mono / Handpump / Not equipped / Powerhead / Windpump / other)	Pump condition	Other pump details	Pump Manufacturer	Is there a pumphouse (Yes / No)	Type (Fence / Fence with gate / Locked hut / Open hut / Shelter)	Engine type (Diesel / Electric / Hand / Wind / Other)	Engine Condition (Good / Moderate / Poor)	Farm Owner
BH1		-	-	-	No	-	-	-	-
BH3	None	N/A	N/A	N/A	No	N/A	N/A	N/A	-
BH4	None	N/A	N/A	N/A	No	N/A	N/A	N/A	-
BH5	None	N/A	N/A	N/A	No	N/A	N/A	N/A	-
BH6	None	N/A	N/A	N/A	No	N/A	N/A	N/A	Stefaan
BH7	None	N/A	N/A	N/A	No	N/A	N/A	N/A	Stefaan
BH10	None	N/A	N/A	N/A	No	N/A	N/A	N/A	Anglo american
BH11	Mono	Good	Connected to jojo tank	N/A	No	N/A	N/A	N/A	Z.J. Young
BH12	Other	Ok	-	Ralister & Co Ltd	Yes	Open hut	Diesel	moderate	Masood Muhammed
Johan Young BH1	-	Good	Pump Depth 40m	-	No	N/A	-	-	Johan Young
Johan Young BH2		Good	Pump Depth 40m	-	Collapse - one being Built	N/A	-	-	-
WM11	None	N/A	N/A	N/A	No	N/A	N/A	N/A	Anglo american
WM6	None	N/A	N/A	N/A	No	N/A	N/A	N/A	Anglo american
SW1	-	-	-	-	-	-	-	-	-
SW2	-	-	-	-	-	-	-	-	-
SW3	-	-	-	-	-	-	-	-	-

HYDROCENSUS DATABASE
Project Name: Siyanda Project

Sampling Point	Other details of farm owner	Locality Description (e.g. Stand nr/ Address etc.)
BH1	-	Grootkuil Portion 3
BH3	-	Grootkuil Portion 3
BH4	-	Grootkuil Portion 3
BH5	-	Grootkuil Portion 3
BH6	-	Grootkuil RE
BH7	-	Grootkuil RE
BH10	Union Mine	Grootkuil. Union Mine Game farm
BH11	-	-
BH12	-	Wildebeestlagte portion 10. Phumane Game farm
Johan Young BH1	johan.mandarin@gmail.com	-
Johan Young BH2	vtkoekemoer@gmail.com	-
WM11	Union Mine	Union Mine
WM6	Union Mine	Union Mine
SW1	-	Grootkuil
SW2	-	Grootkuil
SW3	-	Grootkuil Portion 3

HYDROCENSUS DATABASE
Project Name: Siyanda Project

Sampling Point	Comments (Photo taken etc.)
BH1	Photo taken. BH obstructed at 10m
BH3	Photo taken. BH purged 6m in 2 minutes.
BH4	Photo taken. BH bailed as BH is partially blocked with a welded piece of metal. Pumps into a dam
BH5	Photo taken. Borehole not accessible by vehicle.
BH6	Photo taken. BH closed on arrival Could partailly open to fit a bailer.
BH7	Photo taken. BH closed on arrival Could partailly open to fit a bailer.
BH10	Photo taken. BH Dry.
BH11	Photo taken.
BH12	Photo taken
Johan Young BH1	Photo Taken. Water pumped straight inot JoJO tank and then into house. Water level lower than he expected - he thought it was around 12m. Did pump in am, but normally recovers instadntly., High yielding BH
Johan Young BH2	Photo taken. Water tastes very different then BH1. Water pumped straight inot JoJO tank and then into house
WM11	Photo taken. TSF monitoring borehole. Used purge bailer.
WM6	Photo taken. TSF monitoring borehole. Used purge bailer.
SW1	Photo taken. Stream not flowing.
SW2	Photo taken. No water present
SW3	Photo taken. Stream not flowing.

Siyanda Ferrochrome Project: Hydrocensus Photolog

GROUNDWATER					
Borehole	**Farm**	**Latitude**	**Longitude**	**Use**	**Photo**
BH1	Grootkuil 3	-24.9357222	27.2147222	Not in use	
BH3	Grootkuil 3	-24.9336667	27.2125000	Not in use	

<table>
<tr><th colspan="6">GROUNDWATER</th></tr>
<tr><th>Borehole</th><th>Farm</th><th>Latitude</th><th>Longitude</th><th>Use</th><th>Photo</th></tr>
<tr><td>BH4</td><td>Grootkuil 3</td><td>-24.9306667</td><td>27.2036944</td><td>Livestock watering</td><td></td></tr>
<tr><td>BH5</td><td>Grootkuil 3</td><td>-24.9329167</td><td>27.2180833</td><td>None</td><td></td></tr>
</table>

GROUNDWATER					
Borehole	**Farm**	**Latitude**	**Longitude**	**Use**	**Photo**
BH6	Grootkuil 0	-24.9117222	27.2203888	None	
BH7	Grootkuil 0	-24.9155278	27.2237500	None	-
BH10	Grootkuil 4 (Swartklip Mine)	-24.9315833	27.1821944	None	-

GROUNDWATER					
Borehole	**Farm**	**Latitude**	**Longitude**	**Use**	**Photo**
BH11	Nooitgedacht	-24.8923333	27.1516944	Domestic	
BH12	Wildebeestlagte	-24.9598333	27.2357222	Domestic	

GROUNDWATER					
Borehole	**Farm**	**Latitude**	**Longitude**	**Use**	**Photo**
WM6	Swartklip Mine	-24.9451111	27.1792777	Monitoring of TSF	
WM11	Swartklip Mine	-24.9402500	27.1785000	Monitoring of TSF	

GROUNDWATER					
Borehole	**Farm**	**Latitude**	**Longitude**	**Use**	**Photo**
Johan Young BH1	Kameelhoek 3	-24.9071180	27.1720370	Domestic and Livestock Watering	

<table>
<tr><th colspan="6">GROUNDWATER</th></tr>
<tr><th>Borehole</th><th>Farm</th><th>Latitude</th><th>Longitude</th><th>Use</th><th>Photo</th></tr>
<tr><td>Johan Young BH2</td><td>Kameelhoek 3</td><td>-24.9068800</td><td>27.1687860</td><td>Domestic and Livestock Watering</td><td></td></tr>
</table>

SURFACE WATER					
SW ID	**Details**	**Latitude**	**Longitude**	**Details**	**Photo**
SW1	Grootkuil 4 / Swartklip Mine	-24.9342500	27.17766666	Ephemeral stream / Weir from Mine	
SW2	Grootkuil 0	-24.9237500	27.21511111	Small dam – Livestock Watering	

<table>
<tr><th colspan="6">SURFACE WATER</th></tr>
<tr><th>SW ID</th><th>Details</th><th>Latitude</th><th>Longitude</th><th>Details</th><th>Photo</th></tr>
<tr><td>SW3</td><td>Grootkuil 3</td><td>-24.9335556</td><td>27.21533333</td><td>Ephemeral stream</td><td></td></tr>
</table>

APPENDIX B: LABORATORY CERTIFICATES

WATERLAB (Pty) Ltd
Reg. No.: 1983/009165/07 V.A.T. No.: 4130107891

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SANAS Accredited Testing Laboratory
No. T0391

CERTIFICATE OF ANALYSES
GENERAL WATER QUALITY PARAMETERS

Date received: 2015 - 07 - 20
Date completed: 2015 - 08 – 12
Project number: 139
Report number: 53334
Order number: 0230

Client name: SLR Consulting (Africa) (Pty) Ltd
Contact person: Mr. E. Louw
Ms. J. Ellerton

Address: P.O. Box 1596 Cramerview 2060
e-mail: elouw@slrconsulting.com
e-mail: jellerton@slrconsulting.com

Telephone: 011 326 4158
Facsimile: 011 326 4118
Mobile: 071 365 5538

Analyses in mg/ℓ (Unless specified otherwise)	**Method Identification**	**Sample Identification: Siyanda**				
		BH3	**BH4**	**BH5**	**BH6**	**BH7**
Sample Number		11300	11301	11302	11303	11304
pH – Value at 25°C	WLAB001	7.9	8.2	8.3	8.8	7.7
Electrical Conductivity in mS/m at 25°C	WLAB002	123	144	124	83.8	70.4
Total Dissolved Solids at 180°C *	WLAB003	526	802	810	458	482
Total Alkalinity as $CaCO_3$	WLAB007	620	240	568	196	352
Bicarbonate as HCO_3 *	WLAB023	756	293	692	239	429
Carbonate as CO_3 *	WLAB023	<5	<5	<5	<5	<5
Chloride as Cl *	WLAB046	38	341	140	110	18
Sulphate as SO_4 *	WLAB046	5	<5	10	79	<5
Fluoride as F	WLAB014	0.5	0.3	0.5	1.1	1.4
Nitrate as N *	WLAB046	<0.2	0.2	0.2	<0.2	<0.2
Nitrite as N *	WLAB046	<0.1	<0.1	<0.1	<0.1	<0.1
Free & Saline Ammonia as N *	WLAB046	61	1.0	9.0	3.4	13
ICP-MS Scan *	WLAB050	See Attached Report: 53334-A				
% Balancing *	---	93.1	97.0	98.9	96.7	98.4

A van de Wetering

Technical Signatory

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WATERLAB

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sanas Testing Laboratory
SANAS Accredited Testing Laboratory No. T0391

CERTIFICATE OF ANALYSES
GENERAL WATER QUALITY PARAMETERS

Date received: 2015 - 07 - 20
Date completed: 2015 - 08 – 12
Project number: 139
Report number: 53334
Order number: 0230

Client name: SLR Consulting (Africa) (Pty) Ltd

Contact person: Mr. E. Louw
Ms. J. Ellerton

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Telephone: 011 326 4158
Facsimile: 011 326 4118
Mobile: 071 365 5538

Analyses in mg/ℓ (Unless specified otherwise)	**Method Identification**	**Sample Identification: Siyanda**				
		BH11	**BH12**	**BH13**	**MW6**	**WM11**
Sample Number		11305	11306	11307	11308	11309
pH – Value at 25°C	WLAB001	8.4	8.1	8.6	8.1	8.0
Electrical Conductivity in mS/m at 25°C	WLAB002	153	117	101	423	484
Total Dissolved Solids at 180°C *	WLAB003	940	772	498	3 094	3 646
Total Alkalinity as $CaCO_3$	WLAB007	400	432	600	524	464
Bicarbonate as HCO_3 *	WLAB023	488	527	731	639	566
Carbonate as CO_3 *	WLAB023	<5	<5	<5	<5	<5
Chloride as Cl *	WLAB046	231	128	38	892	1 041
Sulphate as SO_4 *	WLAB046	147	54	14	816	991
Fluoride as F	WLAB014	0.2	0.9	<0.2	<0.2	<0.2
Nitrate as N *	WLAB046	1.4	3.8	2.2	0.6	0.5
Nitrite as N *	WLAB046	<0.1	<0.1	<0.1	<0.1	<0.1
Free & Saline Ammonia as N *	WLAB046	0.2	<0.2	<0.2	0.2	0.2
ICP-MS Scan *	WLAB050	See Attached Report: 53334-A				
% Balancing *	---	99.9	96.7	99.0	96.7	96.2

*** = Not SANAS Accredited**
Tests marked "Not SANAS Accredited" in this report are not included in the SANAS Schedule of Accreditation for this Laboratory.

A van de Wetering

Technical Signatory

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Project Number : 139
Client : SLR Consulting
Report Number : 53334-A

Sample Origin	Sample ID	Ag (mg/L)	Al (mg/L)	As (mg/L)	Au (mg/L)	B (mg/L)	Ba (mg/L)	Be (mg/L)	Bi (mg/L)	Ca (mg/L)	Cd (mg/L)	Ce (mg/L)	Co (mg/L)
BH3	11300	<0.010	<0.100	0.014	<0.010	0.060	0.286	<0.010	<0.010	35	<0.010	<0.010	<0.010
BH4	11301	<0.010	<0.100	<0.010	<0.010	0.074	0.179	<0.010	<0.010	54	<0.010	<0.010	<0.010
BH5	11302	<0.010	<0.100	<0.010	<0.010	0.048	0.099	<0.010	<0.010	96	<0.010	<0.010	<0.010
BH6	11303	<0.010	<0.100	<0.010	<0.010	0.041	0.071	<0.010	<0.010	6	<0.010	<0.010	<0.010
BH7	11304	<0.010	<0.100	<0.010	<0.010	0.083	0.212	<0.010	<0.010	32	<0.010	<0.010	<0.010
BH11	11305	<0.010	<0.100	<0.010	<0.010	0.018	0.034	<0.010	<0.010	38	<0.010	<0.010	<0.010
BH12	11306	<0.010	<0.100	<0.010	<0.010	0.046	0.108	<0.010	<0.010	103	<0.010	<0.010	<0.010
BH13	11307	<0.010	<0.100	<0.010	<0.010	0.068	0.058	<0.010	<0.010	3	<0.010	<0.010	<0.010
MW6	11308	<0.010	<0.100	0.021	<0.010	0.112	0.060	<0.010	<0.010	307	<0.010	<0.010	<0.010
WM11	11309	<0.010	<0.100	0.037	<0.010	0.168	0.071	<0.010	<0.010	397	<0.010	<0.010	<0.010

Sample Origin	Sample ID	Cr (mg/L)	Cs (mg/L)	Cu (mg/L)	Dy (mg/L)	Er (mg/L)	Eu (mg/L)	Fe (mg/L)	Ga (mg/L)	Gd (mg/L)	Ge (mg/L)	Hf (mg/L)	Hg (mg/L)
BH3	11300	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	11	0.052	<0.010	<0.010	<0.010	<0.010
BH4	11301	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	8.46	0.030	<0.010	<0.010	<0.010	<0.010
BH5	11302	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	3.56	0.016	<0.010	<0.010	<0.010	<0.010
BH6	11303	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.202	0.014	<0.010	<0.010	<0.010	<0.010
BH7	11304	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	10.1	0.041	<0.010	<0.010	<0.010	<0.010
BH11	11305	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.183	<0.010	<0.010	<0.010	<0.010	<0.010
BH12	11306	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.387	0.017	<0.010	<0.010	<0.010	<0.010
BH13	11307	0.019	<0.010	<0.010	<0.010	<0.010	<0.010	0.033	<0.010	<0.010	<0.010	<0.010	<0.010
MW6	11308	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	1.02	<0.010	<0.010	<0.010	<0.010	<0.010
WM11	11309	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	1.41	<0.010	<0.010	<0.010	<0.010	<0.010

Sample Origin	Sample ID	Ho (mg/L)	In (mg/L)	Ir (mg/L)	K (mg/L)	La (mg/L)	Li (mg/L)	Lu (mg/L)	Mg (mg/L)	Mn (mg/L)	Mo (mg/L)	Na (mg/L)	Nb (mg/L)
BH3	11300	<0.010	<0.010	<0.010	9.1	<0.010	<0.010	<0.010	25	0.568	<0.010	65	<0.010
BH4	11301	<0.010	<0.010	<0.010	3.1	<0.010	<0.010	<0.010	25	0.177	<0.010	200	<0.010
BH5	11302	<0.010	<0.010	<0.010	3.8	<0.010	<0.010	<0.010	45	1.22	<0.010	137	<0.010
BH6	11303	<0.010	<0.010	<0.010	1.9	<0.010	<0.010	<0.010	21	<0.025	<0.010	133	<0.010
BH7	11304	<0.010	<0.010	<0.010	5.2	<0.010	<0.010	<0.010	10	0.430	<0.010	99	<0.010
BH11	11305	<0.010	<0.010	<0.010	1.4	<0.010	<0.010	<0.010	150	<0.025	<0.010	79	<0.010
BH12	11306	<0.010	<0.010	<0.010	2.2	<0.010	<0.010	<0.010	48	<0.025	<0.010	83	<0.010
BH13	11307	<0.010	<0.010	<0.010	1.2	<0.010	<0.010	<0.010	144	<0.025	<0.010	28	<0.010
MW6	11308	<0.010	<0.010	<0.010	1.4	<0.010	<0.010	<0.010	221	0.056	<0.010	363	<0.010
WM11	11309	<0.010	<0.010	<0.010	4.3	<0.010	<0.010	<0.010	231	<0.025	<0.010	368	<0.010

Sample Origin	Sample ID	Nd (mg/L)	Ni (mg/L)	Os (mg/L)	P (mg/L)	Pb (mg/L)	Pd (mg/L)	Pt (mg/L)	Rb (mg/L)	Rh (mg/L)	Ru (mg/L)	Sb (mg/L)	Sc (mg/L)
BH3	11300	<0.010	0.071	<0.010	0.266	<0.010	<0.010	<0.010	0.014	<0.010	<0.010	<0.010	<0.010
BH4	11301	<0.010	0.057	<0.010	0.020	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
BH5	11302	<0.010	0.026	<0.010	0.402	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
BH6	11303	<0.010	<0.010	<0.010	0.021	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
BH7	11304	<0.010	0.066	<0.010	0.391	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
BH11	11305	<0.010	<0.010	<0.010	0.024	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
BH12	11306	<0.010	<0.010	<0.010	0.012	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
BH13	11307	<0.010	<0.010	<0.010	0.046	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
MW6	11308	<0.010	0.019	<0.010	0.024	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
WM11	11309	<0.010	0.024	<0.010	0.024	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010

Sample Origin	Sample ID	Se (mg/L)	Si (mg/L)	Sm (mg/L)	Sn (mg/L)	Sr (mg/L)	Ta (mg/L)	Tb (mg/L)	Te (mg/L)	Th (mg/L)	Ti (mg/L)	Tl (mg/L)	Tm (mg/L)
BH3	11300	0.012	6.3	<0.010	<0.010	0.368	<0.010	<0.010	<0.010	<0.010	0.071	<0.010	<0.010
BH4	11301	<0.010	1.3	<0.010	<0.010	0.590	<0.010	<0.010	<0.010	<0.010	0.082	<0.010	<0.010
BH5	11302	<0.010	7.0	<0.010	<0.010	0.561	<0.010	<0.010	<0.010	<0.010	0.134	<0.010	<0.010
BH6	11303	<0.010	0.3	<0.010	<0.010	0.035	<0.010	<0.010	<0.010	<0.010	0.010	<0.010	<0.010
BH7	11304	<0.010	4.6	<0.010	<0.010	0.231	<0.010	<0.010	<0.010	<0.010	0.047	<0.010	<0.010
BH11	11305	<0.010	5.7	<0.010	<0.010	0.245	<0.010	<0.010	<0.010	<0.010	0.059	<0.010	<0.010
BH12	11306	<0.010	7.9	<0.010	<0.010	0.580	<0.010	<0.010	<0.010	<0.010	0.158	<0.010	<0.010
BH13	11307	<0.010	7.6	<0.010	<0.010	0.150	<0.010	<0.010	<0.010	<0.010	0.005	<0.010	<0.010
MW6	11308	<0.010	5.8	<0.010	<0.010	1.63	<0.010	<0.010	<0.010	<0.010	0.494	<0.010	<0.010
WM11	11309	0.026	5.9	<0.010	<0.010	1.83	<0.010	<0.010	<0.010	<0.010	0.647	<0.010	<0.010

Sample Origin	Sample ID	U (mg/L)	V (mg/L)	W (mg/L)	Y (mg/L)	Yb (mg/L)	Zn (mg/L)	Zr (mg/L)
BH3	11300	<0.010	<0.010	<0.010	<0.010	<0.010	0.111	<0.010
BH4	11301	<0.010	<0.010	<0.010	<0.010	<0.010	0.033	<0.010
BH5	11302	<0.010	<0.010	<0.010	<0.010	<0.010	0.011	<0.010
BH6	11303	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
BH7	11304	<0.010	<0.010	<0.010	<0.010	<0.010	0.061	<0.010
BH11	11305	<0.010	<0.010	<0.010	<0.010	<0.010	0.010	<0.010
BH12	11306	<0.010	<0.010	<0.010	<0.010	<0.010	2.42	<0.010
BH13	11307	<0.010	0.041	<0.010	<0.010	<0.010	0.033	<0.010
MW6	11308	<0.010	0.023	<0.010	<0.010	<0.010	0.034	<0.010
WM11	11309	<0.010	0.011	<0.010	<0.010	<0.010	0.039	<0.010

RECORD OF REPORT DISTRIBUTION

SLR Reference:	710.19057.00004
Title:	Siyanda Ferrochrome Project: Hydrocensus Report
Site name:	Siyanda Ferrochrome Project
Report Number:	01
Client:	Siyanda Chrome Smelting Company (Pty) Limited

Name	Entity	No. of copes	Date issued	Issuer

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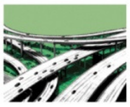
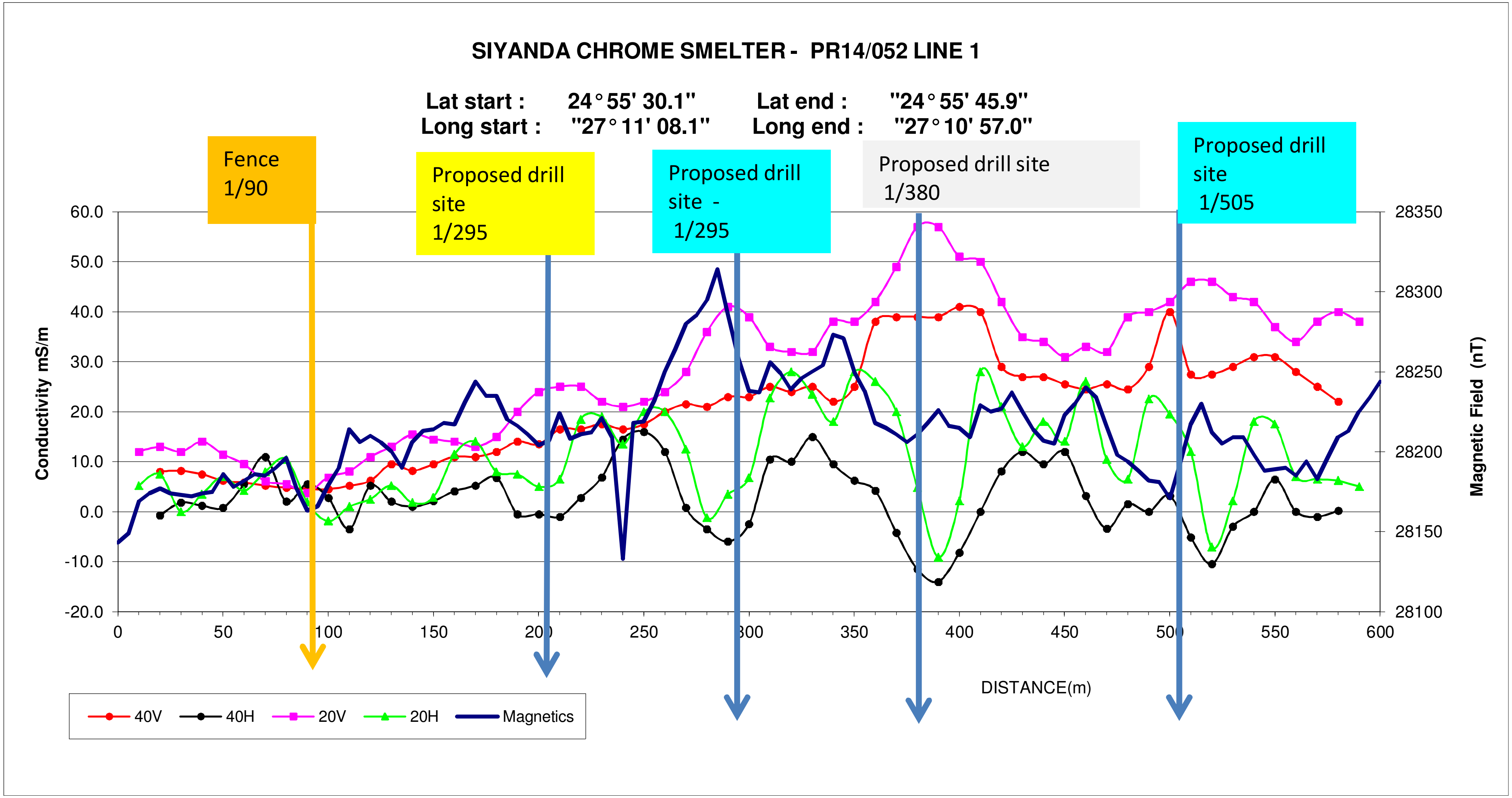
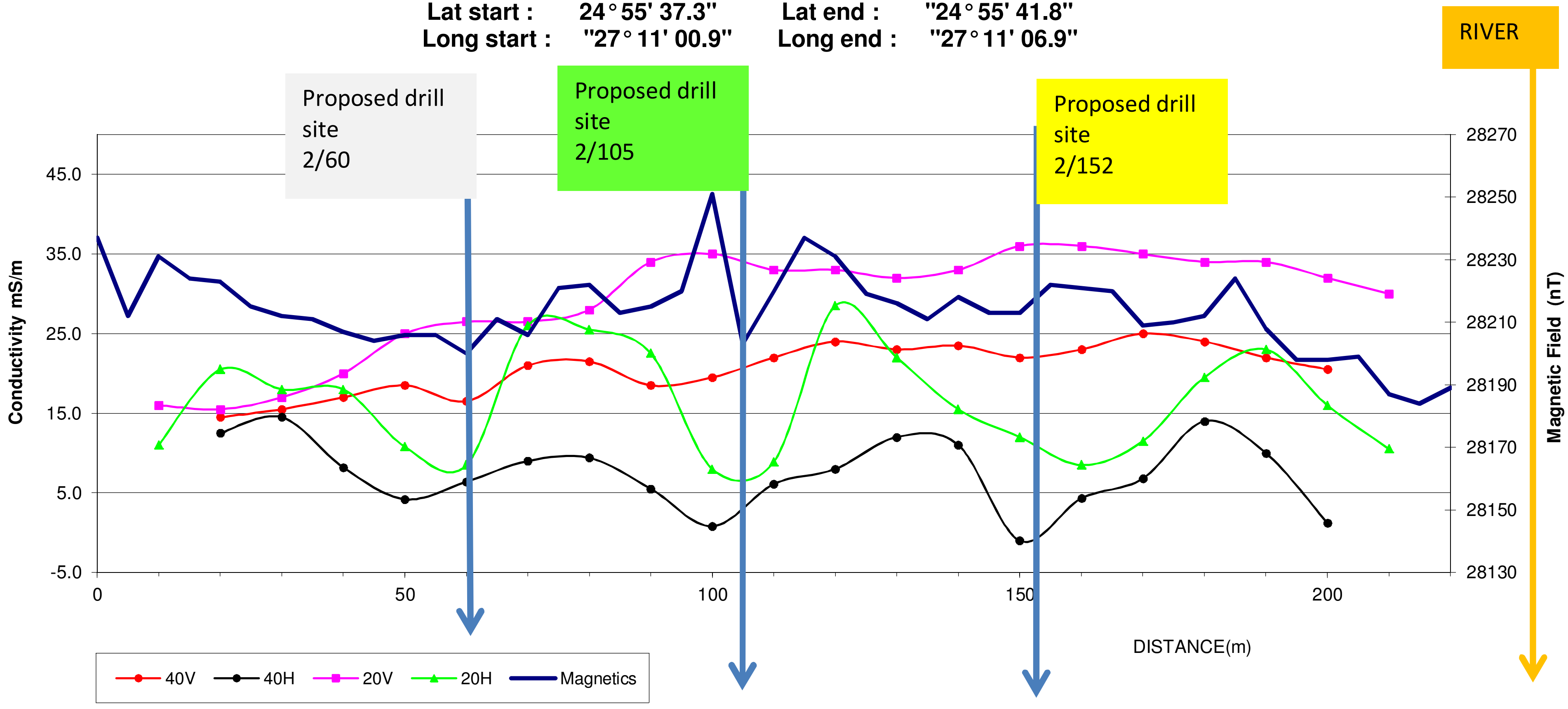

Infrastructure

APPENDIX C: GEOPHYSICAL SURVEY DATA

SIYANDA CHROME SMELTER - PR14/052 LINE 1
Lat start : 24° 55' 30.1"
Long start : "27° 11' 08.1"
Lat end : "24° 55' 45.9"
Long end : "27° 10' 57.0"
Fence
1/90
Proposed drill
site
1/295
Proposed drill
site -
1/295
Proposed drill site
1/380
Proposed drill
site
1/505
Conductivity mS/m
60.0
50.0
40.0
30.0
20.0
10.0
0.0
-10.0
-20.0
Magnetic Field (nT)
28350
28300
28250
28200
28150
28100
0
50
100
150
200
250
300
350
400
450
500
550
600
DISTANCE(m)
40V
40H
20V
20H
Magnetics

SIYANDA CHROME SMELTER - PR14/052 LINE 2

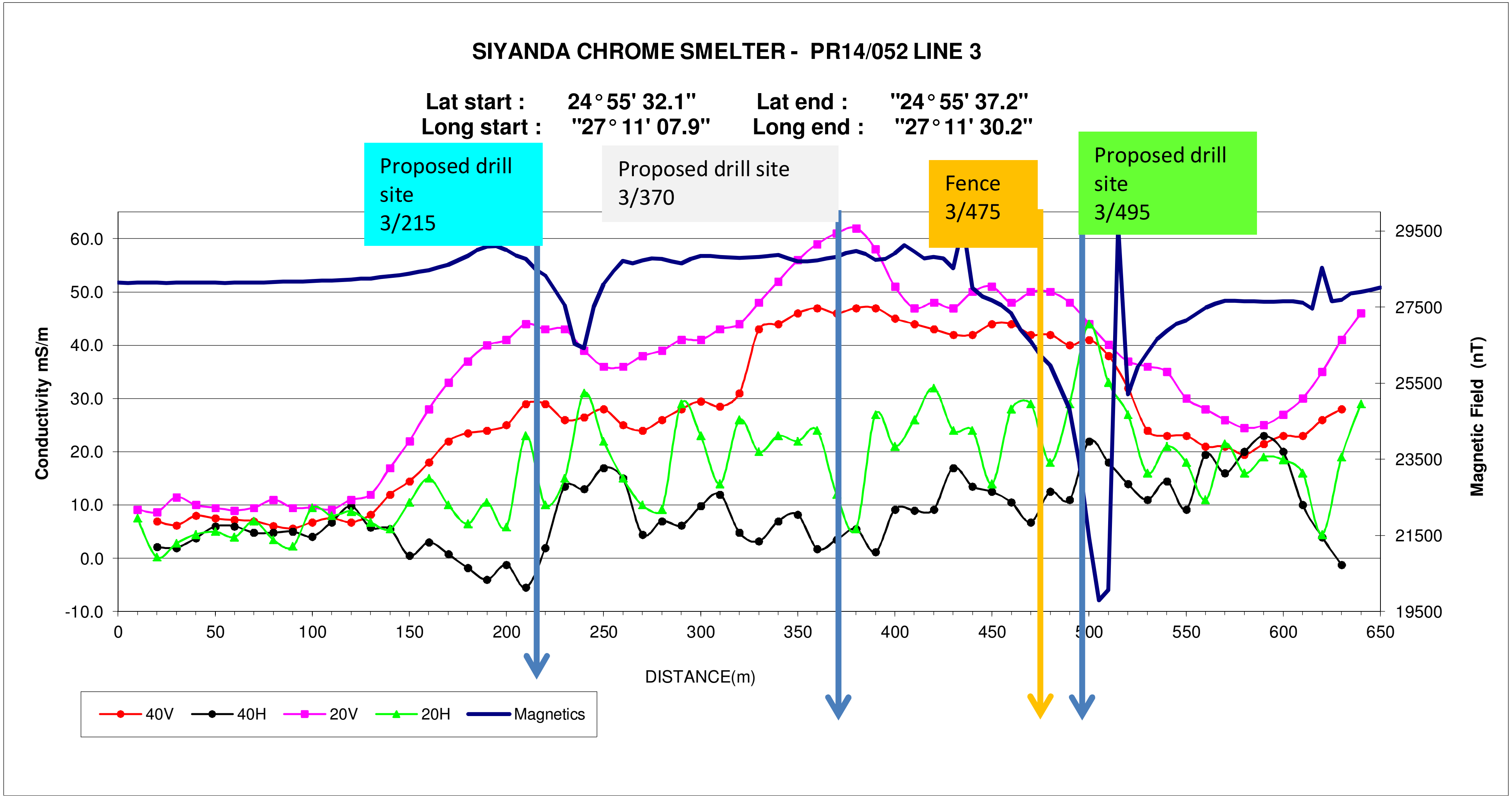
Lat start : 24° 55' 37.3" **Lat end :** "24° 55' 41.8"
Long start : "27° 11' 00.9" **Long end :** "27° 11' 06.9"


Proposed drill site 2/60

Proposed drill site 2/105

Proposed drill site 2/152

RIVER



SIYANDA CHROME SMELTER - PR14/052 LINE 3

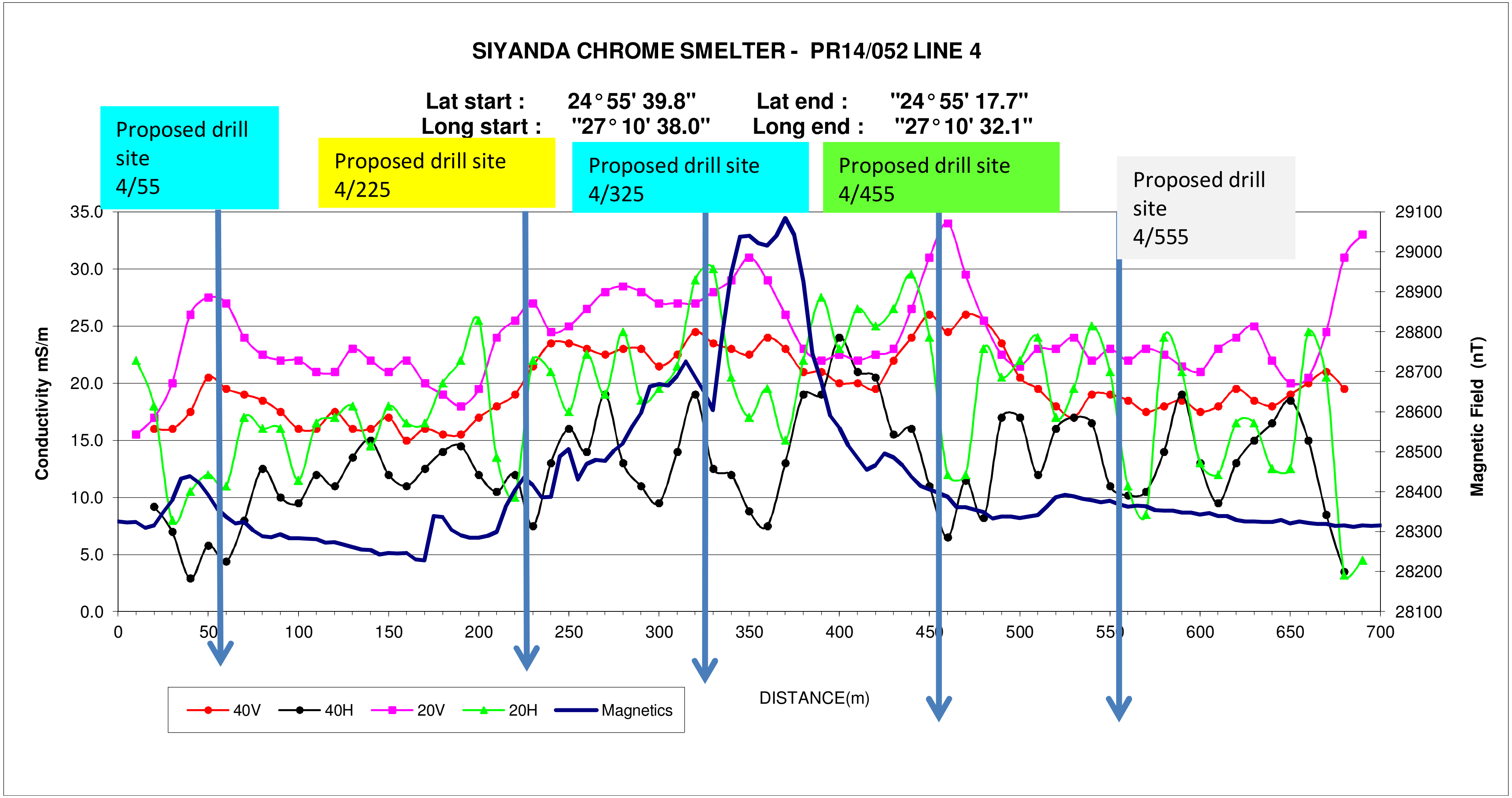
Lat start : 24° 55' 32.1" Lat end : "24° 55' 37.2"
Long start : "27° 11' 07.9" Long end : "27° 11' 30.2"

Proposed drill site 3/215

Proposed drill site 3/370

Fence 3/475

Proposed drill site 3/495



SIYANDA CHROME SMELTER - PR14/052 LINE 4

Lat start : 24° 55' 39.8" Lat end : "24° 55' 17.7"
Long start : "27° 10' 38.0" Long end : "27° 10' 32.1"

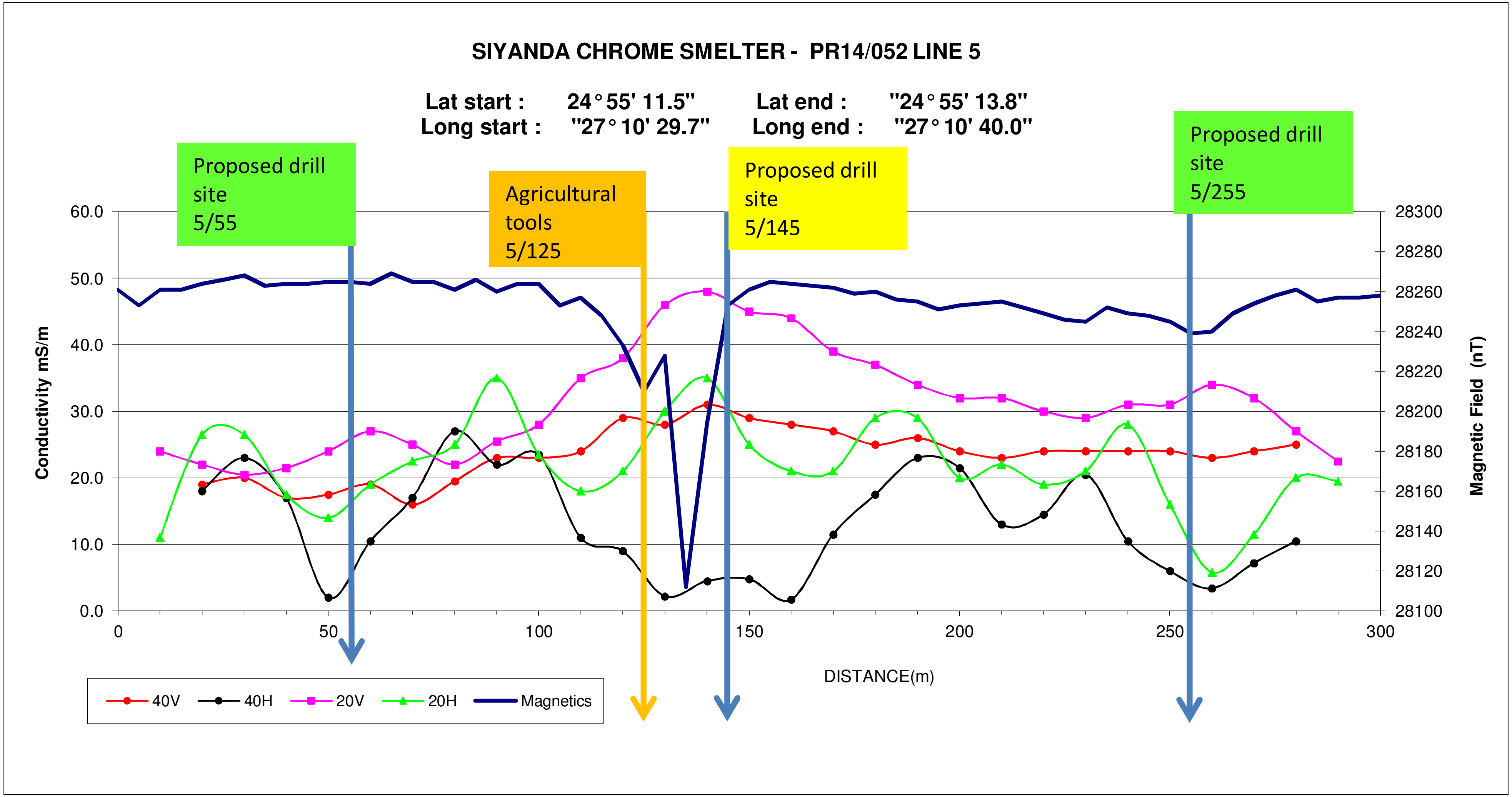
Proposed drill site 4/55

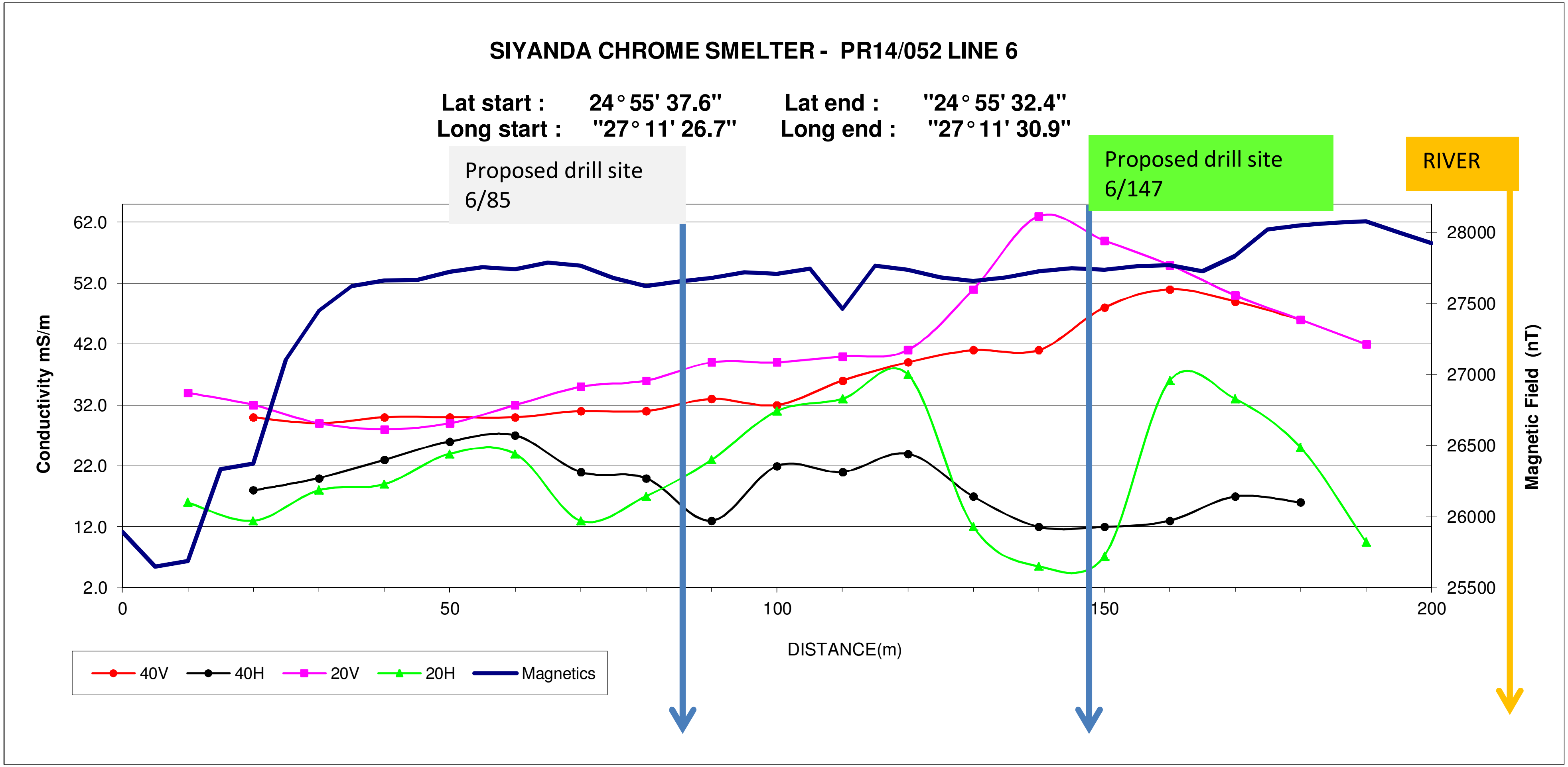
Proposed drill site 4/225

Proposed drill site 4/325

Proposed drill site 4/455

Proposed drill site 4/555


SIYANDA CHROME SMELTER - PR14/052 LINE 5
Lat start : 24° 55' 11.5"
Long start : "27° 10' 29.7"
Lat end : "24° 55' 13.8"
Long end : "27° 10' 40.0"
Proposed drill site 5/55
Agricultural tools 5/125
Proposed drill site 5/145
Proposed drill site 5/255
Conductivity mS/m
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Magnetic Field (nT)
28300
28280
28260
28240
28220
28200
28180
28160
28140
28120
28100
0
50
100
150
200
250
300
DISTANCE(m)
40V
40H
20V
20H
Magnetics



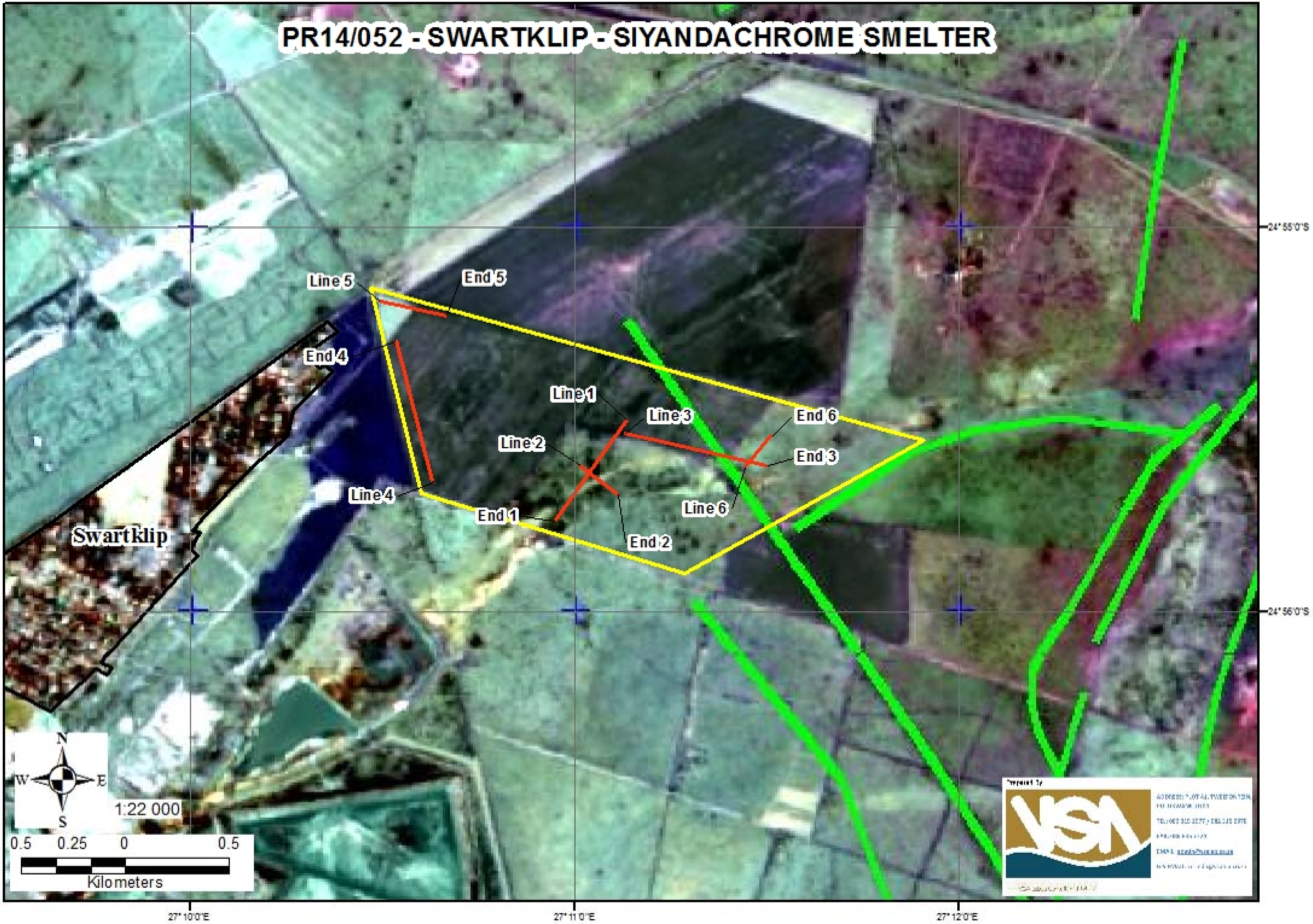
SIYANDA CHROME SMELTER - PR14/052 LINE 6

Lat start : 24° 55' 37.6" Lat end : "24° 55' 32.4"
Long start : "27° 11' 26.7" Long end : "27° 11' 30.9"

Proposed drill site 6/85

Proposed drill site 6/147

RIVER


PR14/052 - SWARTKLIP - SIYANDACHROME SMELTER
Line 5
End 5
End 4
Line 1
Line 3
End 6
Line 2
End 3
Line 4
Line 6
End 1
End 2
Swartklip
24°55'0"S
24°56'0"S
27°10'0"E
27°11'0"E
27°12'0"E
N
S
W
E
1:22 000
0.5
0.25
0
0.5
Kilometers
Prepared by
VSA

APPENDIX D: BOREHOLE LOGS

Project No: 710.19057.00005

BH ID: SIY-BH01D

Project: Siyanda

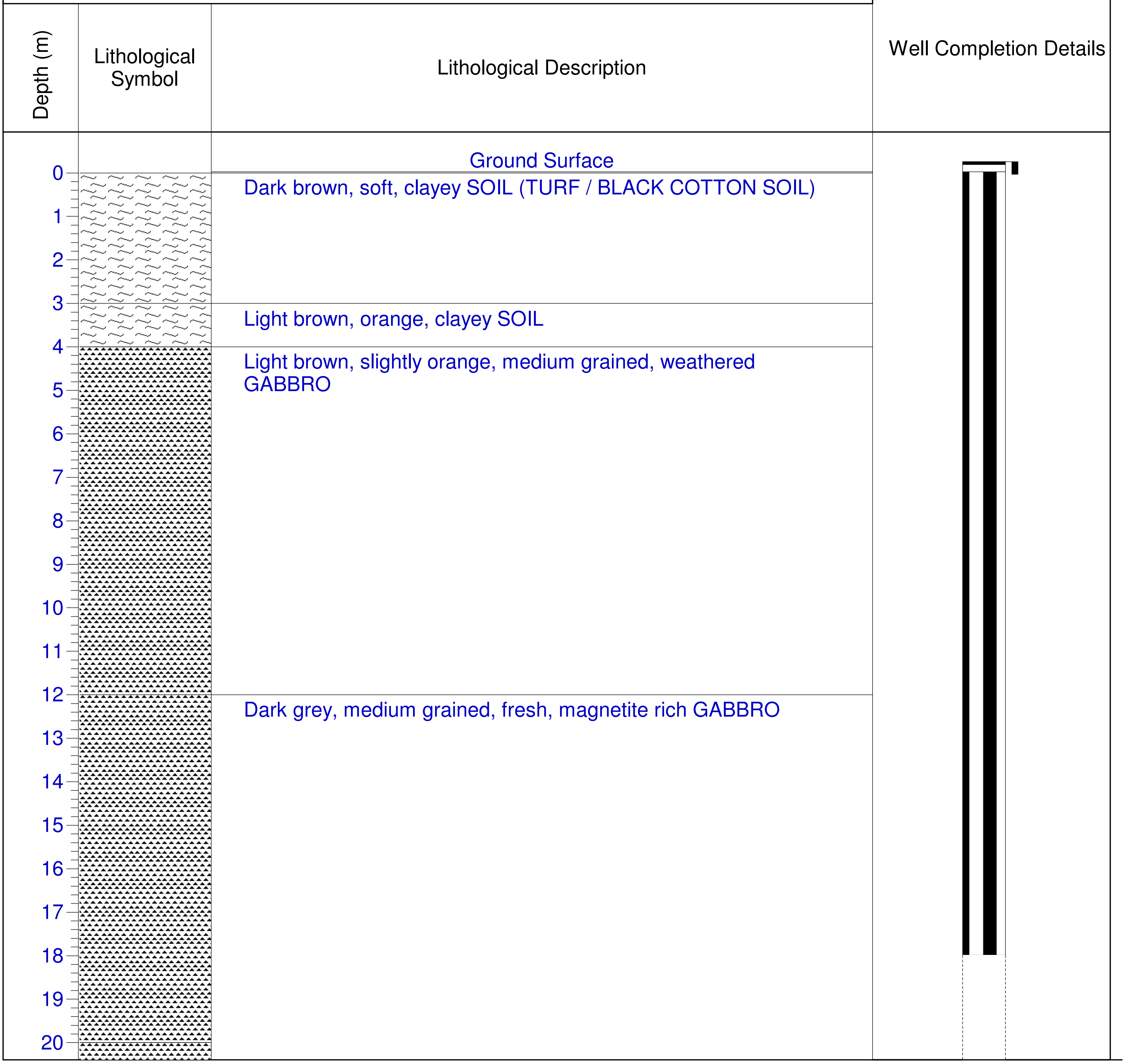
Client: Siyanda Chrome Smelting Company (Pty) Ltd

x: 518937.95

Site Location: Northam, Limpopo

y: 7243222.98

SUBSURFACE PROFILE



Lithological Description

Ground Surface

Dark brown, soft, clayey SOIL (TURF / BLACK COTTON SOIL)

Light brown, orange, clayey SOIL

Light brown, slightly orange, medium grained, weathered GABBRO

Dark grey, medium grained, fresh, magnetite rich GABBRO

Drilled By: Water Worx (Pty) Limited

Logged by: Jenny Ellerton

Drill Method: Rotary air percussion with foam

Datum: UTM35

Drill Date: 2015/07/28

Sheet: 1 of 3

Notes: No Water Strike. Static water level 32m. Long recovery. Locked with 10mm Allen Key

Project No: 710.19057.00005

BH ID: SIY-BH01D

Project: Siyanda

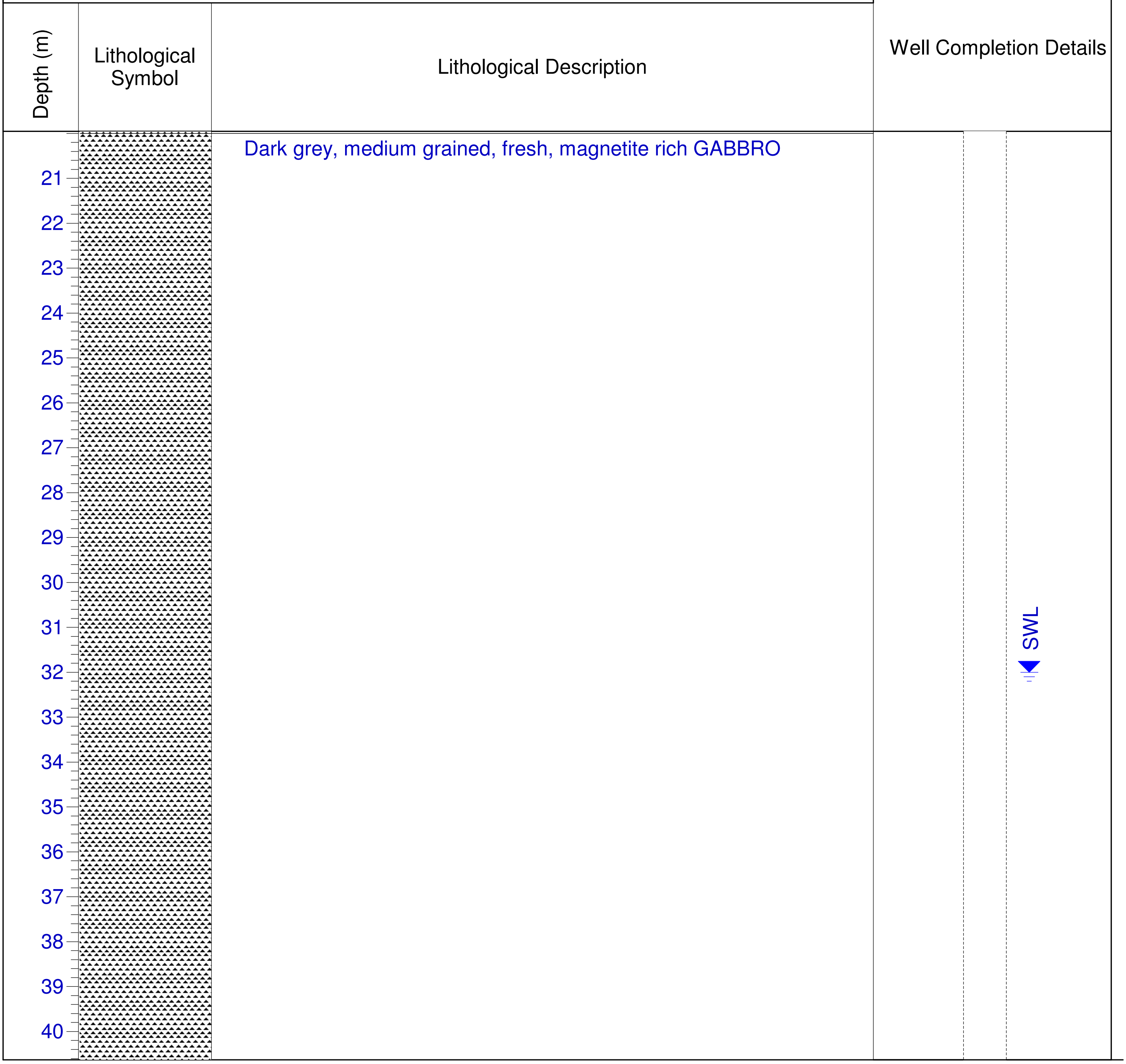
Client: Siyanda Chrome Smelting Company (Pty) Ltd

x: 518937.95

Site Location: Northam, Limpopo

y: 7243222.98

SUBSURFACE PROFILE



Dark grey, medium grained, fresh, magnetite rich GABBRO

Drilled By: Water Worx (Pty) Limited

Logged by: Jenny Ellerton

Drill Method: Rotary air percussion with foam

Datum: UTM35

Drill Date: 2015/07/28

Sheet: 2 of 3

Notes: No Water Strike. Static water level 32m. Long recovery. Locked with 10mm Allen Key

Project No: 710.19057.00005

BH ID: SIY-BH01D

Project: Siyanda

Client: Siyanda Chrome Smelting Company (Pty) Ltd **x:** 518937.95

Site Location: Northam, Limpopo **y:** 7243222.98

SUBSURFACE PROFILE

Depth (m)	Lithological Symbol	Lithological Description	Well Completion Details
41 42 43 44 45			
46 47 48 49 50 51 52 53		Light grey,white and slightly green, medium grained, fresh GABBRO NORITE	
54 55 56 57 58 59		Dark grey, medium grained, fresh, magetite rich GABBRO	
60		End of Borehole	

Drilled By: Water Worx (Pty) Limited

Drill Method: Rotary air percussion with foam

Drill Date: 2015/07/28

Logged by: Jenny Ellerton

Datum: UTM35

Sheet: 3 of 3

Notes: No Water Strike. Static water level 32m. Long recovery. Locked with 10mm Allen Key

Project No: 710.19057.00005

BH ID: SIY-BH01S

Project: Siyanda

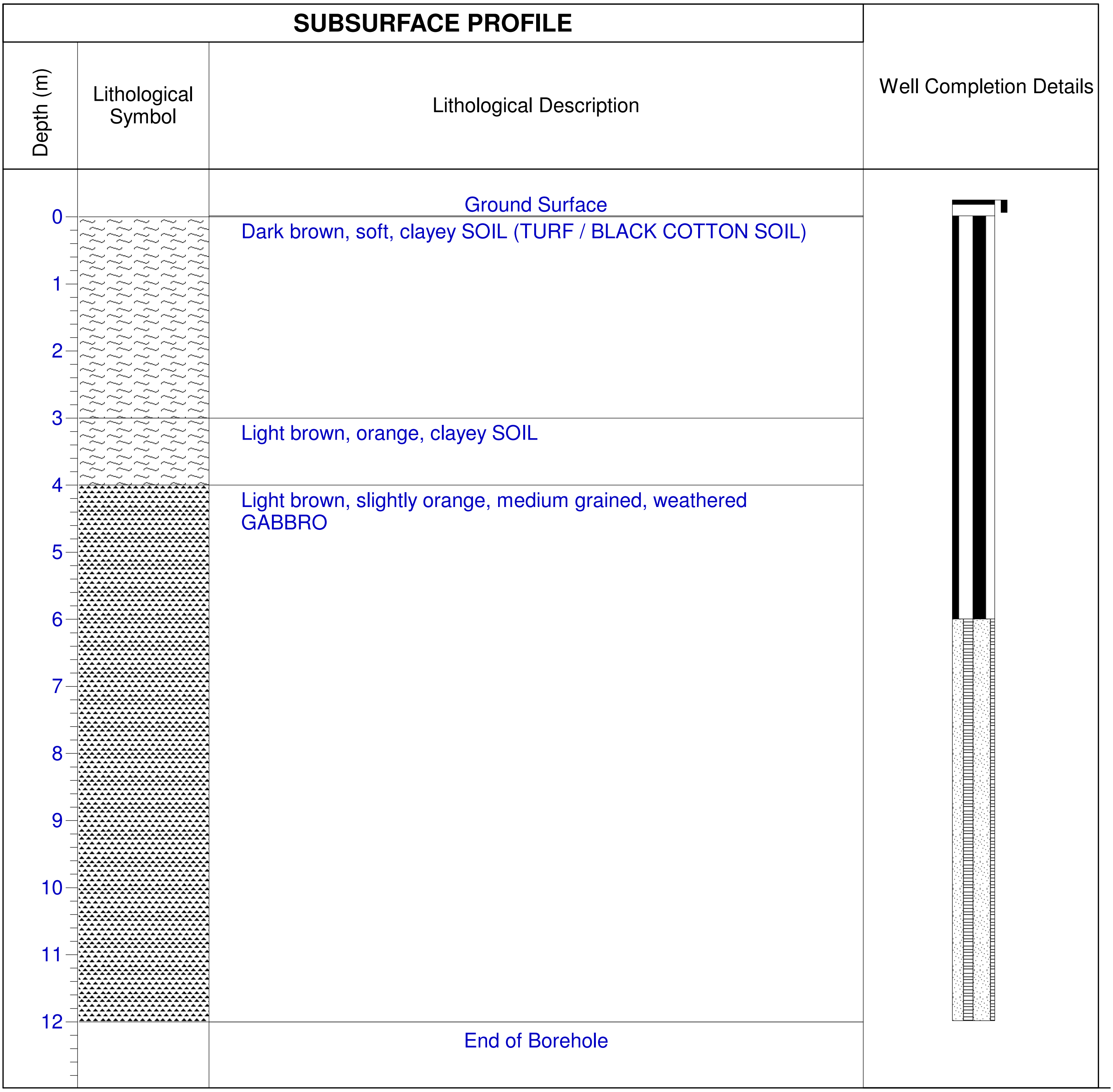
Client: Siyanda Chrome Smelting Company (Pty) Ltd

x: 518940.99

Site Location: Northam, Limpopo

y: 7243226.41

SUBSURFACE PROFILE



Ground Surface

Dark brown, soft, clayey SOIL (TURF / BLACK COTTON SOIL)

Light brown, orange, clayey SOIL

Light brown, slightly orange, medium grained, weathered GABBRO

End of Borehole

Drilled By: Water Worx (Pty) Limited

Logged by: Jenny Ellerton

Drill Method: Rotary air percussion with foam

Datum: UTM35

Drill Date: 2015/07/31

Sheet: 1 of 1

Notes: No Water Strike. Locked with 10mm Allen Key

Project No: 710.19057.00005

BH ID: SIY-BH02D

Project: Siyanda

Client: Siyanda Chrome Smelting Company (Pty) Ltd

x: 518608.59

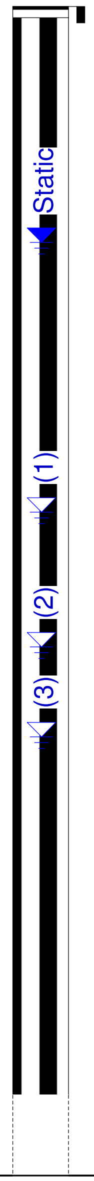
Site Location: Northam, Limpopo

y: 7243073.62

SUBSURFACE PROFILE

Depth (m)	Lithological Symbol	Lithological Description
		Ground Surface
0		Dark brown, soft, clayey SOIL (TURF / BLACK COTTON SOIL)
2		Grey, slightly brown, medium grained, weathered GABBRO NORITE (DRY)
9		Grey, medium grained, weathered GABBRO NORITE (WET) Fractures at: 9m, 13m and 16m
18		Light grey, medium grained, fresh GABBRO NORITE. Possible fracture at 46m
25		

Well Completion Details



Drilled By: Water Worx (Pty) Limited

Logged by: Jenny Ellerton

Drill Method: Rotary air percussion with foam

Datum: UTM35

Drill Date: 2015/07/28

Sheet: 1 of 2

Notes: Water strikes at fractures. Yield (1) 0.7L/S (2) 0.5L/S (3) 1.1L/S. Combined 2L/S. Locked with 10mm Allen Key

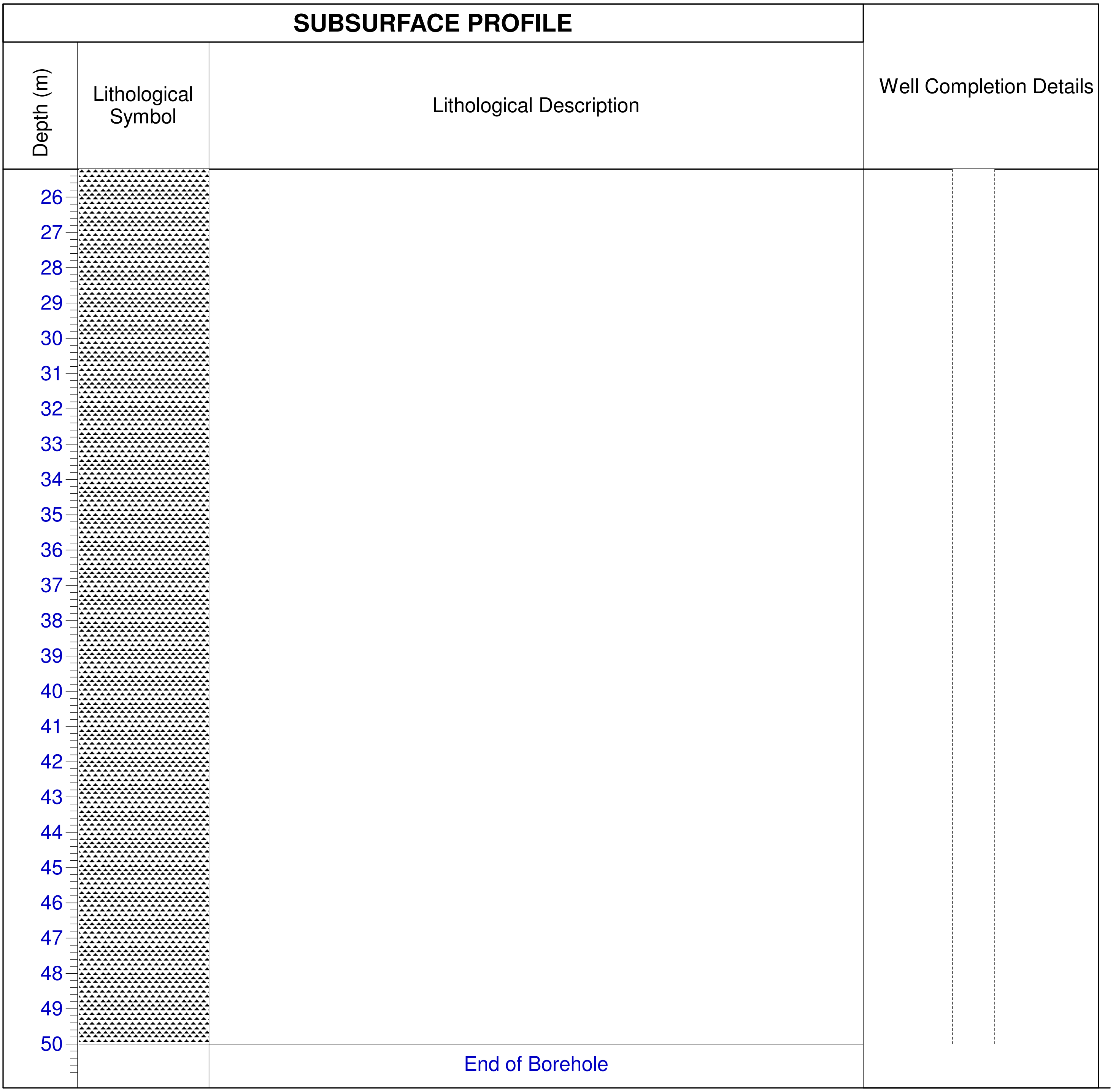
Project No: 710.19057.00005

BH ID: SIY-BH02D

Project: Siyanda

Client: Siyanda Chrome Smelting Company (Pty) Ltd **x:** 518608.59

Site Location: Northam, Limpopo **y:** 7243073.62



Drilled By: Water Worx (Pty) Limited

Logged by: Jenny Ellerton

Drill Method: Rotary air percussion with foam

Datum: UTM35

Drill Date: 2015/07/28

Sheet: 2 of 2

Notes: Water strikes at fractures. Yield (1) 0.7L/S (2) 0.5L/S (3) 1.1L/S. Combined 2L/S. Locked with 10mm Allen Key

Project No: 710.19057.00005

BH ID: SIY-BH02S

Project: Siyanda

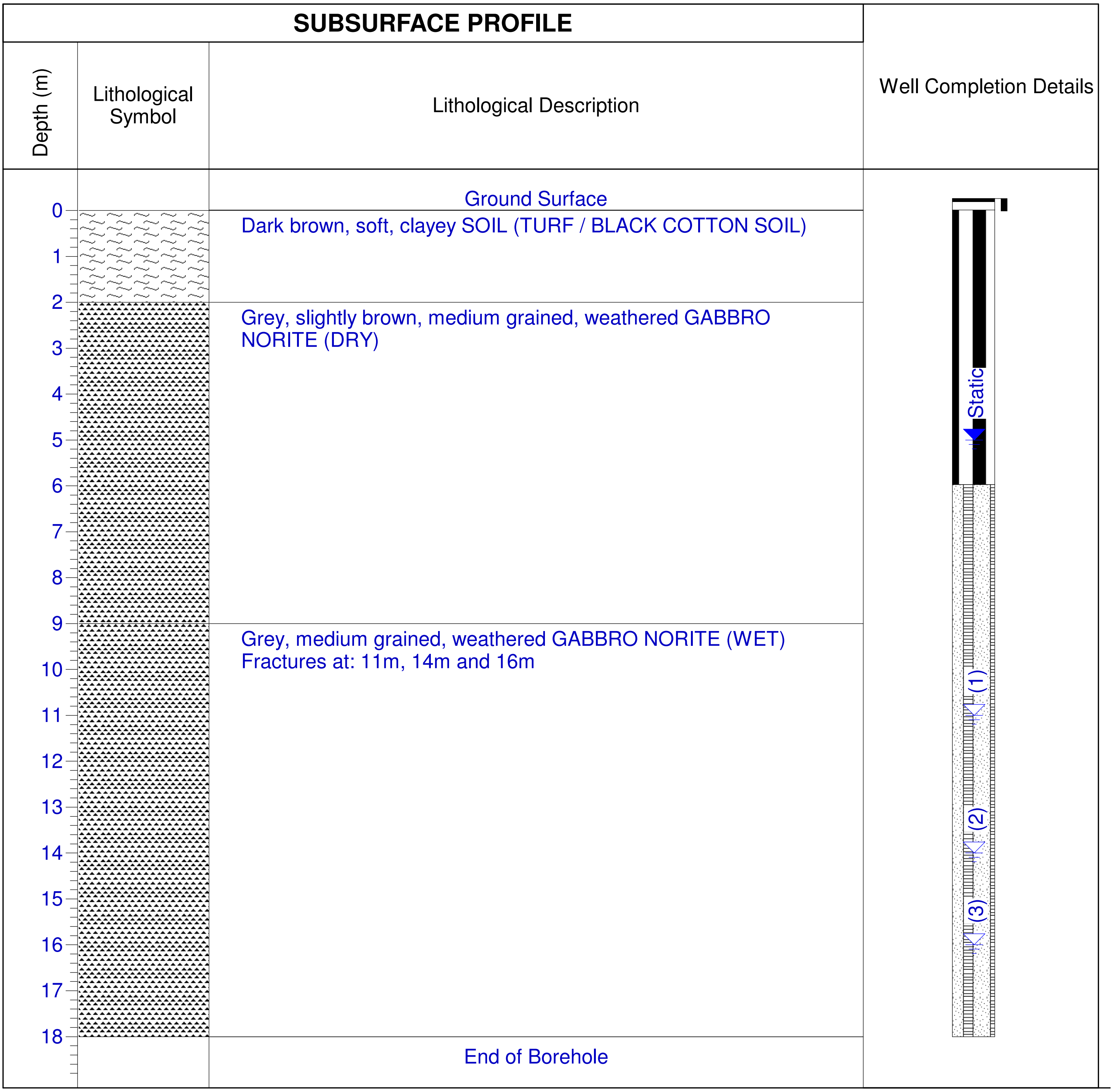
Client: Siyanda Chrome Smelting Company (Pty) Ltd

x: 518618.68

Site Location: Northam, Limpopo

y: 7243072.94

SUBSURFACE PROFILE



Ground Surface

Dark brown, soft, clayey SOIL (TURF / BLACK COTTON SOIL)

Grey, slightly brown, medium grained, weathered GABBRO NORITE (DRY)

Grey, medium grained, weathered GABBRO NORITE (WET)
Fractures at: 11m, 14m and 16m

End of Borehole

Drilled By: Water Worx (Pty) Limited

Logged by: Jenny Ellerton

Drill Method: Rotary air percussion with foam

Datum: UTM35

Drill Date: 2015/07/29

Sheet: 1 of 1

Notes: Water strikes associated with fractures. Locked with 10mm Allen Key

Project No: 710.19057.00005

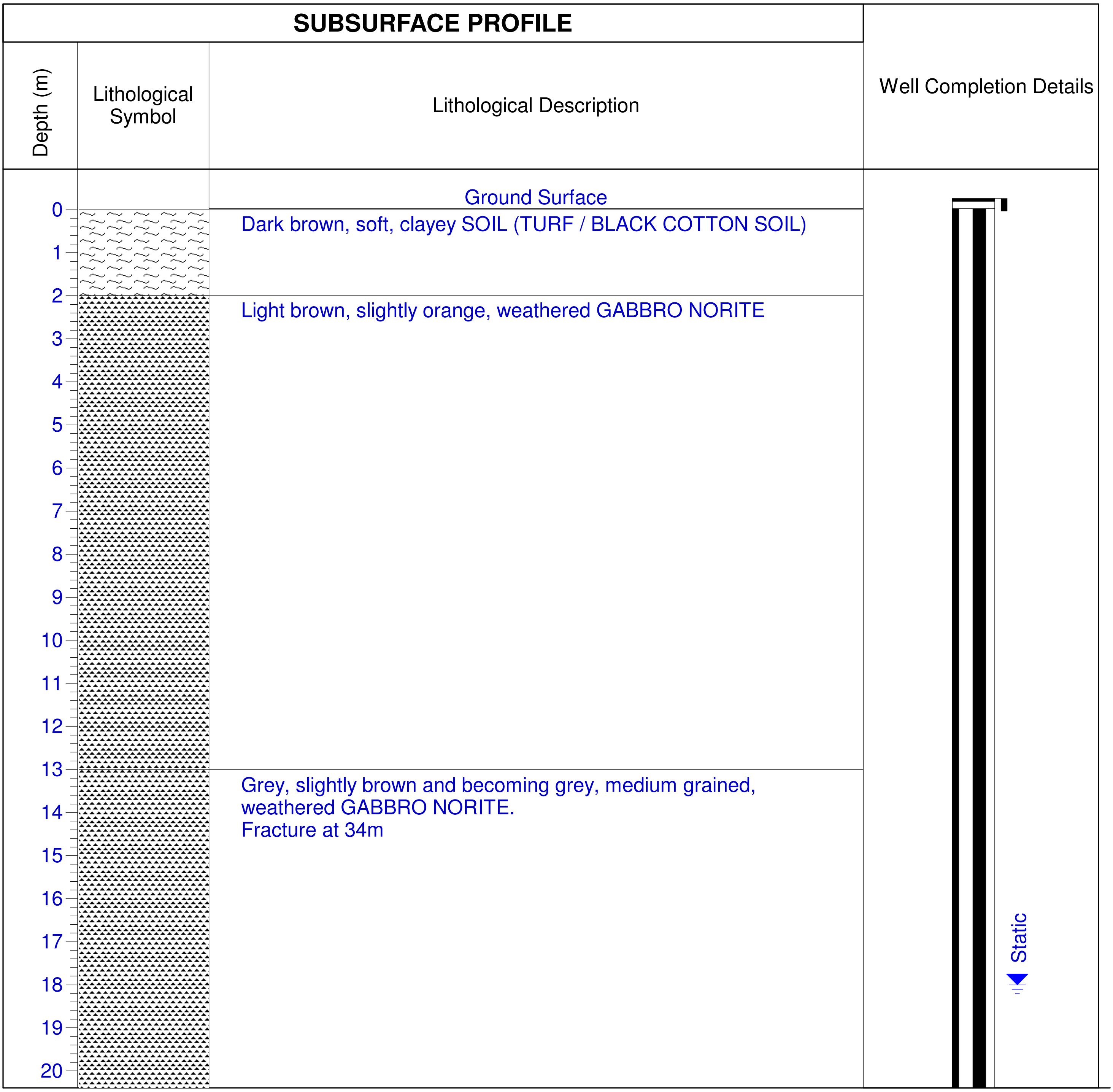
BH ID: SIY-BH03

Project: Siyanda

Client: Siyanda Chrome Smelting Company (Pty) Ltd **x:** 517947.25

Site Location: Northam, Limpopo **y:** 7243854.47

SUBSURFACE PROFILE



Ground Surface

Dark brown, soft, clayey SOIL (TURF / BLACK COTTON SOIL)

Light brown, slightly orange, weathered GABBRO NORITE

Grey, slightly brown and becoming grey, medium grained, weathered GABBRO NORITE.
Fracture at 34m

Drilled By: Water Worx (Pty) Limited

Drill Method: Rotary air percussion with foam

Drill Date: 2015/07/30

Notes: Locked with 10mm Allen Key

Logged by: Jenny Ellerton

Datum: UTM35

Sheet: 1 of 3

Project No: 710.19057.00005

BH ID: SIY-BH03

Project: Siyanda

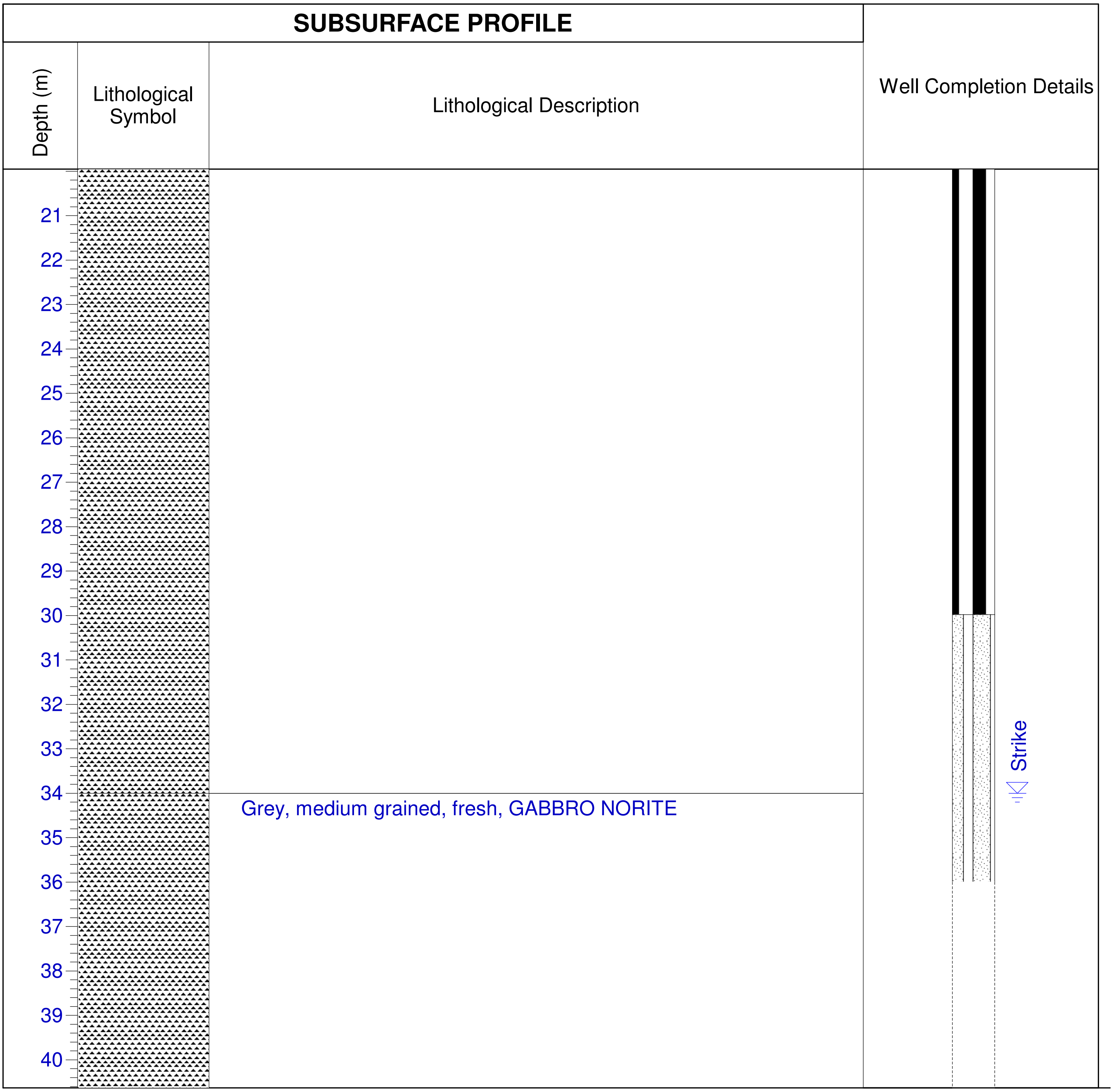
Client: Siyanda Chrome Smelting Company (Pty) Ltd

x: 517947.25

Site Location: Northam, Limpopo

y: 7243854.47

SUBSURFACE PROFILE



Grey, medium grained, fresh, GABBRO NORITE

Drilled By: Water Worx (Pty) Limited

Drill Method: Rotary air percussion with foam

Drill Date: 2015/07/30

Notes: Locked with 10mm Allen Key

Logged by: Jenny Ellerton

Datum: UTM35

Sheet: 2 of 3

Project No: 710.19057.00005

BH ID: SIY-BH03

Project: Siyanda

Client: Siyanda Chrome Smelting Company (Pty) Ltd

x: 517947.25

Site Location: Northam, Limpopo

y: 7243854.47

SUBSURFACE PROFILE

Depth (m)	Lithological Symbol	Lithological Description	Well Completion Details
41			
42			
43			
44			
45			
46			
47			
48		Dark grey, medium grained, fresh, GABBRO NORITE	
49			
50			
51			
52			
53			
54			
55			
56			
57			
58		Grey, medium grained, fresh, GABBRO NORITE	
59			
60		End of Borehole	

Drilled By: Water Worx (Pty) Limited

Drill Method: Rotary air percussion with foam

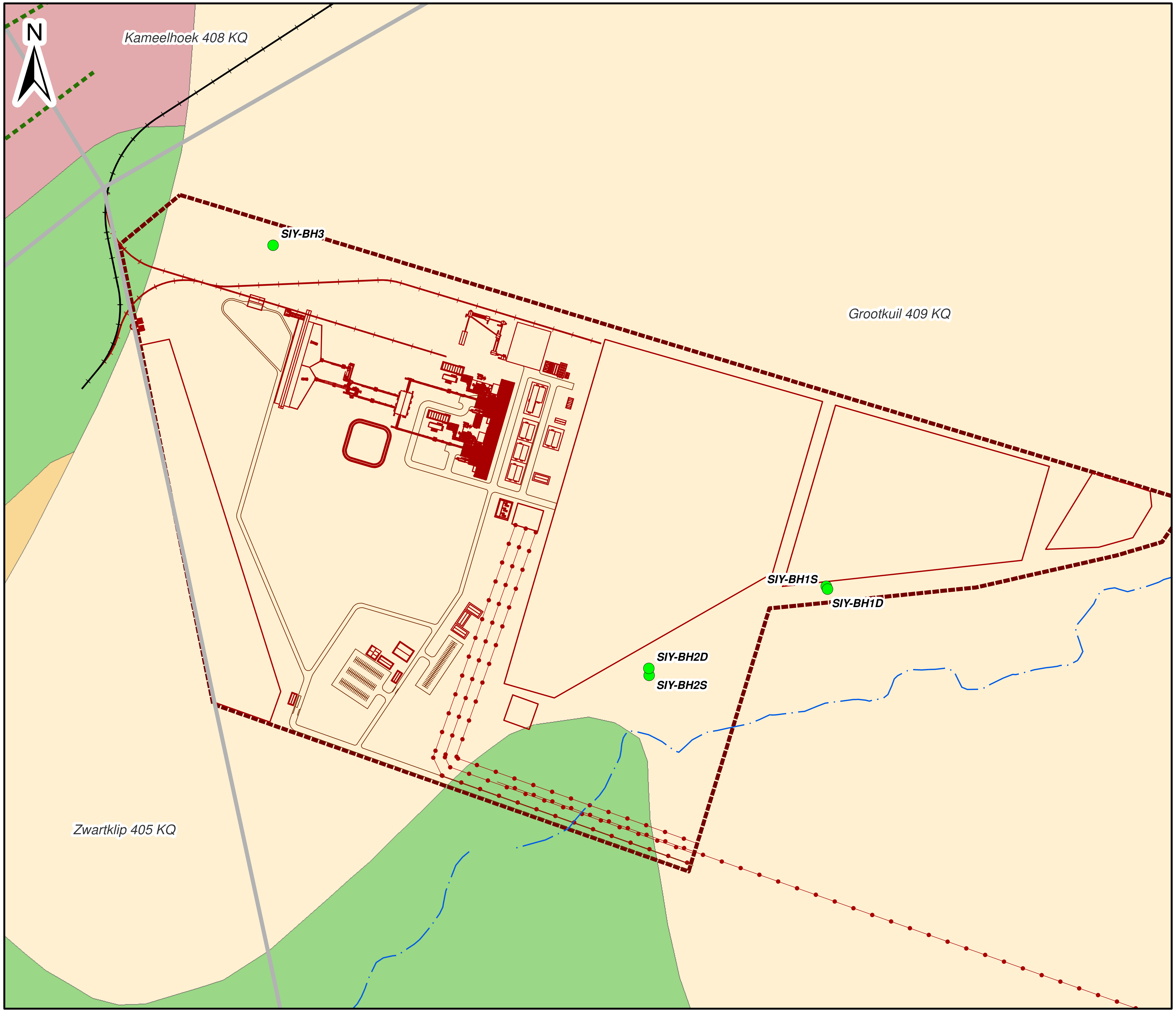
Drill Date: 2015/07/30

Notes: Locked with 10mm Allen Key

Logged by: Jenny Ellerton

Datum: UTM35

Sheet: 3 of 3



Legend

- ● Drilled Boreholes
- ▭ Project Infrastructure Area
- — Proposed Infrastructure Layout
- •—• Proposed Powerline Route
- ▭ Farm Boundaries
- -·- River - Non-Perennial
- —+— Existing Union Section Railway Line

Geology

- ▨ BIERKRAAL MAGNETITE GABBRO
- ▨ MATHLAGAME NORITE-ANORTHOSITE
- 🟩 PYRAMID GABBRO-NORITE
- ▨ VLAKFONTEIN
- ▪▪▪ Stratigraphic/Lithologic Features

0 140 280 Meters

Scale: 1:7 000 @ A3

Projection: Transverse Mercator
Datum: Hartebeeshoek, LO27

Siyanda Chrome Smelting
Company (Pty) Ltd

Location of Drilled Boreholes

SLR Consulting (Africa) (Pty) Ltd
P O Box 1596, Cramerview, 2060, South Africa
Tel: +27 (11) 467-0945 Fax: +27 (11) 467-0978

710.19057.00005

July 2016

APPENDIX E: PUMPING TEST DATA

BH NO:	SIY-BH2S		
DATE:	2015/08/05		
LONGITUDE:	27.184343		
LATITUDE:	-24.927561	DIVER IN:	
CASING DEPTH:	17.65m	SLUG IN:	
BH DEPTH:	17.90m	SLUG OUT:	
WATER LEVEL:	5.31m	DIVER OUT:	
BH DIAMETER:	165mm		
CASING HEIGHT:	0.28m		
CONCRETE PLINTH:			
CONCRETE FLOOR:			

BOREHOLE NO : SIY-BH2S

ALT.BH. NO :

ALT.BH. NO :_________________________

STEP TEST
&
RECOVERY

VSA Leboa Consulting

VILLAGE NAME :

ALT. VILLAGE NAME :

BOREHOLE DEPTH (Before installation of test pump) :	17.90m	DATUM LEVEL ABOVE CASING :	0.21m
WATER LEVEL (Measured at datum point before Steps)	5.70m	CONTRACTOR : VSA LEBOA	
INSTALLATION DEPTH OF TESTPUMP:		FOREMAN :	
Latitude:	**Longitude:**	**Date : 2015/08/05**	**Time : 12:29**

DISCHARGE RATE 1				DISCHARGE RATE 2				DISCHARGE RATE 3			
TIME (min)	ACTUAL TIME	**Water level** (m)	YIELD (l/s)	TIME (min)	ACTUAL TIME	**Water level** (m)	YIELD (l/s)	TIME (min)	ACTUAL TIME	**Water level** (m)	YIELD (l/s)
1	12:30	5.82		**1**	13:30	6.16		**1**	14:30	7.15	
2	12:31	5.86		**2**	13:31	6.25		**2**	14:31	7.21	
3	12:32	5.87		**3**	13:32	6.32		**3**	14:32	7.4	2.9
5	12:34	5.89		**5**	13:34	6.45	1.55	**5**	14:34	7.48	
7	12:36	5.9		**7**	13:36	6.46		**7**	14:36	7.51	
10	12:39	5.91		**10**	13:39	6.47	1.5	**10**	14:39	7.55	3
15	12:44	5.92	0.45	**15**	13:44	6.49		**15**	14:44	7.58	
20	12:49	5.93		**20**	13:49	6.5	1.52	**20**	14:49	7.6	
30	12:59	5.95	0.44	**30**	13:59	6.54		**30**	14:59	7.65	3
40	13:09	5.96		**40**	14:09	6.56	1.5	**40**	15:09	7.66	
50	13:19	5.97	0.45	**50**	14:19	6.57	1.51	**50**	15:19	7.7	3.01
60	13:29	5.98		**60**	14:29	6.58		**60**	15:29	7.73	
70				**70**				**70**			
80				**80**				**80**			
90				**90**				**90**			
100				**100**				**100**			
110				**110**				**110**			
120				**120**				**120**			

DISCHARGE RATE 4				DISCHARGE RATE 5				DISCHARGE RATE 6			
TIME (min)	ACTUAL TIME	**Water level** (m)	YIELD (l/s)	TIME (min)	ACTUAL TIME	**Water level** (m)	YIELD (l/s)	TIME (min)	ACTUAL TIME	**Water level** (m)	YIELD (l/s)
1	15:30	8.38		**1**				**1**			
2	15:31	8.66		**2**				**2**			
3	15:32	8.88	5.44	**3**				**3**			
5	15:34	9.16		**5**				**5**			
7	15:36	9.39	6.33	**7**				**7**			
10	15:39	10.04		**10**				**10**			
15	15:44	10.18	6.38	**15**				**15**			
20	15:49	10.29		**20**				**20**			
30	15:59	10.4	6.57	**30**				**30**			
40	16:09	10.47		**40**				**40**			
50	16:19	10.55	6.53	**50**				**50**			
60	16:29	10.6		**60**				**60**			
70				**70**				**70**			
80				**80**				**80**			
90				**90**				**90**			
100				**100**				**100**			
110				**110**				**110**			
120				**120**				**120**			

RECOVERY		
TIME (min)	ACTUAL TIME	RECOVERY (m)
1	16:30	7.46
2	16:31	7.09
3	16:32	6.97
5	16:34	6.83
7	16:36	6.74
10	16:39	6.61
15	16:44	6.51
20	16:49	6.4
30	16:59	6.28
40	17:09	6.19
60	17:29	6.09
90	17:59	6.01
120	18:29	5.96
150	18:59	5.92
180	19:29	5.91
210	19:59	5.89
240	20:29	5.87
300		
480		
600		
720		
840		
960		
1080		
1200		
1320		
1440		
1560		
1680		
1800		
1920		
2040		
2160		
2280		
2400		
2520		
2640		
2760		
2880		

BOREHOLE NO : SIY-BH2S

CONSTANT RATE DISCHARGE TEST

VSA Leboa Consulting

ALT. BH. NO.:

ALT. BH. NO.:

VILLAGE NAME:

ALT.VILLAGE NAME :

BOREHOLE DEPTH (BEFORE INSTALLATION OF TESTPUMP): 17.90m

WATER LEVEL (Measured at datum point before the Constant) 5.55m

INSTALLATION DEPTH OF TESTPUMP : 15.50m

Datum Level Above Casing : 0.21m

CONTRACTOR : VSA LEBOA

FOREMAN :

Date started: 2015/08/06

Time started: 07:20

Latitude: **Longitude:**

Drawdown still outstanding when constant rate was started:

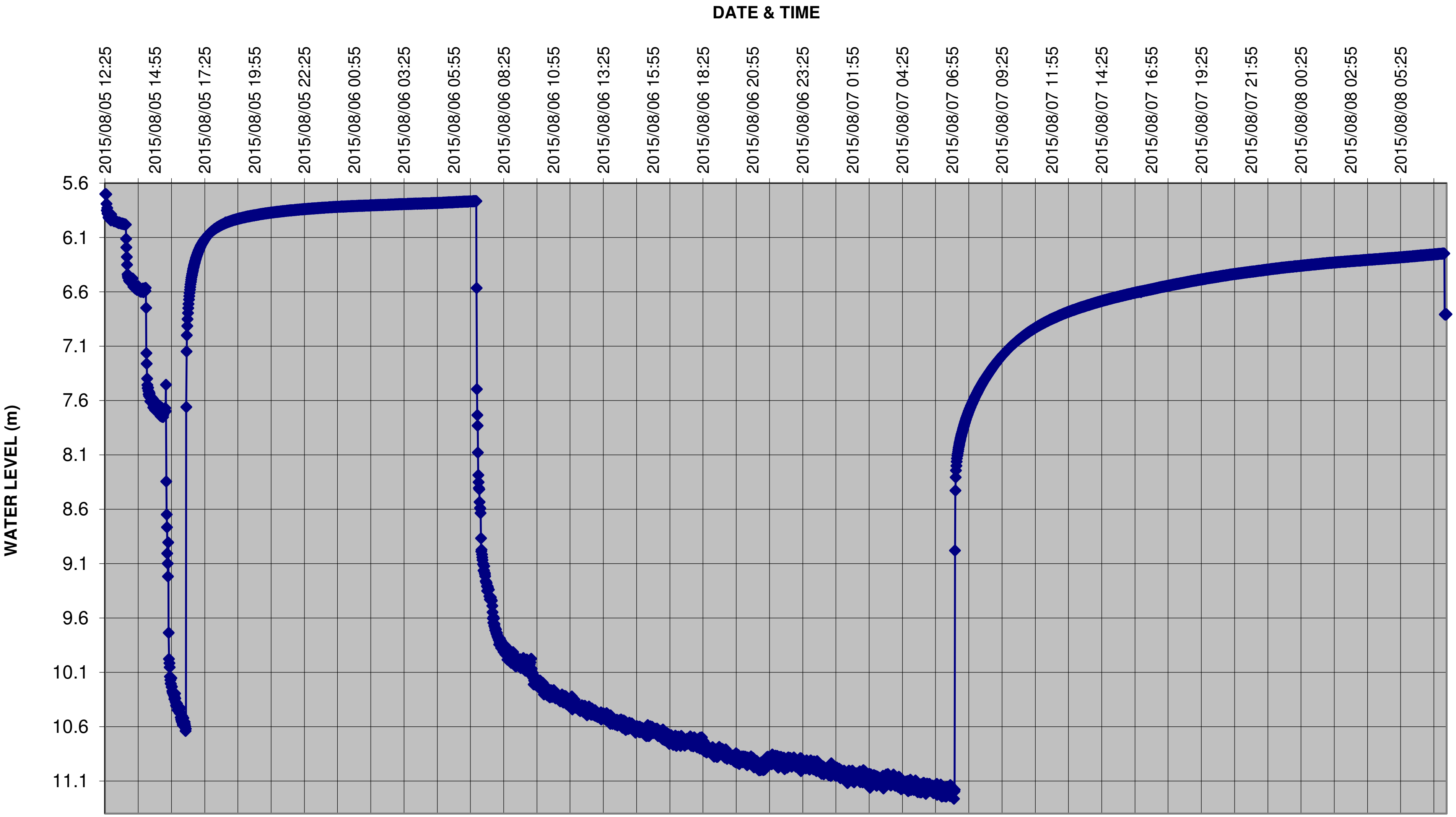
TOTAL DURATION OF TEST : (Pump time + Recovery): min

*** NOTE Distance between discharge and observation holes in (m) >**

OBSERVATION HOLE 1	OBSERVATION HOLE 2	Water level (m)
Bh NO':	Bh NO':	
Distance:	Distance:	

TIME	ACTUAL	**Water level**	YIELD	TIME	ACTUAL	RECOVERY	Water level:		Water level:		Water level:	
(min)	TIME	**(m)**	(l/s)	(min)	TIME	(m)	TIME	Water level	TIME	Water level	TIME	
	(Hour : Min)			(Hour : Min)			(min)	(m)	(min)	(m)	(min)	
1	07:21	7.26		1	07:21	8.68	1		1		1	
2	07:22	7.67		2	07:22	8.43	2		2		2	
3	07:23	7.85	3.74	3	07:23	8.34	3		3		3	
5	07:25	8.31		5	07:25	8.24	5		5		5	
7	07:27	8.46	4.08	7	07:27	8.17	7		7		7	
10	07:30	8.62	4.49	10	07:30	8.11	10		10		10	
15	07:35	9.07	4.91	15	07:35	8.03	15		15		15	
20	07:40	9.26	5.32	20	07:40	7.99	20		20		20	
30	07:50	9.39	5.45	30	07:50	7.87	30		30		30	
40	08:00	9.44		40	08:00	7.78	40		40		40	
60	08:20	9.8	5.55	60	08:20	7.64	60		60		60	
90	08:50	9.97		90	08:50	7.47	90		90		90	
120	09:20	10.07	5.68	120	09:20	7.33	120		120		120	
150	09:00	10.12		150	09:00	7.23	150		150		150	
180	10:20	10.24	5.74	180	10:20	7.14	180		180		180	
210	10:50	10.34		210	10:50	7.05	210		210		210	
240	11:20	10.38	5.55	240	11:20	7	240		240		240	
300	12:20	10.46		300	12:20	6.88	300		300		300	
360	13:20	10.52	5.55	360	13:20	6.8	360		360		360	
420	14:20	10.59		420	14:20	6.73	420		420		420	
480	15:20	10.64	5.52	480	15:20	6.67	480		480		480	
540	16:20	10.68		540	16:20	6.61	540		540		540	
600	17:20	10.76	5.6	600	17:20	6.58	600		600		600	
720	19:20	10.88	5.52	720	19:20	6.52	720		720		720	
840	21:20	10.98		840	21:20	6.46	840		840		840	
960	23:20	11.02	5.54	960	23:20	6.42	960		960		960	
1080	01:20	11.08		1080	01:20	6.38	1080		1080		1080	
1200	03:20	11.15	5.55	1200	03:20	6.35	1200		1200		1200	
1320	05:20	11.22	5.56	1320	05:20	6.32	1320		1320		1320	
1440	07:20	11.31		1440	07:20	6.3	1440		1440		1440	
1560				1560			1560		1560		1560	
1680				1680			1680		1680		1680	
1800				1800			1800		1800		1800	
1920				1920			1920		1920		1920	
2040				2040			2040		2040		2040	
2160				2160			2160		2160		2160	
2280				2280			2280		2280		2280	
2400				2400			2400		2400		2400	
2520				2520			2520		2520		2520	
2640				2640			2640		2640		2640	
2760				2760			2760		2760		2760	
2880				2880			2880		2880		2880	

TEST AT SIY-BH2S



APPENDIX F: WATER QUALITY RESULTS FOR PUMPING TEST

Water Sample Results
Pumping Tests
Constant Discharge Test

Borehole	SIY-BH2S
Latitude	-24.927561
Longitude	27.184343
Sample Date	2015/08/07
BH Depth (m)	18.00
Pump Depth (m)	15.00
Yield of Test (L/s)	5.50
Time of Sampling	07:00

Parameter	Water Quality Standard	DWAF TWQ - Livestock Watering	SANS 241 (2015) Operational	SANS 241 (2015) Aesthetic	SANS 241 (2015) Acute Heath	SANS 241 (2015) Chronic Health	SIY-BH2S
	Unit						
pH (Field)	pH Unit	N/A	5 - 9.7	N/A	N/A	N/A	6.92
EC (Field)	µS/cm	N/A	N/A	N/A	N/A	N/A	3830
TDS (Field)	mg/L	N/A	N/A	1200	N/A	N/A	2730
Temp (Field)	°C	N/A	N/A	N/A	N/A	N/A	18.8
Ag	mg/L	N/A	N/A	N/A	N/A	N/A	<0.010
Al	mg/L	5.00	0.3	N/A	N/A	N/A	0.104
As	mg/L	1.00	N/A	N/A	N/A	0.01	0.016
B	mg/L	5.00	N/A	N/A	N/A	2.4	0.028
Ba	mg/L	N/A	N/A	N/A	N/A	0.7	0.040
Be	mg/L	N/A	N/A	N/A	N/A	N/A	<0.010
Bi	mg/L	N/A	N/A	N/A	N/A	N/A	<0.010
Ca	mg/L	1000	N/A	N/A	N/A	N/A	255
Cd	mg/L	0.01	N/A	N/A	N/A	0.003	<0.010
Co	mg/L	1.00	N/A	N/A	N/A	0.5	<0.010
Cr	mg/L	N/A	N/A	N/A	N/A	0.05	<0.010
Cu	mg/L	0.50	N/A	N/A	N/A	2	<0.010
Fe	mg/L	10	N/A	0.3	N/A	2	0.105
Hg	mg/L	N/A	N/A	N/A	N/A	0.006	<0.010
K	mg/L	N/A	N/A	N/A	N/A	N/A	<1.0
Li	mg/L	N/A	N/A	N/A	N/A	N/A	<0.010
Mg	mg/L	500	N/A	N/A	N/A	N/A	200
Mn	mg/L	10	N/A	0.1	N/A	0.4	<0.025
Mo	mg/L	0.01	N/A	N/A	N/A	N/A	<0.010
Na	mg/L	2000	N/A	200	N/A	N/A	210
Ni	mg/L	1.00	N/A	N/A	N/A	0.07	0.022
P	mg/L	N/A	N/A	N/A	N/A	N/A	<0.010
Pb	mg/L	0.10	N/A	N/A	N/A	0.01	<0.010
Sb	mg/L	N/A	N/A	N/A	N/A	0.02	<0.010
Se	mg/L	50	N/A	N/A	N/A	0.04	<0.010
Si	mg/L	N/A	N/A	N/A	N/A	N/A	24
Sn	mg/L	N/A	N/A	N/A	N/A	N/A	<0.010
Sr	mg/L	N/A	N/A	N/A	N/A	N/A	0.845
Ti	mg/L	N/A	N/A	N/A	N/A	N/A	0.209
U	mg/L	N/A	N/A	N/A	N/A	0.03	<0.010
V	mg/L	1.00	N/A	N/A	N/A	0.2	0.010
Zn	mg/L	20	N/A	5	N/A	N/A	<0.010
Zr	mg/L	N/A	N/A	N/A	N/A	N/A	<0.010
pH Value at 25˚C	pH Value	N/A	5 - 9.7	N/A	N/A	N/A	7.7
Electrical Conductivity	mS/m	N/A	N/A	170	N/A	N/A	352
TDS	mg/L	N/A	N/A	1200	N/A	N/A	2418
Alkalinity as CaCO$_3$	mg/L	N/A	N/A	N/A	N/A	N/A	320
Chloride as Cl	mg/L	1500	N/A	300	N/A	N/A	771
Sulphate as SO$_4$	mg/L	1000	N/A	250	500	N/A	473
Fluoride as F	mg/L	N/A	N/A	N/A	N/A	1.5	0.2
Nitrate as N	mg/L	50	N/A	N/A	11	N/A	<0.2
Nitrite as N	mg/L	N/A	N/A	N/A	0.9	N/A	<0.1
Free & Saline Ammonia as N	mg/L	N/A	N/A	1.5	N/A	N/A	<0.2

* highlighted cells indicated which water quality standard has been exceeded

WATERLAB (Pty) Ltd

Reg. No.: 1983/009165/07 V.A.T. No.: 4130107891

23B De Havilland Crescent
Persequor Techno Park
Meiring Naudé Drive
Pretoria

P.O. Box 283
Persequor Park, 0020
Tel: +2712 – 349 – 1066
Fax: +2712 – 349 – 2064
e-mail: admin@waterlab.co.za

SANAS Accredited Testing Laboratory
No. T0391

CERTIFICATE OF ANALYSES
GENERAL WATER QUALITY PARAMETERS

Date received: 2015 - 08 - 11
Date completed: 2015 - 08 – 31
Project number: 139
Report number: 53731
Order number: 0235

Client name: SLR Consulting (Africa) (Pty) Ltd

Contact person: Mr. E. Louw
Ms. J. Ellerton

Address: P.O. Box 1596 Cramerview 2060

e-mail: edwynn@slrconsulting.com
e-mail: jellerton@slrconsulting.com

Telephone: 011 467 0945
Facsimile: 011 467 0978
Mobile: 083 447 3125

Analyses in mg/ℓ (Unless specified otherwise)	**Method Identification**	**Sample Identification: Siyanda**
		SIY BH2S
Sample Number		12808
pH – Value at 25°C	WLAB001	7.7
Electrical Conductivity in mS/m at 25°C	WLAB002	352
Total Dissolved Solids at 180°C *	WLAB003	2 418
Total Alkalinity as $CaCO_3$	WLAB007	320
Chloride as Cl *	WLAB046	771
Sulphate as SO_4 *	WLAB046	473
Fluoride as F	WLAB014	0.2
Nitrate as N *	WLAB046	<0.2
Nitrite as N *	WLAB046	<0.1
Free & Saline Ammonia as N *	WLAB046	<0.2
ICP-MS Scan *	WLAB050	See Attached Report: 53731-A
% Balancing *	---	99.6

*** = Not SANAS Accredited**
Tests marked "Not SANAS Accredited" in this report are not included in the SANAS Schedule of Accreditation for this Laboratory.

A. van de Wetering

Technical Signatory

The information contained in this report is relevant only to the sample/samples supplied to **WATERLAB (Pty) Ltd**. Any further use of the above information is not the responsibility of **WATERLAB (Pty) Ltd**. Except for the full report, part of this report may not be reproduced without written approval of **WATERLAB (Pty) Ltd**. Details of sample conducted by Waterlab (PTY) Ltd according to WLAB/Sampling Plan and Procedures/SOP are available on request.

WATERLAB (PTY) LTD

CERTIFICATE OF ANALYSIS

Project Number : 139
Client : SLR Consulting
Report Number : 53731-A

Sample Origin	Sample ID	Ag (mg/L)	Al (mg/L)	As (mg/L)	Au (mg/L)	B (mg/L)	Ba (mg/L)	Be (mg/L)	Bi (mg/L)	Ca (mg/L)	Cd (mg/L)	Ce (mg/L)	Co (mg/L)
SIY BH2S	12808	<0.010	0.104	0.016	<0.010	0.028	0.040	<0.010	<0.010	255	<0.010	<0.010	<0.010

Sample Origin	Sample ID	Cr (mg/L)	Cs (mg/L)	Cu (mg/L)	Dy (mg/L)	Er (mg/L)	Eu (mg/L)	Fe (mg/L)	Ga (mg/L)	Gd (mg/L)	Ge (mg/L)	Hf (mg/L)	Hg (mg/L)
SIY BH2S	12808	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.105	<0.010	<0.010	<0.010	<0.010	<0.010

Sample Origin	Sample ID	Ho (mg/L)	In (mg/L)	Ir (mg/L)	K (mg/L)	La (mg/L)	Li (mg/L)	Lu (mg/L)	Mg (mg/L)	Mn (mg/L)	Mo (mg/L)	Na (mg/L)	Nb (mg/L)
SIY BH2S	12808	<0.010	<0.010	<0.010	<1.0	<0.010	<0.010	<0.010	200	<0.025	<0.010	210	<0.010

Sample Origin	Sample ID	Nd (mg/L)	Ni (mg/L)	Os (mg/L)	P (mg/L)	Pb (mg/L)	Pd (mg/L)	Pt (mg/L)	Rb (mg/L)	Rh (mg/L)	Ru (mg/L)	Sb (mg/L)	Sc (mg/L)
SIY BH2S	12808	<0.010	0.022	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010

Sample Origin	Sample ID	Se (mg/L)	Si (mg/L)	Sm (mg/L)	Sn (mg/L)	Sr (mg/L)	Ta (mg/L)	Tb (mg/L)	Te (mg/L)	Th (mg/L)	Ti (mg/L)	Tl (mg/L)	Tm (mg/L)
SIY BH2S	12808	<0.010	24	<0.010	<0.010	0.845	<0.010	<0.010	<0.010	<0.010	0.209	<0.010	<0.010

Sample Origin	Sample ID	U (mg/L)	V (mg/L)	W (mg/L)	Y (mg/L)	Yb (mg/L)	Zn (mg/L)	Zr (mg/L)
SIY BH2S	12808	<0.010	0.010	<0.010	<0.010	<0.010	<0.010	<0.010

Siyanda: Baseline / ongoing monitoring

BH ID	Lab ID	Date	Purpose	Ag	Al	As	B	Ba	Be	Bi	Ca	Cd	Co	Cr	Cu	Fe	Hg	K	Li	Mg	Mn	Mo	Na	Ni	P	Pb	Sb
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
GW SIY BH01D	2233	2016/03/18	Q1	<0.010	0.148	<0.010	0.174	0.028	<0.010	<0.010	115	<0.010	<0.010	0.027	<0.010	0.014	<0.010	2.7	<0.010	<1	<0.010	<0.010	247	<0.010	<0.010	<0.010	<0.010
GW SIY BH02D	2235	2016/03/18	Q1	<0.010	<0.100	<0.010	0.188	0.036	<0.010	<0.010	64	<0.010	<0.010	<0.010	<0.010	2.08	<0.010	1.8	<0.010	26	0.638	<0.010	127	0.022	0.015	<0.010	<0.010
GW SIY BH02S	2234	2016/03/18	Q1	<0.010	<0.100	<0.010	0.120	0.064	<0.010	<0.010	180	<0.010	<0.010	<0.010	<0.010	3.40	<0.010	4.4	<0.010	130	0.295	<0.010	247	0.039	0.015	<0.010	<0.010
GW SIY BH03D	2236	2016/03/18	Q1	<0.010	<0.100	<0.010	0.147	0.100	<0.010	<0.010	176	<0.010	<0.010	<0.010	<0.010	4.32	<0.010	3.7	0.011	154	0.239	<0.010	219	0.044	<0.010	<0.010	<0.010
GW Johan Young BH1	2237	2016/03/18	Q1	<0.010	<0.100	<0.010	0.152	0.078	<0.010	<0.010	47	<0.010	<0.010	<0.010	0.050	0.025	<0.010	3.1	<0.010	307	<0.010	<0.010	201	<0.010	0.020	<0.010	<0.010
GW Jonan Young BH2	2238	2016/03/18	Q1	<0.010	<0.100	<0.010	0.069	0.062	<0.010	<0.010	5	<0.010	<0.010	0.020	<0.010	0.012	<0.010	1.4	<0.010	141	<0.010	<0.010	33	<0.010	0.057	<0.010	<0.010
SWB	2239	2016/03/18	Q1	<0.010	<0.100	<0.010	0.028	0.032	<0.010	<0.010	23	<0.010	<0.010	<0.010	<0.010	0.051	<0.010	5.2	<0.010	9	<0.010	<0.010	18	0.012	0.030	<0.010	<0.010
SWC	2240	2016/03/18	Q1	<0.010	2.10	<0.010	0.014	0.033	<0.010	<0.010	5	<0.010	<0.010	<0.010	<0.010	1.95	<0.010	5.7	<0.010	2	0.278	<0.010	5	0.022	0.051	<0.010	<0.010
GW SIY BH01D	14172	2016/07/29	Q2	< 0.010	0.107	< 0.010	0.132	0.031	< 0.010	< 0.010	112	< 0.010	< 0.010	< 0.010	< 0.010	< 0.025	< 0.010	2.1	< 0.010	< 1	< 0.025	< 0.010	242	< 0.010	0.029	< 0.010	< 0.010
GW SIY BH02S	14173	2016/07/29	Q2	< 0.010	< 0.100	< 0.010	0.111	0.061	< 0.010	< 0.010	236	< 0.010	< 0.010	< 0.010	< 0.010	9.034	< 0.010	1.3	< 0.010	190	0.519	< 0.010	234	0.072	0.035	< 0.010	< 0.010
GW SIY BH03	14174	2016/07/29	Q2	< 0.010	< 0.100	< 0.010	0.090	0.097	< 0.010	< 0.010	183	< 0.010	< 0.010	< 0.010	< 0.010	3.932	< 0.010	2.2	< 0.010	166	0.210	< 0.010	213	0.029	0.049	< 0.010	< 0.010
BH04	14175	2016/07/29	Q2	< 0.010	< 0.100	< 0.010	< 0.010	0.036	< 0.010	< 0.010	63	< 0.010	< 0.010	< 0.010	< 0.010	7.405	< 0.010	2.7	< 0.010	27	0.127	< 0.010	218	0.060	< 0.010	< 0.010	< 0.010
GW Johan Young BH1	14176	2016/07/29	Q2	0.019	< 0.100	< 0.010	0.051	0.078	< 0.010	< 0.010	49	< 0.010	< 0.010	< 0.010	0.062	0.029	< 0.010	3.5	< 0.010	335	< 0.025	< 0.010	186	< 0.010	0.053	< 0.010	< 0.010
GW Jonan Young BH2	14177	2016/07/29	Q2	< 0.010	< 0.100	< 0.010	< 0.010	0.063	< 0.010	< 0.010	3	< 0.010	< 0.010	0.019	< 0.010	< 0.025	< 0.010	1.6	< 0.010	148	< 0.025	< 0.010	33	< 0.010	0.143	< 0.010	< 0.010
SWB	14178	2016/07/29	Q2	< 0.010	2.855	< 0.010	< 0.010	0.110	< 0.010	< 0.010	37	< 0.010	< 0.010	0.018	0.010	2.662	< 0.010	9.0	< 0.010	26	0.324	< 0.010	38	0.053	0.112	< 0.010	< 0.010

APPENDIX G: WATER QUALITY RESULTS FOR BASELINE / ONGOING MONITORING

Siyanda: Baseline / ongoing monitoring

BH ID	Lab ID	Date	Purpose	Se	Si	Sn	Sr	Ti	U	V	Zn	Zr	pH Value at 25˚C	Electrical Conductivity	TDS	Alkalinity as $CaCO_3$	Bicarbonate as HCO_3 *	Carbonate as CO_3 *	Chloride as Cl	Sulphate as SO_4	Fluoride as F	Nitrate as N	Nitrite as N	Free & Saline Ammonia as N	Suspended Solids at 105℃ *
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
GW SIY BH01D	2233	2016/03/18	Q1	0.036	10.5	<0.010	0.307	0.134	<0.010	0.185	<0.010	<0.010	10.7	161	872	56			289	151	0.3	1.9	<0.05	0.2	
GW SIY BH02D	2235	2016/03/18	Q1	0.019	7.7	<0.010	0.340	0.072	<0.010	<0.010	0.034	<0.010	7.9	101	640	160			128	134	0.4	11	0.05	0.9	
GW SIY BH02S	2234	2016/03/18	Q1	0.015	0.2	<0.010	0.855	0.235	<0.010	<0.010	<0.010	<0.010	7.6	296	1 898	8			817	345	<0.2	<0.1	<0.05	1.2	
GW SIY BH03D	2236	2016/03/18	Q1	0.039	13.5	<0.010	1.05	0.216	<0.010	<0.010	<0.010	<0.010	7.6	282	1 688	156			691	369	<0.2	<0.1	<0.05	0.3	
GW Johan Young BH1	2237	2016/03/18	Q1	0.039	31	<0.010	0.688	0.060	<0.010	0.037	0.038	<0.010	7.7	330	2 046	464			747	402	<0.2	0.1	<0.05	0.1	
GW Jonan Young BH2	2238	2016/03/18	Q1	0.025	34	<0.010	0.157	<0.010	<0.010	0.045	0.150	<0.010	8.4	107	626	612			37	16	<0.2	2.1	<0.05	0.1	
SWB	2239	2016/03/18	Q1	0.017	6.6	<0.010	0.090	0.039	<0.010	0.010	0.004	<0.010	7.8	28.5	202	40			28	49	0.2	0.1	<0.05	0.2	45
SWC	2240	2016/03/18	Q1	0.024	7.7	<0.010	0.080	0.066	<0.010	<0.010	<0.010	<0.010	7.7	7.5	110	28			4	4	0.3	<0.1	<0.05	0.2	104
GW SIY BH01D	14172	2016/07/29	Q2	0.049	11.9	< 0.010	0.277	0.237	< 0.010	0.156	0.023	< 0.010	9.1	154	1 030	20	24	<5	369	181	0.4	0.3	0.06	<0.1	
GW SIY BH02S	14173	2016/07/29	Q2	0.073	28	< 0.010	1.291	0.525	< 0.010	< 0.010	0.034	< 0.010	7.6	333	2 710	292	356	<5	811	450	0.2	0.1	<0.05	0.1	
GW SIY BH03	14174	2016/07/29	Q2	0.066	20	< 0.010	1.107	0.381	< 0.010	< 0.010	0.033	< 0.010	7.5	292	1 898	240	293	<5	728	383	<0.2	0.5	<0.05	<0.1	
BH04	14175	2016/07/29	Q2	0.039	7.2	< 0.010	0.603	0.124	< 0.010	< 0.010	0.022	< 0.010	7.7	148	824	232	283	<5	345	<2	0.3	0.1	<0.05	0.7	
GW Johan Young BH1	14176	2016/07/29	Q2	0.071	32	< 0.010	0.623	0.100	< 0.010	0.034	0.101	< 0.010	7.7	325	2 554	468	570	<5	747	417	0.2	0.3	<0.05	<0.1	
GW Jonan Young BH2	14177	2016/07/29	Q2	< 0.010	36	< 0.010	0.147	< 0.010	< 0.010	0.041	0.120	< 0.010	8.2	107	640	612	746	<5	41	14	0.2	2	<0.05	<0.1	
SWB	14178	2016/07/29	Q2	0.011	7.0	< 0.010	0.147	0.177	< 0.010	0.026	0.025	< 0.010	8.2	48.9	296	140	171	<5	51	55	0.3	0.1	<0.05	1.4	373

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CERTIFICATE OF ANALYSES
GENERAL WATER QUALITY PARAMETERS

Date received: 2016 - 03 - 22 **Date completed:** 2016 - 04 – 08

Project number: 139 **Report number: 58325** **Order number: 0332**

Client name: SLR Consulting (Africa) (Pty) Ltd **Contact person: Mrs. J. Ellerton**

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Telephone: 011 467 0945 **Facsimile: 011 467 0978** **Mobile: 072 077 7463**

Analyses in mg/ℓ (Unless specified otherwise)	**Method Identification**	**Sample Identification: Siyanda**			
		GW SIY H01D	**GW SIY BH02S**	**GW SIY BH02D**	**GW SIY BH03D**
Sample Number		2233	2234	2235	2236
pH – Value at 25°C*	WLAB001	10.7	7.9	7.6	7.6
Electrical Conductivity in mS/m at 25°C*	WLAB002	161	101	296	282
Total Dissolved Solids at 180°C *	WLAB003	872	640	1 898	1 688
Total Alkalinity as $CaCO_3$ *	WLAB007	56	160	8	156
Chloride as Cl	WLAB046	289	128	817	691
Sulphate as SO_4	WLAB046	151	134	345	369
Fluoride as F	WLAB014	0.3	0.4	<0.2	<0.2
Nitrate as N	WLAB046	1.9	11	<0.1	<0.1
Nitrite as N	WLAB046	<0.05	0.05	<0.05	<0.05
Free & Saline Ammonia as N	WLAB046	0.2	0.9	1.2	0.3
ICP-MS Scan (Dissolved) *	WLAB050	See Attached Report: 58325-A			
% Balancing *	---	88.5	97.3	99.6	98.7

Analyses in mg/ℓ (Unless specified otherwise)	**Method Identification**	**Sample Identification: Siyanda**			
		GW Jonan Young BH1	**GW Jonan Young BH2**	**SW3A**	**SW5**
Sample Number		2237	2238	2239	2240
pH – Value at 25°C*	WLAB001	7.7	8.4	7.8	7.7
Electrical Conductivity in mS/m at 25°C*	WLAB002	330	107	28.5	7.5
Total Dissolved Solids at 180°C *	WLAB003	2 046	626	202	110
Suspended Solids at 105°C *	WLAB004	---	---	45	104
Total Alkalinity as $CaCO_3$ *	WLAB007	464	612	40	28
Chloride as Cl	WLAB046	747	37	28	4
Sulphate as SO_4	WLAB046	402	16	49	4
Fluoride as F	WLAB014	<0.2	<0.2	0.2	0.3
Nitrate as N	WLAB046	0.1	2.1	0.1	<0.1
Nitrite as N	WLAB046	<0.05	<0.05	<0.05	<0.05
Free & Saline Ammonia as N	WLAB046	0.1	0.1	0.2	0.2
ICP-MS Scan (Dissolved) *	WLAB050	See Attached Report: 58325-A			
% Balancing *	---	96.9	98.4	99.3	97.7

*** = Not SANAS Accredited**
Tests marked "Not SANAS Accredited" in this report are not included in the SANAS Schedule of Accreditation for this Laboratory.

E. Nkabinde

Technical Signatory

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WATERLAB (PTY) LTD

CERTIFICATE OF ANALYSIS

Project Number : 139
Client : SLR Consulting
Report Number : 58325-A

Sample	Sample												
Origin	ID												
		Ag (mg/L)	**Al (mg/L)**	**As (mg/L)**	**Au (mg/L)**	**B (mg/L)**	**Ba (mg/L)**	**Be (mg/L)**	**Bi (mg/L)**	**Ca (mg/L)**	**Cd (mg/L)**	**Ce (mg/L)**	**Co (mg/L)**
GW SIY H01D	2233	<0.010	0.148	<0.010	<0.010	0.174	0.028	<0.010	<0.010	115	<0.010	<0.010	<0.010
GW SIY BH02S	2234	<0.010	<0.100	<0.010	<0.010	0.188	0.036	<0.010	<0.010	64	<0.010	<0.010	<0.010
GW SIY BH02D	2235	<0.010	<0.100	<0.010	<0.010	0.120	0.064	<0.010	<0.010	180	<0.010	<0.010	<0.010
GW SIY BH03D	2236	<0.010	<0.100	<0.010	<0.010	0.147	0.100	<0.010	<0.010	176	<0.010	<0.010	<0.010
GW Jonan Young BH1	2237	<0.010	<0.100	<0.010	<0.010	0.152	0.078	<0.010	<0.010	47	<0.010	<0.010	<0.010
GW Jonan Young BH2	2238	<0.010	<0.100	<0.010	<0.010	0.069	0.062	<0.010	<0.010	5	<0.010	<0.010	<0.010
SW3A	2239	<0.010	<0.100	<0.010	<0.010	0.028	0.032	<0.010	<0.010	23	<0.010	<0.010	<0.010
SW5	2240	<0.010	2.10	<0.010	<0.010	0.014	0.033	<0.010	<0.010	5	<0.010	<0.010	<0.010

Sample	Sample												
Origin	ID												
		Cr (mg/L)	**Cs (mg/L)**	**Cu (mg/L)**	**Dy (mg/L)**	**Er (mg/L)**	**Eu (mg/L)**	**Fe (mg/L)**	**Ga (mg/L)**	**Gd (mg/L)**	**Ge (mg/L)**	**Hf (mg/L)**	**Hg (mg/L)**
GW SIY H01D	2233	0.027	<0.010	<0.010	<0.010	<0.010	<0.010	0.014	<0.010	<0.010	<0.010	<0.010	<0.010
GW SIY BH02S	2234	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	2.08	<0.010	<0.010	<0.010	<0.010	<0.010
GW SIY BH02D	2235	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	3.40	<0.010	<0.010	<0.010	<0.010	<0.010
GW SIY BH03D	2236	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	4.32	<0.010	<0.010	<0.010	<0.010	<0.010
GW Jonan Young BH1	2237	<0.010	<0.010	0.050	<0.010	<0.010	<0.010	0.025	<0.010	<0.010	<0.010	<0.010	<0.010
GW Jonan Young BH2	2238	0.020	<0.010	<0.010	<0.010	<0.010	<0.010	0.012	<0.010	<0.010	<0.010	<0.010	<0.010
SW3A	2239	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.051	<0.010	<0.010	<0.010	<0.010	<0.010
SW5	2240	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	1.95	<0.010	<0.010	<0.010	<0.010	<0.010

Sample	Sample												
Origin	ID												
		Ho (mg/L)	**In (mg/L)**	**Ir (mg/L)**	**K (mg/L)**	**La (mg/L)**	**Li (mg/L)**	**Lu (mg/L)**	**Mg (mg/L)**	**Mn (mg/L)**	**Mo (mg/L)**	**Na (mg/L)**	**Nb (mg/L)**
GW SIY H01D	2233	<0.010	<0.010	<0.010	2.7	<0.010	<0.010	<0.010	<1	<0.010	<0.010	247	<0.010
GW SIY BH02S	2234	<0.010	<0.010	<0.010	1.8	<0.010	<0.010	<0.010	26	0.638	<0.010	127	<0.010
GW SIY BH02D	2235	<0.010	<0.010	<0.010	4.4	<0.010	<0.010	<0.010	130	0.295	<0.010	247	<0.010
GW SIY BH03D	2236	<0.010	<0.010	<0.010	3.7	<0.010	0.011	<0.010	154	0.239	<0.010	219	<0.010
GW Jonan Young BH1	2237	<0.010	<0.010	<0.010	3.1	<0.010	<0.010	<0.010	307	<0.010	<0.010	201	<0.010
GW Jonan Young BH2	2238	<0.010	<0.010	<0.010	1.4	<0.010	<0.010	<0.010	141	<0.010	<0.010	33	<0.010
SW3A	2239	<0.010	<0.010	<0.010	5.2	<0.010	<0.010	<0.010	9	<0.010	<0.010	18	<0.010
SW5	2240	<0.010	<0.010	<0.010	5.7	<0.010	<0.010	<0.010	2	0.278	<0.010	5	<0.010

Sample	Sample												
Origin	ID												
		Nd (mg/L)	**Ni (mg/L)**	**Os (mg/L)**	**P (mg/L)**	**Pb (mg/L)**	**Pd (mg/L)**	**Pt (mg/L)**	**Rb (mg/L)**	**Rh (mg/L)**	**Ru (mg/L)**	**S (mg/L)**	**Sb (mg/L)**
GW SIY H01D	2233	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	418	<0.010
GW SIY BH02S	2234	<0.010	0.022	<0.010	0.015	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	313	<0.010
GW SIY BH02D	2235	<0.010	0.039	<0.010	0.015	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	1027	<0.010
GW SIY BH03D	2236	<0.010	0.044	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	2807	<0.010
GW Jonan Young BH1	2237	<0.010	<0.010	<0.010	0.020	<0.010	<0.010	<0.010	0.010	<0.010	<0.010	2653	<0.010
GW Jonan Young BH2	2238	<0.010	<0.010	<0.010	0.057	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	109	<0.010
SW3A	2239	<0.010	0.012	<0.010	0.030	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	337	<0.010
SW5	2240	<0.010	0.022	<0.010	0.051	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	23	<0.010

Sample	Sample												
Origin	ID												
		Sc (mg/L)	**Se (mg/L)**	**Si (mg/L)**	**Sm (mg/L)**	**Sn (mg/L)**	**Sr (mg/L)**	**Ta (mg/L)**	**Tb (mg/L)**	**Te (mg/L)**	**Th (mg/L)**	**Ti (mg/L)**	**Tl (mg/L)**
GW SIY H01D	2233	<0.010	0.036	10.5	<0.010	<0.010	0.307	<0.010	<0.010	<0.010	<0.010	0.134	<0.010
GW SIY BH02S	2234	<0.010	0.019	7.7	<0.010	<0.010	0.340	<0.010	<0.010	<0.010	<0.010	0.072	<0.010
GW SIY BH02D	2235	<0.010	0.015	0.2	<0.010	<0.010	0.855	<0.010	<0.010	<0.010	<0.010	0.235	<0.010
GW SIY BH03D	2236	<0.010	0.039	13.5	<0.010	<0.010	1.05	<0.010	<0.010	<0.010	<0.010	0.216	<0.010
GW Jonan Young BH1	2237	<0.010	0.039	31	<0.010	<0.010	0.688	<0.010	<0.010	<0.010	<0.010	0.060	<0.010
GW Jonan Young BH2	2238	<0.010	0.025	34	<0.010	<0.010	0.157	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
SW3A	2239	<0.010	0.017	6.6	<0.010	<0.010	0.090	<0.010	<0.010	<0.010	<0.010	0.039	<0.010
SW5	2240	<0.010	0.024	7.7	<0.010	<0.010	0.080	<0.010	<0.010	<0.010	<0.010	0.066	<0.010

Sample	Sample								
Origin	ID								
		Tm (mg/L)	**U (mg/L)**	**V (mg/L)**	**W (mg/L)**	**Y (mg/L)**	**Yb (mg/L)**	**Zn (mg/L)**	**Zr (mg/L)**
GW SIY H01D	2233	<0.010	<0.010	0.185	<0.010	<0.010	<0.010	<0.010	<0.010
GW SIY BH02S	2234	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.034	<0.010
GW SIY BH02D	2235	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
GW SIY BH03D	2236	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
GW Jonan Young BH1	2237	<0.010	<0.010	0.037	<0.010	<0.010	<0.010	0.038	<0.010
GW Jonan Young BH2	2238	<0.010	<0.010	0.045	<0.010	<0.010	<0.010	0.150	<0.010
SW3A	2239	<0.010	<0.010	0.010	<0.010	<0.010	<0.010	0.004	<0.010
SW5	2240	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010

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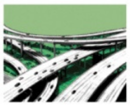
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